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Global Chemicals Outlook

Towards Sound Management of Chemicals



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List of Acronyms

ACC	American Chemistry Council	NGO	Non-Governmental Organization
BRIICS	Brazil, Russia, India, Indonesia, China, South Africa	ODA	Overseas Development Assistance
CEFIC	European Chemicals Industry Council	OECD	Organisation for Economic Cooperation and Development
CFC	Chlorofluorocarbon	PCBs	Polychlorinated Biphenyls
DALY	Disability Adjusted Life Year	PCE	Perchloroethylene
DCEIT	Developing Countries and Countries with Economies in Transition	POPs	Persistent Organic Pollutants
FAO	Food and Agriculture Organization	PRTR	Pollutant Release and Transfer Register
GDP	Gross Domestic Product	PRI	Principles for Responsible Investment
GEF	Global Environment Facility	REACH	Registration, Evaluation and Authorization of Chemicals
GHG	Greenhouse Gas	SAICM	Strategic Approach to International Chemicals Management
GHS	Globally Harmonized System of Classification and Labeling of Chemicals	SME	Small and Medium-sized Enterprise
IOMC	Inter-Organization Programme for the Sound Management of Chemicals	TCE	Trichloroethylene
IARC	International Agency for Research on Cancer	UNDP	United Nations Development Programme
ICCA	International Council of Chemical Associations	UNEP	United Nations Environment Programme
ICMM	International Council on Mining and Metals	UNIDO	United Nations Industrial Development Programme
ILO	International Labour Organization	UNITAR	United Nations Institute for Training and Research
ISO	International Organization for Standardization	VCM	Vinyl Chloride Monomer
IPEN	International POPs Elimination Network	VOC	Volatile Organic Compound
MEA	Multilateral Environment Agreement	WHO	World Health Organization
		WSSD	World Summit on Sustainable Development

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Foreword

The way the world manages chemicals will play a key role in the transition towards an inclusive Green Economy and the realization of a sustainable twenty-first century.

Governments across the globe recognize that chemicals are essential in areas of medicine and agriculture to consumer goods, clean technologies and overcoming poverty, but chemicals and the pollution linked with their manufacture, use and disposal come at a cost.

There is increasing recognition among governments, NGOs and the public that human health and the environment are being compromised by the current arrangements for managing chemicals and hazardous wastes.

These concerns take on a new level of urgency as the quantity and range of new and existing chemicals grow rapidly in developing countries and economies in transition.

At the World Summit on Sustainable Development in 2002, governments agreed on “using and producing of chemicals in ways that do not lead to significant adverse effects on human health and the environment” and set a deadline of 2020 to achieve this goal. This commitment was reaffirmed at the Rio+20 Summit in Brazil in 2012.

This report, Global Chemicals Outlook, compiled by UNEP in cooperation with international experts, is designed to inform governments and industry on trends in chemicals production, use and disposal, while offering policy advice aimed at meeting the 2020 goal. It focusses particularly on the challenges and opportunities facing developing nations.

The report, which also supports the work and actions of the three chemical and hazardous waste conventions—Basel, Rotterdam and Stockholm—and the Strategic Approach to International Chemicals Management, demonstrates the dramatic growth in the industry, which has seen global output climb from US\$ 171 billion in 1970 to over US\$ 4.1 trillion today.

The shift in production from developed to developing countries is underscored by China, which today is the largest consumer of textile chemicals, with 42 per cent of global consumption, and South Africa, where spending on pesticides has grown by close to 60 per cent since the late 1990s.

The Global Chemicals Outlook states that of the 4.9 million metric tonnes of pollutants released in North America (Canada, Mexico and United States), close to 2 million were chemicals that are persistent, able to accumulate in humans and animals, and are toxic. The report also deems toxic a further million tonnes of substances that are linked with or have suspected links with cancer.

An important aspect of this new report is the economic analysis that compares the benefits of action to the costs of inaction in terms of improved management.

Since 2020 is fast approaching. I am sure this report can stimulate some much-needed energy, and can also inspire confidence that the 2020 global agreement to find ways to reduce adverse effects of chemicals use and production on the environment can be upheld. This will bring significant benefits for the world’s population and the environmental services on which each one of us depends for our livelihood and our very survival.

Achim Steiner
UNEP Executive Director
United Nations Under-Secretary General

Introduction

Chemicals are an integral part of modern daily life. There is hardly any industry where chemical substances are not used and there is no single economic sector where chemicals do not play an important role. Millions of people throughout the world lead richer, more productive and more comfortable lives because of the thousands of chemicals on the market today. These chemicals are used in a wide variety of products and processes and, while they are major contributors to national and world economies, their sound management throughout their lifecycle is essential in order to avoid significant and increasingly complex risks to human health and ecosystems and substantial costs to national economies.

Industries producing and using these substances have a significant impact on employment, trade and economic growth worldwide, but the substances can have adverse effects on human health and the environment. A variety of global economic and regulatory forces influence changes in chemical production, transport, import, export, use and disposal over time. In response to the growing demand for chemical-based products and processes, the international chemical industry has grown dramatically since the 1970s. Global chemical output was valued at US\$ 171 billion in 1970; by 2010, it had grown to US\$ 4.12 trillion.

Many national governments have enacted laws and established institutional structures for managing the hazards of this growing volume of chemicals. Leading corporations have adopted chemical management programmes and there are now many international conventions and institutions for addressing these chemicals globally. However, the increasing complexity of the background mix of chemicals and the ever longer and more intricate chemical supply chain including wastes reveal varied gaps, lapses and inconsistencies in government and international policies and corporate practices. They feed growing international concerns over the threat that poor management of chemicals pose to the health of communities and ecosystems and over the capacity to achieve the Johannesburg Plan of Implementation goal that, by 2020, chemicals will be produced and used in ways that minimize significant adverse impacts on the environment and human health.

These concerns are important to all countries but are particularly salient in industrializing economies that face pressing needs to achieve development, national security and poverty eradication objectives. Developing countries and countries with economies in transition can learn lessons from the fragmented sector-by-sector chemical management approaches that have characterized conventional chemicals policies in developed countries. To protect human health and the environment and to fully benefit from the value that chemicals can yield, all countries must include in their economic and social development priorities the means to manage chemicals soundly.

Scope and aim of the report

The Global Chemicals Outlook has been developed to help address this persistent set of challenges and argue for a revitalized commitment to the sound management of chemicals. The report is a comprehensive and practical publication that assembles scientific, technical and socio-economic information on the sound management of chemicals. It is targeted to decision makers in order to build capacity and to implement policy change to protect the environment and human health. As such, the Global Chemicals Outlook covers three broad inter-linked areas building upon the findings of existing and concurrent studies:

1. Trends and indicators for (i) chemical production, transport, use and disposal and (ii) associated health and environment impacts;
2. Economic implications of these trends, including costs of inaction and benefits of action on sound management of chemicals; and

3. Instruments and approaches for sound management of chemicals, including promotion of safer alternatives and guidance to accelerate the achievement of the Strategic Approach to International Chemicals Management (SAICM) goals by 2020.

The first chapter of the Global Chemicals Outlook considers geographic patterns, trends over time, and indicators related to the production, use and disposal of industrial organic and inorganic chemicals, selected metals and agricultural chemicals. Although the subject of the report is anthropogenic chemicals, it is recognized that naturally occurring chemicals can also cause concern. These can include toxins found in plants and fungi, and mineral substances (including flammable and radioactive gases and toxic metals such as arsenic), and substances released during mining operations.

The first chapter of the report examines the health and environmental impacts that may be associated with the production, use and disposal of these substances. The report provides information on a variety of chemicals; some of these are associated with significant health or environmental impacts, while others pose less of a concern. The report also includes a brief, but not comprehensive, discussion of chemicals in consumer products. The report does not discuss pharmaceuticals. Substances released into the environment as a result of fossil fuel combustion are also not a focus of the present report.

The report focusses on issues that fall within the scope of SAICM and have the potential to be addressed through sound management of chemicals. In some instances, these issues overlap with environmental issues that result primarily from fuel combustion. This report notes this overlap where relevant, and disaggregates these factors where possible. In some instances, these areas of focus cannot be disaggregated; for example, Persistent Organic Pollutants (POPs) generated through fuel combustion at industrial facilities are considered to be within the scope of SAICM.

Using existing data, the second part of the Global Chemicals Outlook assimilates a broad array of economic evidence to analyze the economic costs of the failure to take prompt action on sound management of chemicals, and the benefits that could accrue from enhanced policy action, especially in developing countries and countries with economies in transition.

Based on secondary analysis of existing data, this analysis examines values of observed trends in chemicals production, consumption and disposal. Chapter II considers a broad array of economic implications of the trends observed for the synthetic chemicals and toxic metals discussed in Chapter I. Internal and external costs are reflected across two categories – financial implications for industry and monetized values for human health and environmental degradation from mismanagement across chemicals lifecycles. In considering the full range of implications, both ‘hidden’ and ‘visible’ benefits from investment in sound management of chemicals are brought to the fore.

Chapter II of the Global Chemicals Outlook does not estimate the total value of financial impacts, human health and ecosystem services benefits from sound management of chemicals. Rather, the valuations presented here are broadly categorized under potential avoided costs and broader benefits under a scenario of investment in sound management of chemicals keeping pace with the needs generated by increasing chemicals intensification in Developing Countries and Countries with Economies in Transition (DCEITs). Where data is missing, this gap is highlighted in discussions resulting in a holistic discussion of the likely global benefits from sound management of chemicals.

Chapter III of the Global Chemicals Outlook provides a comprehensive menu of instruments and approaches for sound management of chemicals, including promotion of safer alternatives and guidance that are now available to government, business and civil society to accelerate the achievement of SAICM goals by 2020. It identifies useful methodologies and decision-making tools including legal, economic, technical and voluntary instruments for prevention and management of toxic chemical pollution and promotion of safer alternatives. It proposes a set of

responses at the national and international level to develop comprehensive, multi-stakeholder and preventive policies that address chemicals management across chemicals and through the product life cycle.

The Global Chemicals Outlook report constitutes a comprehensive analysis, which addresses chemicals from identifying problems by assessing their root causes to proposing a coherent package of economic and technical decision-making methodologies. It brings forward the concept of chemicals intensification of the economies as an analytical thread to better capture the trends and changes that affect all economies, which make the commonality of issues between developed and developing countries, but calls attention to the need to bridge the widening gap in capacity between them.

The Global Chemicals Outlook provides a wealth of technical and scientific information covering *inter alia* substances that can have adverse impacts on the environment and human health, that are of global and/or national and /or local concern, substances that are produced or used in high volume and/or widely dispersed, used and disposed of (i.e. organic, inorganic, halogenated compounds, metals and waste). It synthesizes and documents the well established environmental and health effects. It reviews knowledge and evidence available in quantifying and, when possible, monetizing the cost of inaction and benefit of action. It includes for the first time a special contribution from the financial and insurance sector analysis, highlighting its perspective in managing the risks to a chemical intensification of the economies. It also reviews many of the approaches, instruments and tools use by governments, industry, NGOs and international organizations to manage chemicals soundly.

The Global Chemicals Outlook proposes addressing needs and challenges, by providing substantive support to the SAICM process including achieving coherence with programmes of other International Government Organizations (IGOs) and supporting the implementation of chemicals-related Multilateral Environmental Agreements (MEAs), while exerting greater influence on the behaviour of the public, the private sector and government policy makers. It also proposes to activate the leadership on global chemicals issues among relevant stakeholders, through generic recommendations and a specific set of recommendations to address challenges identified in the report and responses to be developed at national, corporate and civil society and international level. As such, it stimulates a cross-sectoral, participatory and partnership based on a set of interventions, and promotes a proactive, rather than reactive approach, to the management of harmful substances and hazardous waste, which seeks to avoid problems, rather than just reducing the impacts of such substances/waste once they have been produced.

Global Chemicals Outlook

Chapter I: Trends and Indicators

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1. Introduction

Chemicals are used in a wide variety of products and play an important role in the world economy. They are constituents of materials, are used in preparations and products and are embedded in complex physical systems. While chemicals are a significant contributor to national economies, sound chemical management across the life cycle - from extraction to disposal - is essential to avoid significant risks to human health and the environment, along with their associated economic costs, and to maximize benefits for human well-being.

This report examines trends in global production, use and disposal of chemicals, and in their health and environmental impacts. This includes consideration of chemicals used in industry, agriculture and incorporated into products.

The information presented in this report shows that while chemical production, use and disposal continue to expand worldwide, this expansion is not evenly distributed geographically. Growth in chemical production and use has slowed in many of the developed countries that previously dominated the market, while it has accelerated rapidly in a number of developing countries and countries with economies in transition. These countries are, increasingly, the drivers of global expansion in production and use of these chemicals. Wastes from the chemical industry are also not equally distributed globally, and waste from products containing chemicals is an increasing source of concern in developing countries and countries with economies in transition.

Changing patterns in the global distribution of chemical production and use, in turn, have implications for the environment and human health. Effects on ecosystem resources can include contamination of air, water, and soil, as well as adverse effects on wildlife. Human health effects can include both acute and chronic diseases and disorders. Among other concerns, the adverse health effects of chemicals can be exacerbated by poverty and poor nutrition, in turn increasing susceptibility to disease.

This report undertakes the issue of sound management of chemicals in the context of economic development. A wide range of materials, processes and technologies involving chemicals are relevant for economic development. Economic development capitalizes on the value that chemicals yield, but also creates the need to manage their attendant hazards. Thus, sound chemicals management is an essential component of the economic development agenda.

1.1 Scope

The first part of this report considers geographic patterns, trends over time, and indicators related to the production, use and disposal of industrial organic and inorganic chemicals, selected metals and agricultural chemicals.

The second part of the report examines the health and environmental impacts that may be associated with the production, use and disposal of these substances. The report provides information on a variety of chemicals; some of these are associated with significant health or environmental impacts, while others pose less of a concern.

The report also includes a brief, but not comprehensive, discussion of chemicals in consumer products. The report does not discuss pharmaceuticals. Substances released into the environment as a result of fossil fuel combustion are also not a focus of the report.

This report is focused on issues that fall within the scope of the United Nations Strategic Approach to International Chemicals Management (SAICM) and have the potential to be addressed through sound management of chemicals, including pollution prevention and substitution of safer alternatives. In some instances, these issues overlap with environmental issues that result primarily from fuel combustion. This report notes this overlap where relevant, and disaggregates these factors where possible. In some instances, these areas of focus cannot be disaggregated; for example, persistent organic pollutants generated through fuel combustion at industrial facilities, are considered to be within the scope of SAICM.

Although this report focusses primarily on chemical exposures associated with economic activity – such as chemicals used in industry or in products – it is recognized that other naturally occurring chemicals can also cause concern. These can include toxins found in plants and fungi, and mineral substances (including flammable and radioactive gases and toxic metals such as arsenic).

Chemical Industry Indicators. The report focusses on two main economic indicators to describe historical trends as well as economic forecasts (where possible) for the chemical industry: chemical production (or output), and chemical consumption (or demand). In the choice of these indicators, this report follows the approach used by the Organisation for Economic Co-operation and Development (OECD).¹

Wherever possible, this report uses data on chemical quantities, generally expressed in millions of metric tonnes. For aggregate figures on the chemical industry as a whole, this report follows the approach of other similar analyses and relies upon data expressed in terms of monetary value, rather than chemical quantity. The report also includes some limited information on trade patterns, where other data are lacking.

Waste Indicators. Trends associated with environmental releases, recycling and disposal of chemicals in this report primarily rely on indicators used by Pollution Release and Transfer Registries (PRTRs) in many OECD countries, as well as data regarding the net global movement of hazardous waste as collected under the Basel Convention. While PRTR data are lacking for developing countries and those in economic transition, the report includes case examples of growing threats to the environment and human health from chemical emissions, wastes and high-risk recycling industries in these regions.

Environment and Health Indicators. In the sections on human health, the report provides background information regarding the growing state of knowledge of links to public health and environmental impacts associated with chemicals, including quantification where possible regarding the number of chemicals associated with health and environmental endpoints.

The indicators used in this report for tracking the impact of chemicals on human health and the environment (e.g. wildlife) include environmental monitoring data and biomonitoring data where available. Both of these indicators are among key risk reduction indicators adopted by the SAICM Secretariat in 2009 for tracking the effectiveness of sound chemicals management over time.² This report also provides information from the most comprehensive study to date examining the magnitude of specific health effects attributable (attributable fractions) to industrial chemicals. In addition, geographic and temporal trends, including forecasts for both health (incidence and/or prevalence) and environmental impacts across developed and developing countries are described where available.

1.2 Data Sources

This report draws upon a variety of sources, including both publicly available and proprietary resources. Publicly available data sources on industrial organic and inorganic chemical trends include reports from industry associations such as the International Council of Chemistry Associations (ICCA), the American Chemistry Council (ACC), the European Chemical Industry Association (CEFIC), the International Council on Mining and Metals (ICMM), and CropLife International; reports from intergovernmental agencies including the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), the United Nations Food and Agriculture Organization (FAO) and others; documentation produced under the European Union's Registration, Evaluation, and Authorization of Chemicals (REACH) regulation; national government data sources such as the United States Geological Survey (USGS); and articles in industry journals as well as peer-reviewed academic journals. Proprietary data sources used for this report include the Chemical Economics Handbook and the Specialty Chemicals Update Report series, both published by SRI International; the American Chemistry Council's Guide to the Business of Chemistry; and data from the International Lead and Zinc Study Group. Sources for the health and environmental impact sections include peer-reviewed journal articles as well as reports and statistics from government agencies and intergovernmental organizations, including the World Health Organization (WHO) and the World Bank.

2. Portrait of the Chemical Industry

The chemical industry is divided into a number of broad subsectors. Different classification systems provide different definitions of these subsectors, but they are nonetheless useful in drawing the broad outlines of the industry. This section provides a brief overview of these subsectors and then reviews available information on the total number of chemicals currently on the market.

2.1 Subsectors of the Chemical Industry

Bulk chemicals (also referred to as base chemicals) compose the first tier of production. These include both organic chemicals (also referred to as petrochemicals) and basic inorganics.³ The bulk chemicals are sold within the chemical industry and to other industrial sectors, and are used to make an enormous variety of downstream products.

The organic bulk chemicals can, in turn, be considered in several tiers. The first tier consists of a handful of high-volume chemicals: the olefins (ethylene, propylene and butadiene), the aromatics (benzene, toluene and xylenes) and methanol. The second tier consists of a larger number of chemicals made from these starting materials, sometimes in combination with inorganic chemicals.

A number of inorganic bulk chemicals are used primarily to produce agricultural inputs. Others are added to basic organic chemicals, either to facilitate chemical reactions, or as additions to the product (for example, halogens are added to basic organic chemicals to create a wide variety of halogenated compounds).

Specialty chemicals are smaller-volume, more specialized chemicals. They include “adhesives and sealants, catalysts, coatings, electronic chemicals, institutional and industrial cleaners, plastic additives, water management chemicals,” and others.⁴

Agricultural chemicals include pesticides and fertilizers. Some classification systems include them within the category of specialty chemicals.

Pharmaceuticals are sometimes grouped together with agricultural chemicals in a category of “life sciences chemicals.”

Biocides include both pesticides and antimicrobials. Antimicrobials may be used for pharmaceutical applications, or for industrial applications. In the latter instance, they may be grouped under the heading of specialty chemicals.⁵

The term consumer products is sometimes used within the chemicals industry to refer to formulated chemical products that are sold directly to consumers. Examples include household cleaning products and personal care products.⁶ However, the term can also be used to refer more broadly to any product purchased by consumers, such as apparel or furniture.⁷

Articles are defined under the European chemicals regulation, REACH, as objects whose function is determined primarily by shape, as opposed to depending primarily on chemical composition.⁸

The term chemicals in products refers to chemicals in both liquid chemical products marketed directly to consumers, such as detergents, and to chemicals in articles, such as apparel or building materials. In contrast, the term chemical product may be used to refer to any chemical or chemical preparation, but not to an article.

Metals may be grouped under the heading of inorganic chemicals; however, trends in metal extraction, processing and use are generally treated as a category in their own right in industry literature and economic analyses. Because metals pose particular concerns for health and the environment in developing countries, this report includes a separate section on metals.

Manufactured nanomaterials are a relatively new category of substances on the market. They have been identified as an emerging issue under SAICM.

2.2 Number of Chemicals on the Market

Although the exact number of chemicals on the market is unknown, it is estimated that there are more than 140,000 chemicals on the EU market. REACH requires registration for chemical substances over one tonne and expects to register at least 30,000 in this category prior to 2018.⁹ These figures may be a reasonable guide to the approximate number of chemicals in commerce globally.

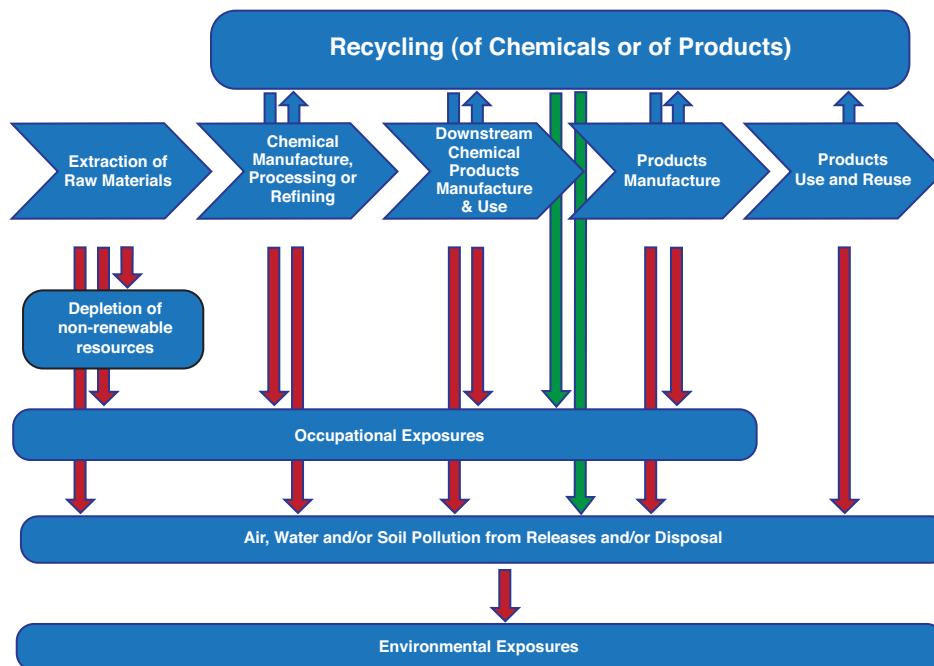
New chemicals are also introduced into commerce each year. For example, the US Environmental Protection Agency adds an average of about 700 new chemicals per year to the Toxic Substances Control Act (TSCA) inventory.¹⁰

2.3 The Chemical Life Cycle

The chemical life cycle begins with extraction of raw materials; this includes mining, extraction of oil and natural gas and other activities. These raw materials are used in chemical manufacturing, processing or refining. Manufactured bulk chemicals are then combined with one another and used to make a wide variety of downstream chemical products. These chemical products may, in turn, be used as: feedstock for chemical products further downstream; for a variety of industrial activities and services as individual chemicals or in preparations; or may be used to make consumer products. At the end of the life cycle, chemicals may be released into the environment, recycled for continued use, disposed of in hazardous waste facilities, or disposed of in other ways. Products containing chemicals, similarly, may be reused, recycled, or disposed of in municipal solid waste, in hazardous waste facilities, or through informal waste disposal systems.

At each stage of the chemical life cycle, there are opportunities for exposure. Occupational and environmental exposures can occur during raw material extraction, during bulk and downstream chemical manufacturing and processing, during use of chemicals or chemical-containing products, and during recycling or disposal. Figure A, below, shows the chemical life cycle, illustrating the opportunities for human and environmental exposure that may exist at each stage.

Figure A. Life Cycle of Chemicals



3. Trends in Global Chemical Production and Consumption

The global chemicals industry has grown rapidly over the past several decades. Within the last decade in particular, this growth has been driven primarily by dramatic growth in developing countries and countries with economies in transition. This section provides an overview of global trends in chemical sales and forecasts of future output. It also examines trends and forecasts in production and consumption volume for a few significant categories of chemical use. The section concludes with a brief overview of key drivers influencing shifts in global chemical production and consumption.

3.1 Global Trends in Chemical Sales

The global chemicals industry has grown steadily over the past several decades. Chemical industry data cited by OECD indicate that global chemical industry output was valued at US\$ 171 billion in 1970.¹¹ In 2010, industry sources valued global output at US\$ 4.12 trillion.¹² These figures are not adjusted to account for inflation or price changes, so they do not represent the real growth of the industry. Figures B and C illustrate the nominal growth of chemical industry output over time, broken out by country or region.

In real terms, information on growth is available through production indices calculated by the industry. In the decade 2000 to 2010, the Global Chemical Production Regional Index calculated by the American Chemistry Council shows that total production increased 54 per cent.¹³ Certain countries experienced particularly rapid growth; for example, in China, production nearly tripled over that time period.¹⁴ In 2010, China was the largest chemical producing country, with sales of US\$ 754 billion.¹⁵

The OECD countries as a group still account for the bulk of world chemical production, but developing countries and countries with economies in transition are increasingly significant.¹⁶ An analysis by OECD notes that while annual global chemical sales doubled over the period 2000 to 2009, OECD's share decreased from 77 to 63 per cent and the share of the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa) increased from 13 to 28 per cent.¹⁷

Countries that accounted for a minimal percentage of global production 40 years ago have grown to become major producers. According to an analysis by the European Chemical Industry Council (CEFIC), over the period 2000 to 2010, the share of the EU chemical industry went from 29.2 per cent of total global sales to just 20.9 per cent of the total. During this same time period, China's share rose from 6.4 to 24.4 per cent. The share of other Asian countries and of Latin America also rose. These figures are all based on dollar values, not chemical production volume.¹⁸

Africa's contribution to global chemical production is small, but the chemicals sector is expected to play an increasingly important role in the economies of specific African countries. For example, although small relative to the primary chemical producing nations, South Africa's chemical industry is the largest in Africa, contributing about 5 per cent of GDP and employing approximately 150,000 people.¹⁹ Annual production of primary and secondary process chemicals is on the order of 13 million metric tonnes, with a value of approximately US\$ 3 million.²⁰ In Northern Africa, there are strong chemicals industries in Algeria, Egypt, Libya, Morocco and Tunisia, while in West Africa, Nigeria is the primary producer and user of chemicals. Currently, petrochemical commodities, polymers and fertilizers are the main chemical products of African countries. However, greater investment in oil and gas in a number of African countries suggests increasing capacity to support production of a range of chemical products, including pharmaceuticals and specialty chemicals.²¹

Earlier analyses emphasized a trend in which production of bulk chemicals was shifting to developing and transition economies, while OECD countries continued to lead in the higher-value chemicals such as specialty and life sciences chemicals.²² However, OECD's most recent analysis notes that some countries with economies in transition are moving increasingly into the markets for specialty and fine chemicals. In particular, OECD notes that companies in

China, India, and the Middle East are investing in production of specialty and fine chemicals. Because these sectors are characterized by rapid innovation, this suggests that increasing numbers of new chemicals may be developed in developing and transition countries.²³

Figure B. Chemical Industry Output: Developed Regions*

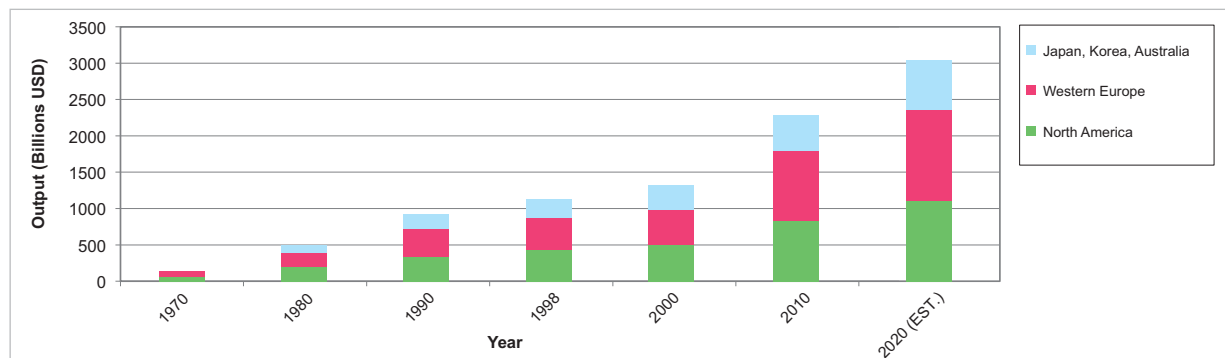
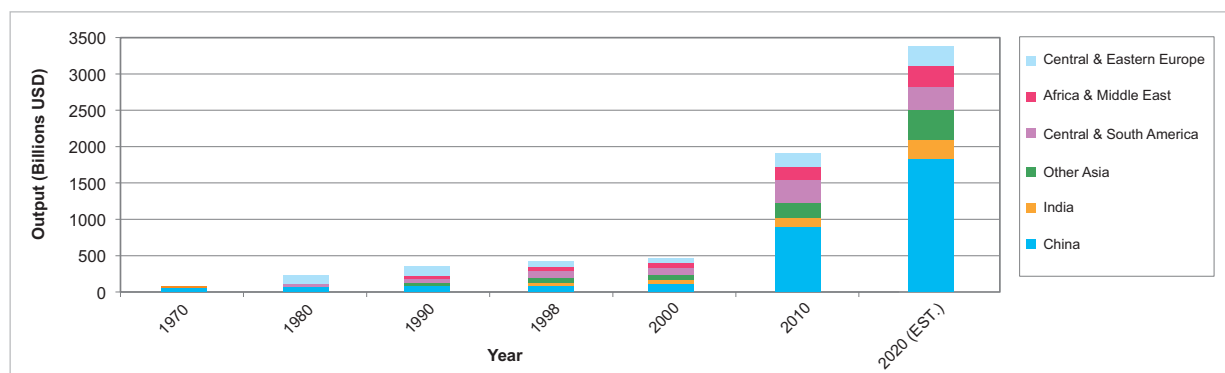


Figure C. Chemical Industry Output: Developing Regions* & Countries with Economies in Transition



*As categorized by UN Statistics Division, <http://unstats.un.org/unsd/methods/m49/m49regin.htm>, with the exception of the Republic of Korea. 1970-1990 Source: Organisation for Economic Development (OECD). (2001). *OECD Environmental Outlook for the Chemicals Industry*. Paris. OECD Environment Directorate. 2000-2010 Source: American Chemistry Council (2011). "Global Business of Chemistry: Global Chemical Shipments by Country/Region (billions of dollars)". Available from <http://www.americanchemistry.com/Jobs/EconomicStatistics/Industry-Profile/Global-Business-of-Chemistry>. 2020 Estimation Source: American Chemistry Council, *Mid-Year 2011 Situation & Outlook*, June 2011. Figures shown here are not adjusted to reflect price changes or inflation.

3.2 Global Forecasts for the Chemical Industry: Looking Forward to 2020

In its 2001 report, OECD Environmental Outlook for the Chemicals Industry, OECD presented forecasts for the global chemicals industry, looking forward to 2020, using a base year of 1995. OECD projected that the share of global chemical production and consumption located in developing countries would increase. OECD noted that production of high volume basic chemicals, in particular, was expected to shift away from OECD countries. Based on its models and data available from industry sources at the time, OECD projected that by 2020, developing countries would be home to 31 per cent of global chemical production, and 33 per cent of global chemical consumption.²⁴ In developing its projections, OECD assumed that the chemicals industry would grow approximately in tandem with world GDP, while population would grow more slowly, meaning that global chemical production per capita would increase.

Table 1. Chemical Production: Predicted Growth, 2012-2020

		Per cent change, 2012-2020	
North America		25%	
	United States		25%
	Canada		27%
	Mexico		28%
Latin America		33%	
	Brazil		35%
	Other		31%
Western Europe		24%	
Emerging Europe		35%	
	Russia		34%
	Other		36%
Africa & Middle East		40%	
Asia-Pacific		46%	
	Japan		22%
	China		66%
	India		59%
	Australia		23%
	Republic of Korea		35%
	Singapore		35%
	Other		44%

Source: Per centages calculated based on projections for the regions and for selected countries. Swift, Thomas Kevin et al. (June 2011). "Mid-Year 2011 Situation & Outlook», American Chemistry Council.

OECD's most recent outlook, projecting trends to 2050, predicts that the global chemical sales will grow about 3 per cent per year to 2050, with growth rates for the BRIICS countries more than double those of the OECD countries. OECD predicts that chemical production in the rest of the world will grow even faster than BRIICS countries in the period 2010 to 2050, although total volumes produced will be lower.²⁵

Recent forecasts developed by the American Chemistry Council (ACC) also predict significant growth in chemical production in developing countries in the period to 2021, and more modest growth in developed countries.²⁶

Consistent with trends seen over the past decade, China is expected to have the highest annual growth rates in chemical production. China's chemical production is expected to exceed 10 per cent per year until 2015, and to drop just 10 per cent per year in the years 2016-2021. Rapid growth is expected in India as well, with predicted annual growth above 9 per cent per year in the period 2012 to 2014, and above 8 per cent per year in the period 2015 to 2021. Annual growth rates for Africa and the Middle East are predicted to be just over 6 per cent per year through 2013, and over 5 per cent per year from 2014 to 2021.²⁷

In contrast, the predicted annual growth rates for chemical production in developed countries are below 4 per cent for the entire period, and below 3 per cent per year for the years 2013 to 2021. Growth in the period 2013 to 2021 is expected to be below 3 per cent per year in the United States and below 4 per cent per year in Canada. Growth in Western Europe, similarly, is expected to be below 3 per cent per year for this period.²⁸

Expected growth rates in Russia and other emerging economies of Eastern Europe are in a middle range, ranging from just over 4 per cent to just under 6 per cent per year in the period 2013 to 2021.²⁹

Table 1 shows predicted global chemical production growth rates for the period 2012 to 2020. As shown in the table, total growth in North America and Western Europe over this period is predicted to be about 25 and 24 per cent, respectively. Growth in Latin America is expected to be slightly higher, at 33 per cent; Russia and the emerging economies of Central and Eastern Europe have a similar forecast, at 35 per cent. Production in Africa and the Middle East is expected to grow 40 per cent. In the Asia-Pacific region, growth is expected to be 46 per cent, with the most rapid growth in China and India (66 and 59 per cent, respectively).³⁰

3.3 Sector-Specific Chemical Use Trends and Projections: Selected Industries

Sections 4 through 7 of this report provide a detailed look at chemical production and use by broad chemical category. A complimentary approach to understanding trends in chemical use is to consider individual industries that are downstream users of chemicals or that emit significant amounts of chemicals as unintentional byproducts. This section briefly presents trends and forecasts for a few sample sectors that are significant users or emitters of chemicals. These sectors, among others, are also featured in the discussion of chemical waste in Section 9.

Chemicals used in electronics. Over 1,000 different chemicals are used in electronics manufacture, such as mobile phones and personal computers.³¹ These include heavy metals, rare earth metals, solvents, polymers and flame retardants, among other categories.³² Chemicals used in electronics may be associated with a variety of adverse health outcomes, including cancers in workers in electronics facilities and birth defects in workers' children.³³ Furthermore, electronics pose significant challenges at the end of their useful life (as discussed later in the section on electronic waste).³⁴

Electronics production has grown globally, and is expected to continue to grow, with an increasing percentage in developing/transition countries. The global electronic chemicals and materials market was estimated at US\$ 28.5 billion in 2010.³⁵ Currently, 77 per cent of the chemicals used for production of integrated circuits and printed circuit boards are being used in Asia. Japan and China account for 21 and 14 per cent of the global total, respectively, and other Asian countries account for 42 per cent of the global total. (These and the following figures are measured in dollar value, not volume)³⁶ Global consumption of electronic chemicals and materials, particularly in developed countries, is projected to increase between 5 per cent and 12.6 per cent annually from 2010 to 2015.³⁷ By 2015, global consumption of electronic chemicals and materials is anticipated to reach US\$ 51.6 billion.³⁸ Growth will be most rapid in China, with an estimated average annual growth rate of 7.7 per cent.³⁹

Chemicals used in textile production. The textile sector uses chemicals including dyes; basic commodity chemicals such as oils, starch, waxes, surfactants, pesticides, and specialized chemicals such as flame retardants and water repellants.⁴⁰ World consumption of textile chemicals is projected to reach US\$ 19 billion in 2012.⁴¹ China is the largest consumer of textile chemicals, with 42 per cent of global consumption. Other Asian countries as a group (excluding Japan) are the next largest consumers, accounting for 20 per cent of global consumption, followed by Western Europe and North America (accounting for 16 and 12 per cent, respectively). The Middle East and Africa account for just 5 per cent of global consumption, and Central and Eastern Europe account for just 2 per cent.⁴²

Consumption of textile chemicals is expected to increase 5 per cent per year in China and other Asian countries (excluding Japan) over the period 2010 to 2015. The rapid projected growth in China is due primarily to manufacturing of clothing. The largest categories of chemicals included in China's textile chemical consumption are surfactants, including dye bath additives, antistatic agents and softeners, which account for 41 per cent of all textile chemical consumption. Sizing chemicals and lubricants account for another 24 per cent and 13 per cent each of the textile chemicals market in China.⁴³

Growth is expected to be slower in other parts of the world, and negative in North America and Western Europe.⁴⁴

Chemicals used as flame retardants. The broad category of flame retardants includes a variety of chemicals, including brominated and chlorinated organic compounds as well as a variety of inorganic compounds. The largest use of flame retardants is in the plastics industry. In some cases, flame retardants are also used as additives to textiles, adhesives, elastomers and paper.⁴⁵

In 2010, global consumption of all types of flame retardants combined was approximately 1.9 million metric tonnes, with a value of about US\$ 4.6 billion. North America and Europe were the largest consumers of flame retardants, with 27 and 24 per cent of the market (measured in dollar value), respectively. China accounted for 19 per cent, and other Asian countries accounted for about 18 per cent of global consumption. However, projected average annual growth rates for the period 2010-2015 are just 1 and 3 per cent in North America and Europe, whereas consumption of flame retardants in China is projected to grow an average of 10 per cent per year over this period.⁴⁶

A variety of factors influence trends in the global flame retardant industry. Regulations, including both fire safety requirements and regulation of specific classes of flame retardants based on health and environmental concerns, are one important factor. Development of new products, substitution of new flame retardants for existing ones, and other factors also play a role.⁴⁷

Chemicals associated with cement production. Hydraulic cement manufacturing can emit a range of hazardous air emissions and can be significant sources of pollution. The air pollution composition and emission levels depend on a variety of factors, including the composition of raw materials used, the type of fuels used in the cement kiln (e.g. petroleum coke, coal, natural gas or alternative fuels, which include tire-waste derived fuel) operation characteristics, as well as the effectiveness of emission control devices. Air pollutants include particulate matter, heavy metals such as mercury, acid gases, VOCs, PAHs and dioxins/furans (PCDD/PCDF).

In 2010, the world production of hydraulic cement was estimated at 3.3 billion metric tonnes.⁴⁸ The top three producers were China, with 1.8 billion metric tonnes; India, with 220 million metric tonnes; and the US, with 63.5 million metric tonnes.⁴⁹ Global consumption of hydraulic cement is anticipated to increase 4.1 per cent per year to 3.5 billion metric tonnes in 2013, with a value of US\$ 246 billion.⁵⁰ Sixty-nine per cent of the world consumption in 2013 is predicted to be in China and India.⁵¹ Africa and the Middle East are predicted to be the next largest consumers, accounting for 12 per cent of global demand in 2013.⁵²

3.4 Driving Forces Influencing Global Trends

A variety of global economic forces influence changes in chemical production, use and disposal over time. Chemical use is influenced both by countries' domestic needs, and by global trade. Factors influencing the location of chemical use in manufacturing include proximity to raw materials, proximity to final markets, labour costs, and a range of other factors.

For certain categories of manufacturing, proximity to raw materials can have a significant effect on costs of production and as a result, can influence chemical production near the source. For example, the 1970s saw the emergence of chemical producing companies in fossil fuel rich nations, producing basic petrochemicals from which the wide variety of other organic chemicals are made.⁵³ As a consequence, in 2010, Saudi Arabia was the third largest producer of ethylene behind only China and the US⁵⁴ Similarly, China makes use of its extensive natural fluorospar deposits in producing fluorine compounds.⁵⁵ Scholars have also suggested that as high-quality natural resources are exhausted in industrialized countries, energy and pollution-intensive activities are more likely to shift to less developed countries.⁵⁶

For certain categories of products, proximity to final markets is an important factor determining location of production. This is particularly true for categories of products that pose limitations with regard to international trade. For example, production of materials such as cement may be located close to the locations where they will be used. As demand for a wide variety of consumer products increases in many developing countries and countries with economies in transition, there are increasing benefits for companies producing such products in those regions.

The worldwide expansion of the chemicals industry has been driven in large part by the emergence of multinational chemical companies as OECD-based companies invested in production facilities in non-OECD countries. Global investment has been driven by lower labour costs in non-OECD countries, world economic growth, the reduction of tariffs and other trade barriers, and advances in telecommunication and transportation.⁵⁷ Moreover, technology transfer from developed countries to countries in economic transition as a result of joint ventures, mergers and acquisitions among other investment initiatives, have helped such emerging economies to play a larger role in the global market.⁵⁸ As a consequence, the majority of global investment in chemical plants is occurring in the developing world. Approximately 80 per cent of new chemical production capacity is being developed in emerging economies, while many European and North American plants are closing.⁵⁹ These key drivers have facilitated the move of a very significant portion of chemical production activity from developed countries to developing countries and countries with economies in transition over the past several decades.

It is worth noting that the economic development assistance agenda has not necessarily kept pace with these changes in the global distribution of chemical-intensive activities. Chemicals management is usually not included either in development assistance packages, or in recipient countries' aid requests. Consultations by UNEP with donor countries reveal a pattern of treating chemical management problems on a case-by-case basis, rather than integrating them into a broader environment and development agenda. Factors contributing to this pattern include a lack of awareness of the risks posed by poorly-managed chemicals and waste, and lack of coordination among national institutions regulating chemical use and disposal. For example, traditional chemical safety control and regulations may be ineffective without more general environmental protection controls which prohibit pesticides and other chemical activities close to drinking water resources, or attempts to contain vector borne diseases may be undertaken with unsafe pesticides. Thus, there is a need to build awareness about linkages among the chemicals sector, health, environment and other sectors involved in the development planning processes in order to reduce chemical risks to health and the environment.⁶⁰

4. Trends in Production and Consumption of Industrial Chemicals: Bulk Organics; Bulk Inorganics; Halogens and Halogenated Organic Compounds

This section provides more detailed information on trends in the production and consumption of some of the highest volume organic and inorganic chemicals as well as a discussion of halogenated organic compounds — a category of downstream chemical products that are of particular interest from a health and environmental perspective.

4.1 Bulk Organic Chemicals

A small number of bulk organic chemicals serve as the feedstock for tens of thousands of downstream chemical products. Seven bulk chemicals serve as the starting point for creating a number of key feedstock chemicals. Each of these feedstock chemicals, in turn, is used to make other important products downstream. Table 2 provides a bird's eye view of the value chain associated with the top bulk organic chemicals. For example, as shown in the table, methanol is used to create formaldehyde and other key feedstock chemicals used in resins, latex, paints, coatings, adhesives, solvent applications, and many other applications. Similarly, ethylene is used to make a number of chemical products, including: high and low density polyethylene; ethylene dichloride; ethylene oxide; ethylbenzene; linear alcohols; vinyl acetate; and others. Each of these in turn is used to make other products. Some are converted directly into consumer products; for example, high- and low-density polyethylene are used to make products such as food packaging, toys, and containers. Others go through additional intermediate stages; for example, ethylene dichloride is used to make vinyl chloride, which in turn is used to make polyvinyl chloride (PVC), used in a wide variety of final products.

Because these seven bulk chemicals are the source of so many other chemical products downstream, trends in production and consumption of these chemicals provide insight into trends in the chemical industry more broadly. As shown in Table 3, global production of each of these chemicals has increased over the last twenty years, while the share of production in the traditional leaders – the US, Western Europe, and Japan – has declined. For example, while global production of methanol has more than doubled, the share produced in the US, Western Europe and Japan has declined from just under a third of the global total to just 6 per cent of the global total. Similarly, while global production of xylenes has increased nearly 200 per cent, the percentage being produced in these traditionally leading regions has declined from about two-thirds of global production to less than half of global production.⁶¹

Increasingly, countries with economies in transition are driving the trends in both production and consumption of these bulk organic chemicals and their downstream chemical products. China was the largest producer of methanol in 2010, accounting for nearly a third of the global total, and China's share of methanol production is estimated to rise to 42 per cent of the global total by 2015. China's share in global production of other bulk organic chemicals is smaller, but still significant. The US is still the largest producer of ethylene and propylene, and Western Europe is the largest producer of butadiene and benzene; the Republic of Korea is the largest producer of xylenes, and China is the largest producer of toluene. The Middle East and Japan are also important producers of bulk organic chemicals.

The consumption data tell a similar story. China accounted for 41 per cent of global methanol production in 2010, with a share estimated to rise to 54 per cent by 2015.⁶² The US continues to be the largest consumer of the olefins, but Africa and the Middle East now account for a significant percentage of ethylene consumption, and China and other Asian countries account for a significant portion of butadiene consumption. China is now the largest consumer of xylenes and toluene.

Table 4 shows the largest producers and consumers of bulk organic chemicals in the most recent year for which data are available. In the years ahead, growth in consumption of these chemicals is expected to be unevenly distributed among regions. Table 5 shows expected annual growth rates in the regions with highest expected growth over the next three to five years.

Table 2. Bulk Organic Chemicals and their Downstream Products: Examples

Bulk Chemical	Sample chemical products	Sample downstream or intermediate products	Sample final products
Methanol	Formaldehyde	Phenol formaldehyde	Resins used in plywood and particle board
	Acetic acid		Latex, paints, coatings, adhesives, textile finishing
	Chloromethanes		Electronics, metal cleaning, paint remover, silicones, insulation
	Methylmethacrylate		Glazing, acrylics
Olefins			
Ethylene	Ethylene dichloride	Vinyl chloride monomer (VCM)	Polyvinyl chloride (PVC) used to make siding, window frames, pipes, other consumer products
	Ethylbenzene	Styrene	Polystyrene (cups, insulation); styrene acrylonitrile resins (instrument lenses, houseware); styrene butadiene rubber (tires, footwear, sealants); styrene butadiene latex (carpet backing, paper coatings)
	Low Density Polyethylene (LDPE), Linear Low Density Polyethylene (LLDPE), High Density Polyethylene (HDPE)		Food packaging, plastic bags, toys, housewares, containers, bottles, and other consumer products made from HDPE, LDPE or LLDPE
	Ethylene oxide	Ethylene glycol	Antifreeze, fibers (clothing and carpets) and polyester resin (bottles and other consumer items)
Propylene	Polypropylene		Polypropylene used to make resins (automobile components, packaging, rope) and fibers (carpets and matting)
	Propylene oxide	Propylene glycol	Polyesters (furniture, boats, fibers and compounds used in automobiles)
	Isopropyl alcohol	Acetone	Methyl methacrylate, used to make plastics, signs, paints, lenses and lighting panels. Isopropyl alcohol used directly in solvents, coatings, cosmetics and health care applications
	Styrene butadiene rubber; polybutadiene rubber; styrene-butadiene latex; ABS resins; chloroprene rubber; nitrile rubber		Styrene butadiene rubber used in tires, footwear; polybutadiene rubber used in tires, golf balls; styrene-butadiene latex used in carpet backing, adhesives; ABS resins used in automotive parts and spas; chloroprene rubber used in gaskets, seals, hoses; nitrile rubber used in shoes, hoses and gaskets
Aromatics			
Xylenes	o-xylene	Phthalic anhydride, polyester polyol	Plasticizers; resins used auto parts, coatings, furniture; urethanes used in foams and insulation
	p-xylene	Isophthalic acid	Polyamide resins used in adhesives
	m-xylene	Terephthalic acid	Polyester fibers used in apparel; polyethylene terephthalate (PET) used in bottles, film and other products
Benzene	Ethylbenzene	Styrene	See styrene products listed above
	Cumene	Phenol	Bisphenol A, used to make polycarbonate resins (eyeglasses, containers, computers) and epoxy resins (coatings, adhesives); phenolic resins, used in plywood and other applications
	Cyclohexane	Caprolactam	Nylon fibers and resins
	Aniline	Isocyanates	rubber chemicals, pesticides and dyes
	Chlorobenzenes		Pesticides and dyes
Toluene	Benzene, xylene – see above		
	Toluene diisocyanate		Urethane foams used in bedding and insulation, urethane elastomers used in footwear, urethane coatings used in varnishes, adhesives and sealants.
	Solvents		

Table 3. Global Production of Bulk Organic Chemicals: Changes in Geographic Distribution, 1990-2010

Chemical category	Chemical	Global production in 2010 (millions of metric tonnes)	% Increase in global production, 1990-2010	% produced in US, Western Europe and Japan		% produced in Rest of World	
				1990	2010	1990	2010
	Methanol	49.1	143%	30%	6%	70%	94%
Olefins	Ethylene	123.3	117%	66%	41%	34%	59%
	Propylene	74.9	154%	73%	45%	27%	54%
	Butadiene	10.2	62%	65%	48%	35%	52%
Aromatics	Xylenes	42.5	199%	64%	35%	36%	65%
	Benzene	40.2	80%	66%	44%	34%	56%
	Toluene	19.8	85%	64%	39%	36%	61%

Source: Davis, S. (April 2011). *Chemical Economics Handbook Product Review: Petrochemical Industry Overview*. SRI Consulting.

Table 4. Bulk Organic Chemicals: Largest Producers and Consumers

Chemical category	Chemical [year*]	Largest producers (% of global total) in most recent year for which data are available	Largest consumers (% of global total) ⁶³ in most recent year for which data are available
	Methanol ⁶⁴ [2010]	China (32%), Middle East (29%)	China (41%), Western Europe (13%)
Olefins	Ethylene ⁶⁵ [2010]	United States (19%), Africa and the Middle East (17%), Western Europe (16%)	United States (19.3%), Western Europe (16.3%), Africa and the Middle East (15.9%)
	Propylene ⁶⁶ [2010]	United States (18%), China (16%)	United States (19%), China (18%)
	Butadiene ⁶⁷ [2009]	Western Europe (22%), Other Asia (19%), United States (18%), China (16%)	United States (22%), Western Europe (20%), Other Asia (18%), China (16%)
Aromatics	Xylenes ⁶⁸ [2009]	Republic of Korea (15%), China (15%), United States (13%), Japan (13%)	China (17%), Republic of Korea (15%), United States (11%), Japan (11%)
	Benzene ⁶⁹ [2008]	Western Europe (20%), United States (14%), Japan (13%), China (13%)	Western Europe (23%), United States (18%), China (13%), Japan (11%)
	Toluene ⁷⁰ [2009]	China (18%), United States (17%)	China (22%), United States (18%)

*Most recent year for which data were available at the time of writing. Sources: Guillermo, S.A. (July 2011). *Chemical Economics Handbook Marketing Research Report: Methanol*. SRI Consulting. Devanney, M.T. (July 2011). *Chemical Economics Handbook Marketing Research Report: Ethylene*. SRI Consulting. Giacobbe, G.B. (August 2011). *Chemical Economics Handbook Marketing Research Report: Propylene*. SRI Consulting. Davis, S. (October 2009). *Chemical Economics Handbook: Butadiene*. SRI Consulting. Guillermo, S.A. and Yoneyama, M. (September 2010). *Chemical Economics Handbook Marketing Research Report: Xylenes*. SRI Consulting. Davis, S. (May 2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting. Davis, S. and Yoneyama, M. (February 2010). *Chemical Economics Handbook Marketing Research Report: Toluene*. SRI Consulting.

Source: American Chemistry Council (2011). *Guide to the Business of Chemistry*.

Table 5. Bulk Organic Chemicals: Predicted Average Annual Consumption Growth

Bulk Organic Chemical (period for which estimated growth rates are available)	Regions and countries with highest predicted growth (average annual growth, rounded to nearest whole number)*
Methanol (2010-2015) ⁷¹	Africa (27%); China (16%); Middle East (11%); Central and South America ⁷² (7%)
Ethylene (2009-2014) ⁷³	China (10%); Africa and the Middle East (9%); Singapore (8%)
Propylene (2010-2015) ⁷⁴	Middle East (14%); China (10%); CIS (10%); India (8%)
Butadiene (2009-2013) ⁷⁵	China (9%); Central and South America ⁷⁶ (3%)
Xylenes (2009-2014) ⁷⁷	Mexico (59%); South America (18%); China (13%); Middle East (12%); India (6%)
Benzene (2008-2013) ⁷⁸	Middle East ⁷⁹ (14%); China (11%); Central and South America ⁸⁰ (8%); Other Asia ⁸¹ (7%)
Toluene (2009-2014) ⁸²	India (14%); Other Asia ⁸³ (13%); China (7%)

*All figures shown are for most recent year for which data are available. Sources: Guillermo, S.A. (July 2011). *Chemical Economics Handbook Marketing Research Report: Methanol*. SRI Consulting. Devanney, M.T. (July 2011). *Chemical Economics Handbook Marketing Research Report: Ethylene*. SRI Consulting. Giacobbe, G.B. (August 2011). *Chemical Economics Handbook Marketing Research Report: Propylene*. SRI Consulting. Davis, S. (October 2009). *Chemical Economics Handbook: Butadiene*. SRI Consulting. Guillermo, S.A. and Yoneyama, M. (September 2010). *Chemical Economics Handbook Marketing Research Report: Xylenes*. SRI Consulting. Davis, S. (May 2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting. Davis, S. and Yoneyama, M. (February 2010). *Chemical Economics Handbook Marketing Research Report: Toluene*. SRI Consulting.

4.1.1 Sample Bulk Organic Chemical: Benzene

In 2008, benzene consumption world wide totaled just under 40 million metric tonnes. About half of this total was accounted for by consumption in Western Europe (just over 9 million metric tonnes, or 23 per cent of the total), North America (around 8 million metric tonnes, or 18 per cent), China (13 per cent), and Japan (11 per cent).⁸⁴ In the period 1990 to 2008, benzene consumption has increased in most parts of the world for which data are available, with the most rapid increase occurring in China. Benzene consumption in China has risen nearly 800 per cent in the period 1990 to 2008. Consumption also grew rapidly in the Republic of Korea over the same time period (over 500 per cent).⁸⁵ Benzene consumption increased rapidly in the Middle East as well, rising 360 per cent from 1990 to 2008, driven by the ready availability of feedstocks.⁸⁶

The patterns in North America and Europe are in marked contrast to these rapid increases. Benzene consumption has risen in North America and Western Europe as well, but at a much slower rate (13 per cent and 50 per cent respectively);⁸⁷ and consumption in Central and Eastern Europe declined 31 per cent over this period.⁸⁸

Looking forward to 2013, global benzene consumption is expected to grow at an average rate of about 3 per cent per year, with considerable variation in growth rates among regions. Growth is expected to be below 1 per cent per year in the US and Canada, and slightly negative in Mexico, Western Europe and Japan. In contrast, rapid growth is expected in the Middle East, China, Central and South America, and “Other Asia” (13.5, 10.8, 8.4 and 7.0 per cent per year, respectively).⁸⁹

Selected regional trends in benzene consumption are shown in Figure D and Figure E. As shown in these figures, benzene consumption in traditional leaders such as North America, Western Europe and Japan has leveled off, while consumption in other regions has grown rapidly.

These trends may have implications for the environment and human health, as discussed in later sections of this report. Benzene exposure is associated with a number of diseases, including leukemia and multiple myeloma. The International Agency for Research on Cancer (IARC) has classified benzene in Group 1 (carcinogenic to humans).⁹⁰

ⁱ “Other Asia” is defined in this source as: India, Indonesia, Malaysia, Singapore, Thailand and other Southeast Asian countries.

Figure D. Benzene Consumption: North America, Western Europe and Japan (1990-2012)

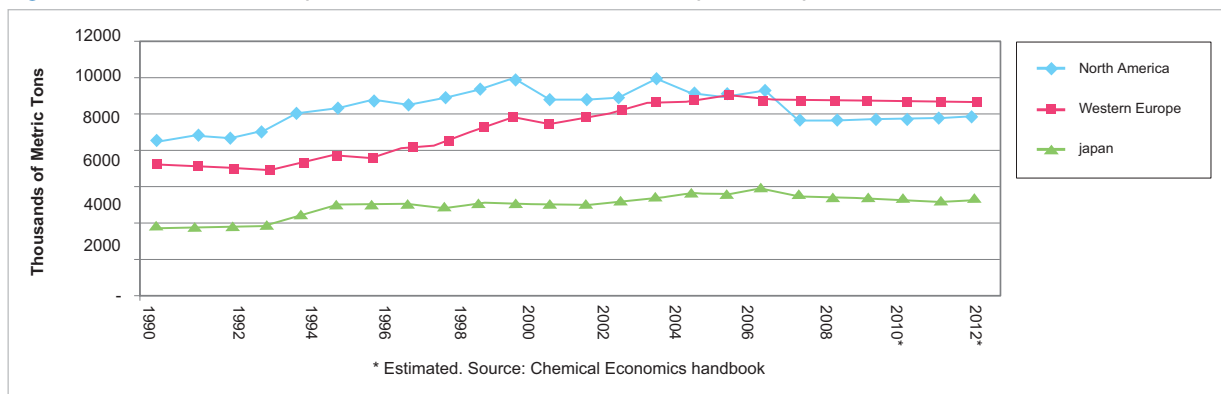
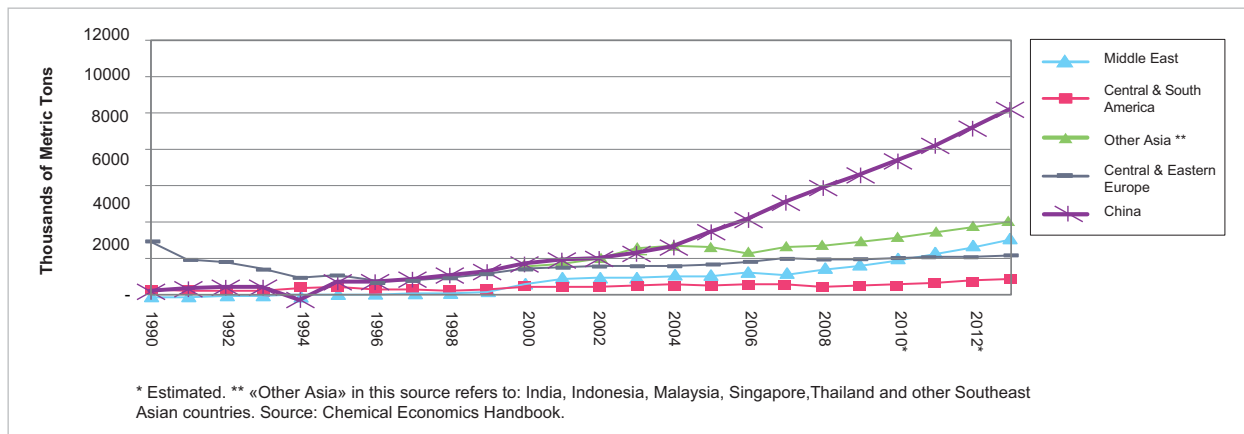


Figure E. Benzene Consumption: China, Other Asia, Central & Eastern Europe, Central & South America and the Middle East (1990-2012)



4.2 Bulk Inorganic Chemicals

As with bulk organic chemicals, a relatively small number of inorganic inputs are used in large volumes worldwide and are important components of a wide range of downstream products. A number of the high volume inorganic chemicals are used primarily for production of agricultural inputs.

China is now the largest producer and consumer of the highest-volume inorganic chemicals. In the case of lime and limestone, used in a variety of applications including metallurgy and building products, China accounted for over 60 per cent of global production in 2008, and was the largest consumer as well. Similarly, China is the largest single producer and user of the major inorganic chemicals used to produce agricultural inputs: sulfur and sulfuric acid (used to produce phosphate fertilizer materials); ammonia (used to produce nitrogen fertilizer) and phosphoric acid (used to produce phosphate fertilizers). Table 6 shows global production volumes, principal uses and production trends for some of the highest-volume inorganic chemicals.

China's leading role has emerged recently, due to rapid growth in China's production. Sulfuric acid production provides an example. Global production of sulfuric acid increased 25 per cent over the period 1990 to 2008, due in large part to increasing production in China. China's production of sulfuric acid increased over 400 per cent in the period 1990 to 2007. Production in Central and South America also increased significantly over this period (163 per cent from 1990 to 2008). In contrast, production in North America, Western Europe, and Central and Eastern Europe declined over the same period (15, 40, and 34 per cent decrease, respectively).⁹¹

Table 6. Sample High-volume Inorganic Chemicals

Chemical (most recent year for which data are available)	Principal uses*	Global production* (million metric tonnes)	Largest producers*	Largest consumers*
Lime/limestone ⁹² (2008)	Metallurgy, building products, environmental applications, pulp and paper	285	China (over 60% of total production), Europe (12%), United States (7%)	China (61%), Europe (12%), United States (7%)
Sulfuric acid ⁹³ (production: 2010; consumption: 2008)	Production of phosphate fertilizer materials (53% of world consumption)	198	East Asia (primarily China) (40%); North America (15%)	Asia (primarily China) (28%), United States (18%), Africa (10%)
Ammonia ⁹⁴ (2010)	Production of nitrogen fertilizer (over 80% of consumption)	134	China (34%), CIS (former USSR) (13%), Southwest Asia (10%)	China (34%), Southwest Asia (11%), CIS (former USSR) (10%)
Sulfur (production: 2010; consumption: 2008) ⁹⁵	Sulfuric acid production (See above)	77	East Asia (primarily China) (30%); North America (21%)	Asia (primarily China) (29%), United States (15%), Africa (10%)
Phosphoric acid, wet process (2009) ⁹⁶	Production of phosphate fertilizers (80-85%)	46	China & other Asia (28%)**, United States (21%), Africa (17%)	China & other Asia (30%)**, United States (22%), Southwest Asia (9.7%)

* All figures shown are for most recent year for which data are available. ** Data are aggregated for China, Cambodia, the Democratic People's Republic of Korea, Laos, Mongolia and Vietnam as a group. For sulfuric acid and sulfur, within this group, China accounts for nearly all production and a significant portion of consumption. Sources: Schlag, S. Funada, C. (July 2009). *Chemical Economics Handbook Marketing Research Report: Lime/Limestone*. SRI Consulting. Suresh, B. (September 2009); *Chemical Economics Handbook Marketing Research Report: Sulfuric Acid*. SRI Consulting; Glauser, J. and Kumamoto, T. (November 2010). *Chemical Economics Handbook Marketing Research Report: Ammonia*. SRI Consulting. Suresh, B. (August 2009). *Chemical Economics Handbook Marketing Research Report: Sulfur*. SRI Consulting. Schlag, S. (January 2010). *Chemical Economics Handbook Marketing Research Report: Wet-Process Phosphoric Acid*. SRI Consulting.

4.3 Halogens and Halogenated Organic Compounds

It is beyond the scope of this report to provide a comprehensive discussion of the vast universe of downstream chemical products that are manufactured from the building blocks described above, among others. This section focusses on halogenated organic compounds both as an example of the wide variety of downstream chemical products and their uses, and as context for the discussion of health and environmental impacts of chemicals in Sections 10 and 11.

A wide variety of industrial chemicals are created by adding halogens – especially chlorine, bromine and fluorine – to organic compounds. The resulting compounds include: chlorinated and brominated solvents, widely used in industrial cleaning applications; vinyl chloride monomer, used to make polyvinyl chloride (PVC) plastic; chlorinated and brominated pesticides; chlorofluorocarbons, targeted for elimination under the Montreal Protocol due to their ozone depleting activity; perfluorinated compounds, used to make water and soil-resistant coatings among other applications; and many other products. Some halogenated organic compounds have been identified as POPs under the Stockholm Convention⁹⁷; others, such as chlorinated paraffins, have been targeted for elimination in the European Union.

4.3.1 Production and Use of Halogens

As of 2008, the largest use of chlorine was in production of ethylene dichloride (just under 35 per cent of total chlorine consumption). Ethylene dichloride, in turn, is used to manufacture vinyl chloride monomer (VCM), the building block for polyvinyl chloride (PVC) plastic. Other significant uses of chlorine, in terms of volume, include the production of isocyanates, used to make foams, paints, coatings and other products; and propylene oxide, used to make polyurethane plastics, among other products. These two applications together account for another 15 per cent of chlorine use.⁹⁸ In

addition, chlorine is a component of a number of pesticides and a variety of relatively low-volume industrial chemicals that are significant for their health impacts and environmental persistence. China is the largest producer and user of chlorine, followed by the US and Europe.

Bromine is used to make brominated flame retardants, which account for nearly half of all bromine consumption. It is also used to produce drilling fluids; as hydrogen bromide in the production of purified terephthalic acid, used to make plastics and other products; for water treatment; and to manufacture the fumigant methyl bromide.⁹⁹ Although the total amount of bromine produced and used globally is small, brominated compounds are, like chlorinated compounds, significant due to their health impacts and their persistence in the environment. The US is the largest producer of bromine, followed by Israel and China. The US is also the largest bromine consumer, followed by China and Africa and the Middle East.

Fluorine is obtained primarily through mining of fluorspar (calcium fluoride). A major use of fluorspar is production of hydrofluoric acid, which in turn has a variety of industrial applications. Among other applications, hydrofluoric acid is used to manufacture chlorinated fluorocarbons (CFCs) as well as fluoropolymers. Other uses include production of fluosilicic acid (used for water fluoridation, aluminum production and to manufacture compounds used in laundry detergents, and silicofluoride salts and cryolite, with applications in aluminum manufacturing).¹⁰⁰ China is the largest producer and consumer of fluorine globally. Mexico is the second largest producer of fluorine, while Europe is the next largest consumer. Table 7 summarizes production and consumption information for chlorine, bromine and fluorine.

Table 7. Chlorine, Bromine, and Fluorine: Uses, Global Production, Principal Producers and Consumers

Chemical [most recent year for which data are available]	Principal uses	Global production (millions of metric tonnes)	Principal producers	Principal consumers
Chlorine ¹⁰¹ [2010]	Manufacture of ethylene dichloride (35%), isocyanates and propylene oxide (15%)	56	China (34%), United States (19%), European Union (18%)	China (34%), United States (19%), European Union (18%)
Bromine ¹⁰² [2008]	Manufacture of brominated flame retardants (48%), clear brine fluids (11%), hydrogen bromide (4%), methyl bromide (3%)	0.563	United States (31%), Israel (29%), China (25%)	United States (30%), China (28%), Africa and the Middle East (26%)
Fluorine ¹⁰³ [2008]	Production of hydrofluoric acid, aluminum smelting, steel manufacturing	5.6 (million metric tonnes of fluorspar)	China (49%), Mexico (21%)	China (38%), Europe, including Russia (17%)

Sources: Beal, M., and Linak, E. (June 2011). *Chemical Economics Handbook Marketing Research Report: Chlorine/Sodium Hydroxide*. SRI Consulting. Glauser, J. (November 2009). *Chemical Economics Handbook Marketing Research Report: Bromine*. SRI Consulting. Will, R.K. (March 2009). *Chemical Economics Handbook Marketing Research Report: Fluorspar and Inorganic Fluorine Compounds*. SRI Consulting.

4.3.2 Production and Use of Halogenated Organic Compounds

Over time, production and consumption of some halogenated compounds has been reduced or eliminated, while production and consumption of others has increased. Some chlorinated compounds were developed in the 1940s, and were used widely until evidence of their health and environmental impacts made it necessary to reduce or eliminate their use. Polychlorinated biphenyls (PCBs) are one example. In a number of cases, halogenated substances have been substituted for one another; for example, some brominated compounds have been adopted as substitutes for chlorinated compounds.

Early examples of fluorinated compounds included the CFCs, and perfluorinated compounds used as non-stick or water- and stain-resistant coatings on consumer products. As a number of fluorinated compounds were found to be ozone depleting substances, some of them have in turn been replaced by chlorinated compounds.

Table 8 shows examples of several types of halogenated compounds, illustrating the wide variety of uses of these compounds. Trends in production and use of three of these sample compounds are discussed below.

Table 8. Halogenated Compounds: Examples		
Category	Sample compounds	Type of product
Chlorinated compounds	Vinyl chloride monomer (VCM)	Monomer used in polymer manufacture
	Trichloroethylene (TCE); perchloroethylene (PCE)	Solvents
	DDT; Lindane; Endosulfan	Pesticides
Brominated compounds	Polybrominated diphenyl ethers (PBDEs)	Flame retardants
Fluorinated compounds	Fluoropolymers	Polymers used for stain resistance and other functions

Halogenated Compound Trends: Vinyl Chloride Monomer. VCM is used to make PVC plastic. Over the ten-year period 1998-2008, VCM production in China grew 500 per cent. China is now the largest producer and consumer of vinyl chloride monomer, followed by the US and Western Europe. As of June 2009, VCM production growth was planned for plants in the Middle East, Russia and China, although the recent economic crisis has delayed and in some cases cancelled many of these plans.¹⁰⁴

As shown in Figure F, consumption of VCM in China has risen since 1998, surpassing consumption in North America and Western Europe since 2005 and continuing to grow steadily. Figures G and H show VCM consumption trends in other regions.

Figure F. VCM Consumption: North America, Western Europe and China

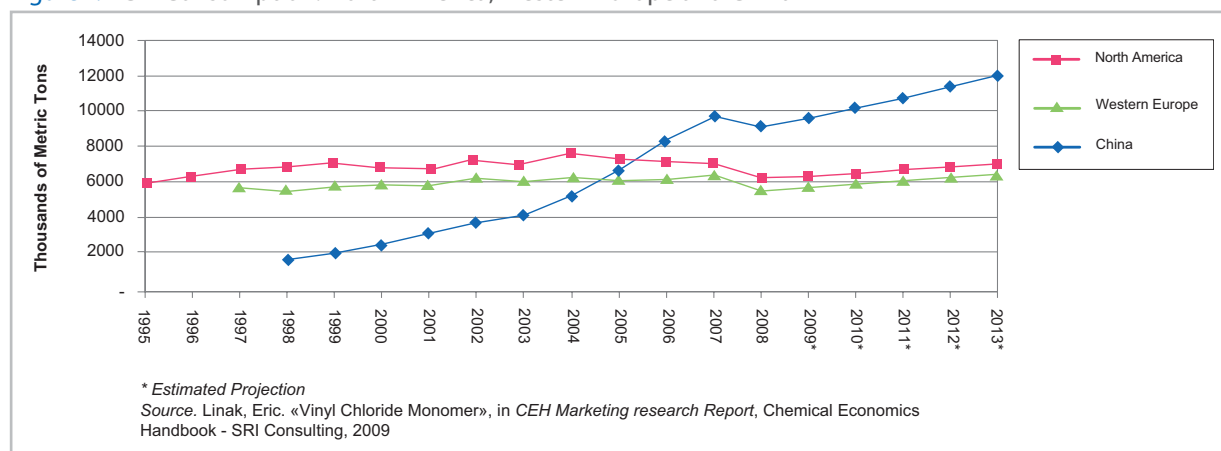


Figure G. VCM Consumption: Central & South America, Eastern Europe, Africa, Middle East and India

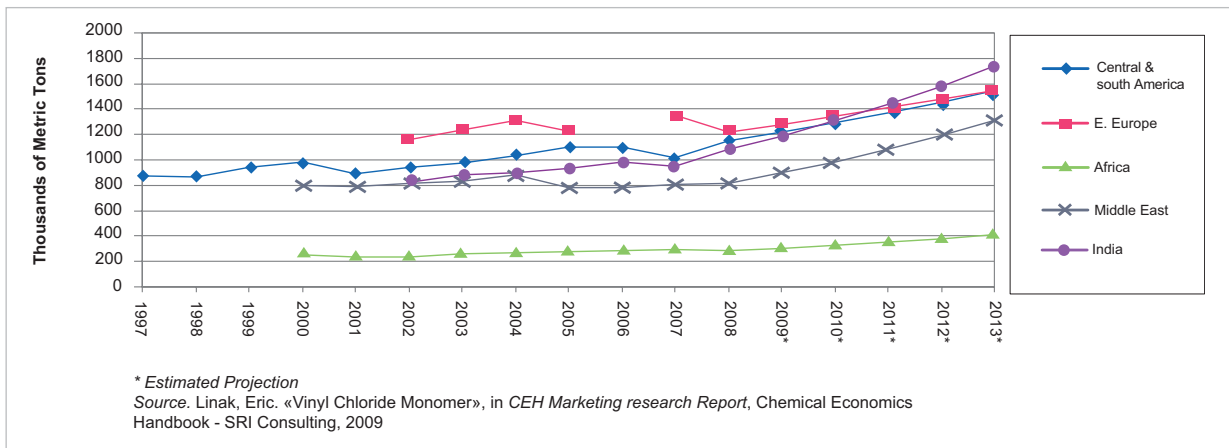
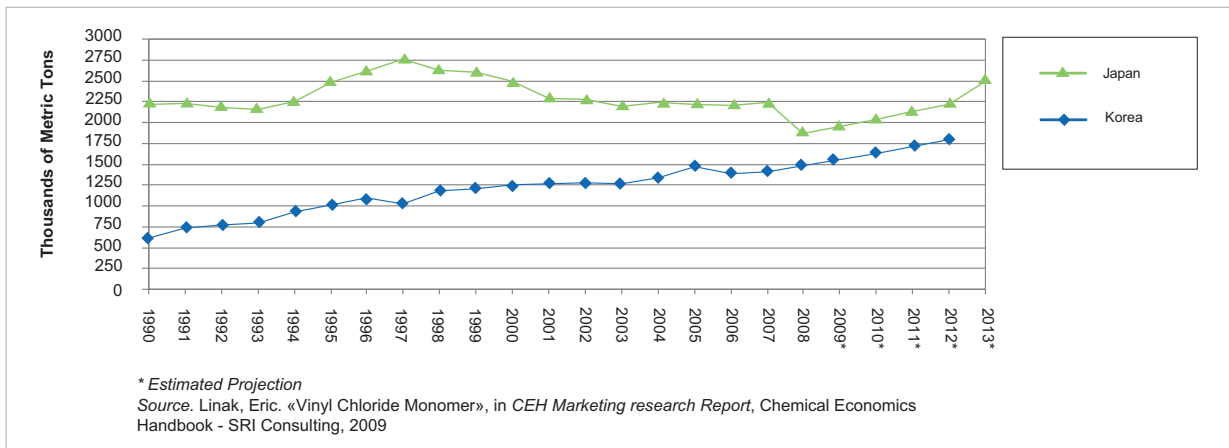


Figure H. VCM Consumption: Republic of Korea and Japan



Halogenated Compound Trends: Trichloroethylene and Perchloroethylene. Trichloroethylene (TCE) and perchloroethylene (PCE) are two chlorinated solvents used for industrial cleaning and degreasing applications, and as components of a variety of chemical formulations. PCE is also used in professional garment cleaning (dry cleaning). In some applications, TCE and PCE have risen as they have been adopted as substitutes for methyl chloroform (1,1,1-trichloroethane, or TCA), an ozone depletor. In 2007, the United States was the largest consumer of both TCE and PCE, followed by Western Europe, China, and Japan (27, 24, 18 and 13 per cent of TCE demand; and 43, 19, 10, and 9 per cent of PCE demand, respectively).¹⁰⁵ Over all, use of TCE and PCE has declined in developed countries in recent years, due in part to regulatory initiatives responding to widespread environmental contamination by these solvents. At the same time, use of these substances has been increasing in developing countries and countries with economies in transition. The largest use of these solvents globally is as feedstock in the production of fluorocarbons. However, in some parts of the world, nearly all consumption of these solvents is for industrial cleaning applications.

5. Trends in Production and Consumption of Metals

Globally, three metals have drawn particular attention from the international community due to their toxicity and widespread human and environmental exposures through occupational and environmental routes, as well as through use and disposal of consumer products. Lead, mercury and cadmium are highly toxic in small quantities. Significant efforts have been undertaken to reduce the use of all three of these metals, but all of them continue to be used in industrial processes and in consumer products.

Global trade plays a significant role in the life cycle of these metals. They are often sourced in one region of the world, refined in a second, incorporated into products in a third, and disposed of still elsewhere. For example, Peru exports significant quantities of unrefined or partly refined lead ores to China, and China in turn exports refined lead to other countries in Asia. Similarly, in production of nickel-cadmium batteries, these may be produced in one country, incorporated into products in another, used by consumers in yet another country, and disposed of in yet another.¹⁰⁶ Mercury is widely traded in global markets.¹⁰⁷

In addition, a number of other metals pose significant concerns related to occupational and/or environmental exposures. These include beryllium, hexavalent chromium, and nickel, among others. The toxic metals are of interest not because they are used in high volumes, but also because of their disproportionate effects on human health. Other metals that pose concerns primarily related to the processes used to extract them, as opposed to inherent toxicity of the metals themselves, include aluminum, silver, gold and the rare earth metals. Arsenic contamination, from both natural and industrial sources, is also a significant concern.

5.1 Lead

The major use for lead globally is in lead-acid batteries. This application accounted for about 89 per cent of lead consumption in 2009.¹⁰⁸ Other uses include pigments and compounds, cable sheathing, rolled/extruded products and ammunition.

Global production and consumption of refined lead in 2010 was 9.6 million metric tonnes. Of this amount, 4.1 million metric tonnes entered the market through primary production from mining, and the remainder entered the market through secondary production (recycling).¹⁰⁹

In 2009, China was the leading producer of lead from mining, producing 1.6 million metric tonnes of lead, or about 40 per cent of global primary lead production. The second largest producer in 2009 was Australia, followed by the US, Peru, Mexico, India, Bolivia and Russia.¹¹⁰ China was also the leading producer of refined lead, accounting for about 42 per cent of global refined lead production.¹¹¹

Global lead consumption has increased around 2.5 per cent annually since 2000. However, this trend has not been evenly distributed globally; rather, the gradual upward trend in global consumption is being driven by rapid, dramatic increases in some parts of the world. China's consumption of lead increased by an average of 20 per cent per year between 1999 and 2009. This increase was driven largely by increasing production of lead-acid batteries for use in automobiles, electric bicycles, and motorcycles.¹¹² By 2009, there were approximately 100 million electric bicycles in China, each using at least one lead-acid battery each year; this use alone accounted for about one metric tonne of lead consumption in 2009.¹¹³

5.2 Mercury

Mercury is used in a variety of products and processes, including production of mercury-containing batteries, chlor-alkali production, vinyl chloride monomer (VCM) production and small-scale gold mining. While consumption of mercury in developed countries continues to decline, evidence suggests that mercury consumption remains significant in many developing countries, especially South and East Asia (associated with mercury use in products, VCM production and artisanal gold mining), and Central and South America (associated with mercury use in artisanal and small-scale gold mining).¹¹⁴ Factors driving the decrease in mercury consumption in developed countries include the use of chemical alternatives or the substantial reduction of mercury in regulated products and processes, such as paints, batteries, pesticides, and the chlor-alkali industry.¹¹⁵ However, reductions in developing countries have also occurred due to a general shift of mercury-product manufacturing operations (e.g., thermometers and batteries) from higher income to lower income countries. In addition, some economic trends are driving increases in mercury use; for example, increases in gold prices contribute to increased use of mercury in artisanal gold mining, while China’s increasing production of vinyl chloride monomer has led to increasing use of mercury in vinyl chloride production facilities.¹¹⁶

Global primary production of mercury (mining production) in 2009 was estimated at 1,920 metric tonnes.¹¹⁷ Secondary production primarily from recycling and recovery activities is also an important source of mercury. While recent estimates are unavailable, a 2004 report estimated secondary mercury production in 2000 at 1,780 tonnes (66 per cent from decommissioned chlor-alkali cells, 3 per cent from wastes of operating chlor-alkali cells, and 31 per cent from other sources).¹¹⁸ The largest source of secondary mercury production continues to be decommissioning of chlor-alkali plants. Both the EU and the US have taken steps to reduce the global supply of mercury by restricting exports of recycled mercury.¹¹⁹

China was the leading producer of mercury from mining in 2009, producing 1,400 metric tonnes, or 73 per cent of total global production. The next largest primary producer was Kyrgyzstan, with 250 metric tonnes.¹²⁰

Total mercury consumption in 2005 was estimated at just under 3,800 metric tonnes. Artisanal gold mining accounted for the largest percentage of global consumption, followed by vinyl chloride manufacturing and chlor-alkali plants (an estimated 21, 20, and 13 per cent of the global total, respectively). Batteries and dental amalgam are estimated to account for 10 per cent each; measuring and control devices account for 9 per cent; and lighting, electrical devices, and “other” uses account for 4, 5, and 8 per cent, respectively.¹²¹

Nearly half (48 per cent) of all estimated mercury consumption in 2005 occurred in East and Southeast Asia. The next largest consumer was the European Union, with 13 per cent of the global total. Table 9 shows the global distribution of mercury consumption in 2005.¹²²

Region	Sub-Region	Percentage
Asia	East & Southeast Asia	48%
	South Asia	5%
Americas	South America	9%
	North America	9%
	Central America & the Caribbean	2%
Europe	European Union (EU25)	13%
	CIS & Other European Countries	6%
Africa & Middle East	Sub-Saharan Africa	3%
	Middle Eastern States	3%
	North Africa	1%
Oceania	Australia, New Zealand and Other Oceania	1%

Source: AMAP and UNEP. (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment. Consumption data summarized from Table 3.4.*

Total global use of mercury is expected to decline over time, while use in compact fluorescent bulbs and in small-scale artisanal gold mining is expected to increase.¹²³ The price of mercury is an important factor influencing global mercury consumption. Changes in mercury supply and demand, in turn, affect mercury prices.¹²⁴ Prices of other commodities may affect mercury demand as well. For example, rising gold prices could increase demand for mercury for small-scale gold mining applications.¹²⁵

UNEP has developed three future scenarios of projected global mercury consumption in 2020. Under UNEP's projections, consumption in 2020 could be over 3,300 metric tonnes under a status quo scenario, or could be as low as just under 1,300 tonnes under a scenario of significant policy interventions to reduce consumption. The status quo scenario would represent a 13 per cent reduction in global consumption over the period 2005 to 2020, and the scenario of aggressive mercury reduction measures would represent a 66 per cent reduction over that period.¹²⁶

5.3 Cadmium

The largest use of cadmium globally is in battery manufacturing. Other uses of cadmium are in pigments; stabilizers for plastics; coatings and plating on iron and steel; stabilizers for plastics; nonferrous alloys; and specialized uses such as photovoltaic devices. Cadmium use in nickel cadmium (NiCd) batteries has increased over time, while use in other applications such as pigments, stabilizers and alloys has declined. NiCd batteries accounted for 81 per cent of refined cadmium consumption in 2004.^{127 128}

Global production of cadmium nearly doubled over the period 1950 to 1990 and has remained approximately constant since 1990, at about 20,000 metric tonnes per year. However, the geographic distribution has changed significantly. In particular, since 1997, cadmium production in Asia has increased rapidly, while production in Europe has declined. By 2004, primary production of cadmium in Asia was five times as large as production in Europe. A review of cadmium data by UNEP notes that, as a result of this shift, an increasing portion of cadmium production is now occurring in countries that do not provide data on environmental releases.¹²⁹ Thus, the environmental impacts of this shift may be difficult to monitor quantitatively.

The largest primary producers of cadmium are now China, Japan and the Republic of Korea, followed by North America, Central Europe/Eurasia and Western Europe.¹³⁰ Secondary production (recycling) accounted for about a quarter of cadmium production in 2010, primarily from facilities that recycle NiCd batteries.¹³¹

Looking forward, some factors are likely to reduce cadmium demand while others are likely to increase it. Regulations, particularly in the European Union, are designed to reduce or eliminate cadmium use in many applications. On the other hand, demand for NiCd batteries may increase demand for cadmium. NiCd batteries are used in a variety of industrial applications, as well as in some electric vehicles and in "hybrid-power systems developed to generate electricity in remote locations." Regardless of cadmium demand, zinc smelting processes will continue to produce cadmium-containing byproducts. There could be a need to develop systems to stockpile and manage excess cadmium, similar to the need to stockpile and manage excess mercury.¹³²

Both use and environmental releases of cadmium have declined in developed countries with increasing awareness of its adverse health effects. However, use in applications such as plastics and paints has continued or increased in developing and transition countries. A UNEP report notes that cadmium-containing products continue to be disposed of through means such as burning and dumping in rivers and wetlands.¹³³ Trade in both new and used products containing cadmium, including electronic equipment and batteries, is an additional source of concern. These products are generally disposed of as part of the general waste stream in developing countries, leading to environmental releases. Finally, cadmium is found in products, including toys, which expose consumers to the toxic metal during normal use.¹³⁴

5.4 Other Metals

Global production of a number of other metals has increased steadily over the past two decades. In many cases, increases in production in countries with economies in transition have driven these trends. For example, world production of aluminium has more than doubled over the period 1994 to 2010. This increase has been largely driven by a rapid increase in China (more than 800 per cent over the period 1996 to 2010). A significant increase occurred in Brazil as well (just under 30 per cent over the period 1994 to 2010). In contrast, production in the US has declined 48 per cent over the period 1994 to 2010.¹³⁵

Similarly, world production of nickel from mining has increased over 70 per cent over the period 1994 to 2010. The largest producers of nickel in 2010 were Russia and Indonesia, with 17 and 15 per cent of global production, respectively. Other important producers were the Philippines and Canada (10 per cent each of global production) and Australia (9 per cent). Of these leading producers, Australia, Indonesia, and the Philippines have all emerged through significant growth in nickel production over a decade and a half. The increase in production in the Philippines was particularly dramatic, increasing by more than a factor of 15.¹³⁶

Arsenic is a source of significant health impacts, with exposures resulting both from industrial activities and from inadvertent exposure to naturally occurring sources of arsenic. Important industrial applications of arsenic include the use of arsenic metal in electronics and in nonferrous alloys and use of arsenic trioxide in production of chromated copper arsenate (CCA), a pesticide and wood preservative. Due to its use in electronics applications, arsenic is one of the metals of concern that may be found in electronic waste. In 2010, China was the largest producer, and the US was the largest consumer of both arsenic trioxide and arsenic metal. Other significant producers of arsenic trioxide in 2010 were Chile, Morocco and Peru.¹³⁷

At least two important factors are expected to influence future trends in industrial use of arsenic. In the US, a voluntary phaseout of CCA for use in certain wood products has led to a decline in demand for arsenic trioxide, with a corresponding decline in production in China. Industry is expected to continue using alternative wood preservatives in preference to CCA for many, though not all, applications. On the other hand, demand for gallium arsenide (GaAs) semiconductor technology for electronics applications may continue to grow.¹³⁸

Widespread exposure to high levels of arsenic occurs through contamination of drinking water with naturally-occurring arsenic.¹³⁹ This aspect of arsenic pollution is not covered in the present report.

New developments in electronics manufacturing have also led to changing patterns and new hazards related to extraction and use of metals. Electronic products contain a wide variety of materials, including rare earth minerals. Extraction of these resources is associated with significant health and environmental impacts.¹⁴⁰

6. Trends in Production and Consumption of Fibers: Asbestos

Asbestos is a general term used to refer to six fibrous minerals: chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite. Of these six, five are no longer produced in significant quantities; almost all asbestos produced globally is chrysotile.^{141 142} The International Agency for Research on Cancer (IARC) classifies all forms of asbestos as Group 1 carcinogens (carcinogenic to humans).¹⁴³

Total global production and use of asbestos has declined over time. However, production and use of chrysotile continue in many parts of the world, and have increased in some countries. Global asbestos production was approximately 2 million metric tonnes in 2010. Five countries – Russia, China, Brazil, Kazakhstan and Canada – accounted for 99 per cent of world production.¹⁴⁴ Table 10 shows the global distribution of asbestos production in 2010.

Country	Asbestos production (metric tonnes)
Russia	1,000,000
China	400,000
Brazil	270,000
Kazakhstan	214,000
Canada	100,000
India	20,000
Zimbabwe	1,000
Argentina	300

Source: Virta, R.L. (August 2011). *2010 Minerals Yearbook: Asbestos*. US Geological Survey. Note: Afghanistan, North Korea, Romania, and Slovakia also produce asbestos, but reliable data are unavailable for these countries.

Total global asbestos production decreased 18 per cent over the period 1994 to 2010. However, this decrease was not evenly distributed, and production actually increased significantly in certain countries. Of the leading producers, Canada and Kazakhstan decreased production, while Brazil, China and Russia increased production (an increase of 54, 46, and 25 per cent, respectively, over the period 1994 to 2010).¹⁴⁵

Asbestos trade data provide some insight into consumption patterns. Russia, the largest asbestos producer, was also the largest exporter in 2009, followed by Canada, Brazil and Kazakhstan.¹⁴⁶ India was the largest importer in 2009, followed by China, Thailand, Indonesia and Vietnam.¹⁴⁷ Russia was the top country from which India imported asbestos in 2009, followed by Canada, Brazil, Kazakhstan and Zimbabwe. India's imports of asbestos approximately doubled over the period 2003 to 2009.¹⁴⁸ Table 11 shows the top importers of asbestos in 2009.

Table 11. Top Importers of asbestos, 2009	
Country	Asbestos imports (US\$)
India	\$ 192,718,072
China	\$ 55,770,693
Thailand	\$ 41,651,987
Indonesia	\$ 37,893,809
Vietnam	\$ 30,088,950
Others	\$ 108,072,176
Total	\$ 466,195,687

Source: United Nations Commodity Trade Statistics Database.

According to the WHO, 125 million people continue to be exposed to asbestos in the workplace, and more than 107,000 people die annually from diseases resulting from workplace exposure to asbestos, in addition to several thousand deaths from exposure in homes.¹⁴⁹ The largest on-going use of asbestos is in asbestos-cement building materials, which are used primarily in developing countries.¹⁵⁰

The principal use of asbestos in India is in asbestos-cement roofing sheets. These pose health hazards during manufacture and installation, and create a lasting source of asbestos exposures over time, through dismantling or degradation of the roofing materials. Earthquakes and other disasters can also release significant amounts of asbestos from these building materials into air.¹⁵¹

7. Trends in Production and Consumption of Agricultural Chemicals

7.1 Fertilizers

There are three major categories of fertilizers: those providing crops with nitrogen, phosphate and potassium. The FAO, in collaboration with industry associations and others, reviewed global fertilizer markets in 2010, and developed forecasts of expected trends in these markets over the period 2010-2014.

As shown in Table 12, in 2009, East Asia was the largest consumer of all three classes of fertilizers, accounting for 41 per cent of global nitrogen consumption, 37 per cent of global phosphate consumption, and 31 per cent of global potash consumption. South Asia was the next largest, accounting for 19, 22, and 17 per cent of global consumption of the three fertilizer types, respectively.

Table 12. Global Distribution of Fertilizer Consumption, 2009

		Nitrogen (thousand metric tonnes N)	%	Phosphate (thousand to metric tonnes P ₂ O ₅)	%	Potassium (potash) (thousand metric tonnes K ₂ O)	%
Africa		2,809	3%	901	2%	412	2%
Americas	North America	12,988	13%	4,068	11%	3,579	16%
	Central & South America & Caribbean	6,154	6%	4,651	13%	3,984	17%
Asia	West Asia	3,164	3%	1,336	4%	290	1%
	South Asia	19,758	19%	8,021	22%	3,818	17%
	East Asia	41,496	41%	13,652	37%	7,090	31%
Europe	Central Europe	2,574	3%	860	2%	630	3%
	West Europe	7,737	8%	1,535	4%	1,784	8%
	East Europe & Central Asia	3,824	4%	1,025	3%	1,203	5%
Oceania		1,160	1%	903	2%	254	1%
Total		101,664		36,952		23,044	

Source: Food and Agriculture Organization of the United Nations (2010). *Current World Fertilizer Trends and Outlook to 2014*. Pages 28 to 30.

FAO also developed estimates of likely trends in fertilizer consumption in the period 2009 to 2014. FAO estimated that world consumption of fertilizer would grow 2.6 per cent per year in the period 2010 to 2014.¹⁵² As shown in Table 13, the highest rates of growth are expected in Latin America, Eastern Europe and Central Asia, Africa and Central Europe (4.6, 3.8, 3.6, and 3.5 per cent, respectively, compound annual growth rates).

Table 13. Expected Growth in Total Fertilizer Demand, 2010-2014

World	2.6%
Africa	3.6%
America	3.0%
North America	1.8%
Latin America	4.6%
Asia	2.4%
West Asia	2.2%
South Asia	3.3%
East Asia	1.9%
Europe	2.5%
Central Europe	3.5%
West Europe	1.4%
East Europe & Central Asia	3.8%
Oceania	3.2%

Source: Food and Agriculture Organization of the United Nations (2010). *Current World Fertilizer Trends and Outlook to 2014*. Page 12.

7.2 Pesticides

According to CropLife International, an industry association, the total value of the global agricultural pesticide market (including herbicides, insecticides, fungicides and others) was nearly US\$ 38 billion in 2009.¹⁵³ Herbicides accounted for the largest proportion of the global market, as shown in Table 14. An industry research firm, the Freedonia Group, projects that this market will continue to grow, reaching US\$ 52 billion by 2014.

In 2009, North America accounted for the largest percentage of global pesticide expenditure, followed closely by the Asia/Pacific region (27 and 24 per cent, respectively). Central and South America and Western Europe accounted for 19 and 17 per cent of expenditure, respectively.¹⁵⁴

Looking forward to 2014, analysts predict that the most rapid growth in pesticide expenditure will occur in Central and South America. Pesticide consumption in Africa and the Middle East is also expected to grow rapidly, although total consumption in the region will continue to be small compared to that in other regions.¹⁵⁵

Table 14. Global Pesticide Markets

	Global sales in 2009 (million US\$)	Percentage of total global pesticide sales
Herbicides	\$ 17,527	46%
Insecticides	\$ 9,411	25%
Fungicides	\$ 9,726	26%
Other	\$ 1,196	3%

Source: Croplife International (2010). *Facts and Figures: The Status of Global Agriculture*.

FAO maintains a database of individual countries' reports on pesticide use and consumption. Most countries have submitted data only haphazardly, making it difficult to develop meaningful comparisons among countries or regions using this database.¹⁵⁶

7.2.1 Herbicides

Herbicides account for the largest percentage of expenditure on pesticides worldwide, due primarily to large expenditure in developed countries. However, their use in developing countries is increasing as well. The global market in herbicides is highly concentrated, with a handful of multinational companies accounting for the vast majority of herbicide sales.¹⁵⁷ Adoption of herbicides in developing countries is often associated with a package of agricultural inputs including fertilizers and insecticides.

In some countries, herbicide use has been influenced significantly by the adoption of genetically modified crops that are designed to be grown in combination with specific herbicides. The US is the largest user of genetically modified crops, but they have been adopted in a number of developing countries and countries with economies in transition as well. Brazil has the second largest acreage of genetically modified crops, followed by Argentina and India.¹⁵⁸ An analysis of US Department of Agriculture data by a NGO indicates that over time, use of genetically modified herbicide resistant crops has been associated with a significant increase in herbicide use.¹⁵⁹

There are ten major groups of herbicides based on synthetic organic molecules: “amides, arsenicals, carbamates and thiocarbamates, carboxylic acids and derivatives, dinitroanilines, heterocyclic nitrogen herbicides, organophosphates, phenyl ethers, urea herbicides, and quaternary and other herbicides.” A small number of inorganic chemicals are also sometimes used as herbicides. Herbicides have a range of types of action, including selective and nonselective activity. Some also act as insecticides.¹⁶⁰

7.2.2 Insecticides

Important classes of insecticides include chlorinated hydrocarbons (organochlorines), carbamates, organophosphates and synthetic pyrethroids. Examples of organochlorine insecticides include DDT, aldrin, dieldrin, toxaphene, chlordane, heptachlor, lindane, endosulfan and dicofol. A number of these insecticides have been classified as POPs under the Stockholm Convention. Efforts to reduce the use of organochlorine insecticides have, in some cases, led to increased use of organophosphate insecticides as an alternative. In some instances organophosphates have, in turn, given way to newer synthetic pyrethroid insecticides. One of the factors driving change in insecticide markets over time is the development of insect resistance to specific chemicals. A factor influencing over-all insecticide use rates is the fact that some pyrethroid insecticides are effective at lower volumes than the chemicals they frequently replace.¹⁶¹ Some uses of organochlorine insecticides persist; this is a trend of significant concern even at low volumes, due to the long persistence of these chemicals in the environment.

7.2.3 Fungicides

Fungicides include both inorganic compounds such as sulfur and copper compounds, and a variety of organic compounds; the principal categories of organic compounds used as fungicides are anilines/anilides, dithiocarbamates, halogenated compounds and heterocyclic nitrogen compounds. Fungicides are used in a variety of agricultural applications, including cultivation of peanuts, cotton and a variety of fruit and vegetable crops.¹⁶²

7.2.4 Trends in Pesticide Use in Africa

Africa accounts for only a small proportion of global expenditure on pesticides. However, the conditions under which pesticides are used in Africa can lead to significant hazardous exposures. This section provides an overview of trends in pesticide expenditure in Africa and the Middle East, because data for the two regions are often combined. It then provides information on pesticide use trends in South Africa, the largest pesticide user in Africa, and in Nigeria, which also has substantial pesticide use in comparison with other African countries. Finally, this section briefly summarizes the findings of studies of pesticide use in selected African countries that are characterized by widespread subsistence farming. Actual volumes of pesticides use in these countries are low, but management practices associated with subsistence farming raise particular concerns that differ from those associated with larger-scale agriculture.

Broad trend information is available for Africa and the Middle East together. Total agricultural output of Africa and the Middle East increased 43 per cent over the period 1999 to 2009, and is projected to continue increasing, with a projected growth of 35 per cent over the decade from 2009 to 2019. Pesticide use has also increased over this period, and is projected to continue to increase. Interestingly, expenditures on pesticides per unit of value gained through agricultural production have increased and are projected to continue increasing to 2019, indicating some decline in efficiency of these expenditures.¹⁶³

Total expenditures on pesticides increased 61 per cent over the period 1999 to 2009, from US\$ 1.1 billion to US\$ 1.9 billion. These expenditures are projected to increase another 44 per cent over the period 2009 to 2019, reaching a total of about US\$ 2.7 billion in 2019.¹⁶⁴

Although herbicides account for the largest proportion of pesticide expenditures globally, in Africa and the Middle East insecticides dominate. In 1999, nearly half of all pesticide expenditures in the region were accounted for by insecticides. By 2019, the balance is expected to have shifted somewhat. Insecticides will still be the largest category of pesticide expenditures, but the portion devoted to herbicides, fungicides and other categories of pesticides will have increased, as shown in Table 15.¹⁶⁵

It is worth noting that information on pesticide expenditures may lead to underestimates of total pesticide use in Africa compared with use in other parts of the world. A report by the NGO Pesticide Action Network, notes that farmers in developing countries frequently purchase older pesticides products due to the fact that they are generally less expensive. Pesticide producing countries may also sell their products at relatively inexpensive prices in developing countries. Thus, information on pesticide sales may downplay the volume of pesticides sold and used in developing countries. These older and inexpensive pesticides may also be some of the most hazardous pesticides on the market.¹⁶⁶

Table 15. Pesticide Expenditure: South Africa (Historical & Projected)

	Expenditure (million US\$*)			% change	
	1999	2009	2019	1999-2009	2009-2019
Herbicides	\$ 22	\$ 37	\$ 57	68%	54%
Insecticides	\$ 28	\$ 35	\$ 50	25%	43%
Fungicides	\$ 8	\$ 18	\$ 31	125%	72%
Other	\$ 5	\$ 10	\$ 17	100%	70%
Total	\$ 63	\$ 100	\$ 155	59%	55%

Source: Freedonia Group (August 2010). *World Pesticides to 2014 -- Demand and Sales Forecasts, Market Share, Market Size, Market Leader*. Study #2664. * Figures are in nominal dollar values, not adjusted for inflation.

South Africa is the largest consumer of pesticides in Africa, accounting for 2 per cent of global pesticide consumption.¹⁶⁷ Total pesticide expenditures in South Africa rose 59 per cent over the period 1999 to 2009, and are projected to rise another 55 per cent in the period 2009 to 2019 (Table 15). Expenditures on pesticides per unit value of agricultural production have also risen and are predicted to continue rising over the forecast period.¹⁶⁸

Insecticide expenditures increased 25 per cent over the period 1999 to 2009, and are projected to increase another 43 per cent over the period 2009 to 2019, to a total of US\$ 50 million in 2019. Herbicide expenditures have increased more rapidly, rising 68 per cent from 1999 to 2009 and are projected to rise 54 per cent from 2009 to 2019, to a total of US\$ 57 million in 2019. Fungicide expenditure account for a smaller portion of the total, but have increased most rapidly, rising 125 per cent over the period 1999 to 2009 and projected to increase another 72 per cent over the period 2009 to 2019.

8. Products Containing Chemicals

The sections above have considered geographic and temporal trends in the production and use of bulk chemicals and some of their downstream chemical products. Additional insight can be gained by considering trends in products that contain chemicals. As consumption of a wide range of products increases over time, these products themselves become a significant vehicle, increasing the presence of chemicals in developing and transition economies. Emissions from products pose different management challenges from those associated with manufacturing, as they are diffused throughout the economy, rather than being concentrated at a limited number of manufacturing facilities.

The universe of products containing chemicals can be divided into categories. One important category consists of liquid chemical products packaged for sale directly to consumers. These include products such as detergents, bleaches, other chemicals used in laundering clothing, and personal care products such as fragrances. Unlike other chemical industry products, these products are packaged for direct sale to consumers, and brand differentiation can be an important aspect of these products' commercial success.¹⁶⁹

Developing and transition economies have been identified as important areas for growth by leading companies selling household chemicals and consumer products. For example, a recent statement by a leading household chemical and personal care products company noted that the Asia-Pacific region accounted for 16 per cent of the company's global revenues, and that the importance of the region is expected to continue growing as incomes rise.¹⁷⁰

Another is the broad category of articles: products whose function is determined primarily by shape, as opposed to depending primarily on chemical composition.¹⁷¹ Articles ranging from textiles to electronics, from building materials to toys, all contain chemicals and can be important vehicles through which chemicals move through economies.¹⁷² Table 16 describes important examples of toxic chemicals in articles.

Chemicals in electronics including personal computers (PCs) and mobile phones illustrate how chemicals in articles have become an important vehicle increasing the presence of chemicals particularly at the point of production and during recycling/disposal. These products can contain over a thousand different chemicals, many of which are hazardous.¹⁷³ These hazardous chemicals include lead, mercury, cadmium, zinc, yttrium, chromium, beryllium, nickel, brominated flame retardants, antimony trioxide, halogenated flame retardants, tin, PVC and phthalates among others. Consumer demand for smaller and lighter electronic products with greater processing and storage capacity has led to the introduction of an increasing number of rare materials, especially metals. During just the first quarter of 2010, worldwide shipments of personal computers were estimated to total 84.3 million units, an increase of 27.4 per cent from the first quarter in 2009.¹⁷⁴ Worldwide sales of mobile phones were estimated to total 314.7 million units in the first quarter of 2010, a 17 per cent increase from the same period in 2009. With the increasing consumption of electronics is an increasing volume of electronic waste, much of which is being exported to developing countries in large part due to the lower cost associated with waste handling.¹⁷⁵ Waste issues associated with electronic products are further described in Section 9.

Increasingly, articles are important vehicles of the global transport of chemicals, with significant impacts at every stage of the product life cycle. For example, trade in articles has been identified as a significant driver of global transport of lead and cadmium.¹⁷⁶ In many cases, articles containing toxic substances may be purchased in developed countries, but disposed of or recycled under unsafe conditions in developing or transition countries. Electrical and electronic equipment is an important example of this pattern. In addition, when a hazardous article is restricted or banned in some countries, sales of that article may be diverted to countries where it is not yet regulated.¹⁷⁷

In some instances, the majority of human and environmental exposures occur through product use and disposal, rather than occurring during manufacturing. For example, the majority of emissions of di(2-ethylehexyl)phthalate (DEHP), a plasticizer, occur during product use and disposal.¹⁷⁸

The increasing use of products containing chemicals, many of which may be associated with acute or chronic health impacts, requires significant management capacity to deal with impacts at every stage of the product life cycle. This includes capacity to design safer products; capacity to generate and transmit information on hazardous chemicals included in products; and capacity to recycle or dispose of these products appropriately at the end of their useful life.

Studies have shown that products can be a significant source of chemical exposures. For example, a Swedish government study found releases of significant amounts of three antibacterial agents – silver, triclosan, and trichlorcarban – into washing water from fabrics. This illustrates one route by which chemicals can be introduced into the environment through normal use of articles containing chemicals.¹⁷⁹ In another example, studies have found high concentrations of endocrine disrupting chemicals in indoor air and dust,¹⁸⁰ and high levels of brominated flame retardants have been found within homes, indicating that products used within homes can be significant sources of chemicals that affect human health.¹⁸¹

Table 16. Examples of Toxic Substances in Articles

Article	Chemical & Health Effects	Pathways of Exposure
Automobiles		
Automotive Switches	Mercury. Effects include neurotoxicity, including developmental neurotoxicity (methyl mercury) and organ damage. ¹⁸²	Mercury can be released when automobiles with mercury-containing switches are crushed or shredded. ¹⁸³ Elemental mercury can be transformed into methylmercury, which is bioaccumulative. Humans can be exposed through consumption of contaminated fish and other routes.
Tires	Polycyclic aromatic hydrocarbons (PAHs); 1,3-butadiene. Effects include the following: some PAHs are carcinogenic, and 1,3-butadiene is a known human carcinogen. ¹⁸⁴	Highly aromatic oils containing PAHs are used to make the rubber polymer easier to work and to make the tire tread soft. Rubber particles containing PAHs can wear off tires over time, dispersing PAHs into the environment. ¹⁸⁵
Wheel Weights	Lead. Effects include neurotoxicity, including developmental neurotoxicity; high blood pressure and organ damage. ¹⁸⁶	Lead wheel balancing weights fall off car wheels, then are run over by other cars and dispersed into the environment. ¹⁸⁷
Electronic Products		
Electronic Products	Lead, mercury, cadmium, brominated flame retardants. Effects of cadmium include carcinogenicity; possible damage to fertility; possible fetal damage; organ damage. ¹⁸⁸ Effects of brominated flame retardants include neurotoxicity and thyroid disorders. ¹⁸⁹ Effects of lead and mercury are listed above.	Heavy metals and brominated flame retardants are released during disposal or recycling of electronic wastes. Developing countries and countries with economies in transition bear a particularly large burden from unsafe disposal and recycling of these articles. ¹⁹⁰
Batteries	Lead. Effects of lead are listed above.	The major use for lead globally is in lead-acid batteries. ¹⁹¹ In many countries, recycling of batteries/car batteries is a common source of human and environmental exposure to lead. ¹⁹²
Children's Products		
Toys	Lead, cadmium, phthalates. Effects of some phthalates include endocrine disruption, effects on fertility and possible effects on sexual development. Some phthalates are possible carcinogens. ¹⁹³ Effects of lead and cadmium are listed above.	Toys and children's jewelry can contain lead in the form of lead paint and metal clasps, chains or charms. Lead is also used as a stabilizer in some toys and other children's items made from PVC plastics. Lead can leach out of these products during use. ¹⁹⁴ Phthalates are used as plasticizers (i.e., chemical agents that make plastics soft and flexible) in toys made of polyvinyl chloride (PVC) plastics. These substances leach out of toys during use.

Adapted from: Massey, R., Becker, M., Hutchins, J. (2008). *Toxic Substances in Articles: The Need for Information*. Swedish Chemicals Agency.

9. Environmental Releases, Recycling and Disposal of Chemicals

The total quantity of chemicals released to the environment as waste globally is unknown. Among the OECD countries, waste information is available through PRTRs. Unfortunately, detailed data of this kind are lacking for non-OECD countries. In the absence of good data on environmental releases of chemicals in the majority of developing countries, OECD data can serve as an order of magnitude indicator of the levels of waste that may be found in non-OECD countries. In addition, some country-specific information is available through data submitted under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

While there is a serious lack of information regarding hazardous waste trends in environmental releases from developing countries and many of those in economic transition, data from scientific studies provide detailed documentation of specific chemical waste issues in these regions. These studies make it possible to develop a more complete picture of chemical waste in developing countries and countries with economies in transition.

9.1. PRTR Data: Chemical Release, Disposal and Recycling Inventories

PRTR data show that industry continues to generate large amounts of waste in those countries for which data are available. In North America (US, Canada and Mexico), 4.9 million metric tonnes of chemicals were released to the environment or disposed of in 2009. This included nearly 1.5 million metric tonnes of chemicals that are persistent, bioaccumulative, and toxic (PBTs); over 756,000 metric tonnes of known or suspected carcinogens; and nearly 667,000 metric tonnes of chemicals that are considered reproductive or developmental toxicants. The top four industry sectors contributing to these releases and wastes were mining and associated support activities; primary metal manufacturing¹⁹⁵; utilities; and chemical manufacturing. These levels of waste are generated in developed nations with well established regulatory systems requiring emission controls and other technological changes among industries to reduce toxic chemical emissions and waste generation. Where such measures are lacking, quantities of waste generated per unit of production may well be larger.

Among countries with PRTRs, the data indicate that inorganic chemicals such as ammonia, hydrogen sulfide, sulfuric acid, and hydrochloric acid and organic chemicals such as styrene, formaldehyde, toluene and acetaldehyde are routinely among the air pollutants released in large quantities.^{196 197} Pollutants commonly discharged in large quantities to surface waters include inorganic chemicals such as nitric acid/nitrate compounds, ammonia and manganese and organic chemicals such as methanol, ethylene glycol, phenol, toluene and formaldehyde.^{198 199} However, there is significant variation over time and among countries. For example, in Mexico, the top chemicals released to surface water in 2009 were vinyl chloride, pyridine, and acrylamide.²⁰⁰ In addition, chemical release and waste trends aggregated on the national level can mask important patterns in local pollution of air, water and soil in individual communities.

As developing countries and those in economic transition intensify activities associated with chemicals across their lifecycle, there is a need for more comprehensive information on pollution releases from these regions. While there is extensive evidence regarding chemical releases to air, water and soil (See Table 17), there is no comprehensive system to track and monitor pollution in these areas.

9.2 Studies of Chemical Emissions and Waste in Developing Countries

While developing countries lack PRTRs, several atmospheric emissions inventory studies as well as pollution studies demonstrate that the problem of chemical releases from industrial activity exists throughout the world. Table 17 illustrates key examples of chemical contamination and waste associated with several industrial sectors of importance in developing countries. As shown in the table, examples include pesticide contamination of water sources resulting from agricultural runoff; heavy metal pollution associated with cement production; dioxin contamination associated with electronics recycling; mercury and other heavy metal contamination associated with mining; contamination with butyltins, heavy metals and asbestos associated with shipbreaking; heavy metal contamination from tanneries; and mutagenic dyes as well as heavy metals associated with textile production.

Table 17. Examples of Industrial Sectors and Their Chemical Contaminants and Waste in Developing Countries and Countries with Economies in Transition

Sector	Chemicals	Examples
Agriculture	Fertilizers and pesticides, including organochlorines and organophosphates	<ul style="list-style-type: none"> Runoff transported pesticides into the Lourens River, South Africa, contaminating water with azinphos-methyl, chlorpyrifos, endosulfan and prothiofos.²⁰¹
Cement production	POPs ²⁰² , heavy metals other combustion byproducts	<ul style="list-style-type: none"> Heavy metals including, arsenic, lead, nickel, chromium among others were found at high levels in the neighborhoods near the premises of 3 Nigerian cement plants compared to the control sites.²⁰³
Electronics production and recycling	Combustion byproducts: dioxins, VOCs, PAHs; solvents, heavy metals, PCBs and PBDEs	<ul style="list-style-type: none"> Dioxin and furan levels among the highest in the world were measured in ambient air in Guiyu, China, associated with e-waste dismantling.²⁰⁴ Combustion of e-waste containing flame retardants has resulted in concentrations of PBDEs in the air of Guiyu China that were 300 times higher than nearby Hong Kong.²⁰⁵ In Bangalore, India, soil contaminants of several heavy metals, such as cadmium, lead, mercury, indium and tin were one-hundred fold higher than those found at a nearby control site in the same city.²⁰⁶
Mining	Heavy metals	<ul style="list-style-type: none"> In sub-Saharan Africa, mercury emissions from artisanal and small-scale gold mining are estimated at 8 metric tonnes/year. Similar emissions in East and Southeast Asia and South America are estimated at 233 metric tonnes per year and 64 metric tonnes per year, respectively.²⁰⁷ In Hunan China where a tailing dam for the Chenzhou lead/zinc mine collapsed in 1985, soil became significantly contaminated with heavy metals and edible portions of crops reveal high concentrations of cadmium, zinc and lead that exceed recommended daily allowance levels.²⁰⁸
Shipbreaking	Asbestos, PCBs, hydraulic fluids, heavy metals, tributyl tin, organomercury compounds, flame retardants, oils and fuel ²⁰⁹	<ul style="list-style-type: none"> High levels of butyltin (found in antifouling paints used on ships) have been found in fish harvested for consumption in the entire Asia-Pacific region.²¹⁰ In Gujarat, India at the Alang-Sosiya ship-breaking yard, high concentrations of heavy metals within airborne suspended particulate matter significantly exceed WHO guidelines.²¹¹ Concentrations of heavy metals and petroleum hydrocarbons were multiple orders of magnitude higher at Alang than a control site 10 km away.²¹²
Tanneries	Organic material, sulphides and chromium	<ul style="list-style-type: none"> In Kano, Nigeria, where 70 per cent of the country's tanneries are located (in addition to other industries), waste effluent has contaminated irrigation water with heavy metals (Cd, Cr, Hg, Pb) that are orders of magnitude above WHO's safe drinking water standards.²¹³
Textile production	Organic material, dyes, heavy metals (zinc, copper, chromium, lead, nickel), organic chemicals (toluene, ethylbenzene, chlorobenzene, naphthalene, phenol) and alkaline effluents ²¹⁴	<ul style="list-style-type: none"> Mutagenic dyes from textile production were detected in river water and drinking water in the Cristais River, Sao Paulo, Brazil.²¹⁵ In Mumbai, India, air emissions of heavy metals from local textile industries during 2000-2001 were estimated at nearly 16 metric tonnes.²¹⁶ In Faisalabad, Pakistan high levels of cadmium, lead and copper were found in multiple agricultural crops as a result of using city sewage water to irrigate crops that contained untreated industrial waste effluent primarily from the city's textile industry.²¹⁷

9.3 Hazardous Waste Data Submitted under the Basel Convention

Under the Basel Convention, 64 countries provided hazardous waste generation data for the years 2004-2006. Table 18 shows the net generation of hazardous wastes by countries providing data as well as per cent changes from 2004-2006. For the 46 countries that provided data for each of the three years, there was a 12 per cent increase in global hazardous waste generation over the period 2004-2006.²¹⁸ On average, 10 million metric tonnes of wastes were imported annually by the 64 countries providing data. The amount of hazardous wastes imported by developing countries and countries with economies in transition decreased by 45 per cent in two years, while the amount exported from these countries increased. Thus, from data collected under the Basel Convention, there are no apparent trends of legal transboundary movements of hazardous wastes from richer to poorer countries.²¹⁹ These data suggest that efforts to prevent export of hazardous waste from developed to developing countries have largely been successful. Counterbalancing these encouraging data, the report acknowledges that data are incomplete, even for the limited period that was assessed and calls for more information on illegal traffic to be made available to improve implementation of the Basel Convention.

Table 18. Hazardous Waste Generation by Country (Reported in 2004, 2005, or 2006)

Country	Generation of Hazardous Waste (metric tonnes)
Algeria	325,000
Andorra	936
Argentina	151,923
Armenia	513,258
Australia	3,258,266
Austria	838,646
Azerbaijan	13,000
Bahrain	38,740
Belarus	2,733,536
Belgium	2,711,176
Bosnia and Herzegovina	4,447
Brunei Darussalam	30
Bulgaria	1,158,936
Chile	6,091
China	10,840,000
Costa Rica	1,245
Croatia	39,879
Cuba	1,253,673
Cyprus	50,443
Czech Republic	1,455,000
Denmark	423,807
Dominican Republic	9,390
Ecuador	146,606
Equatorial Guinea	1,288
Estonia	6,763
Ethiopia	1,043
Finland	1,129,299
France	6,748,000
Germany	18,529,000
Greece	333,155
Hungary	796
Ireland	720,976

Israel	328,400
Italy	5,906,000
Kazakhstan	146,111,000
Kiribati	82
Kyrgyzstan	6,409,968
Latvia	45,047
Lithuania	43,714
Luxembourg	90,810
Malaysia	1,103,457
Malta	1,346
Mauritius	580,000
Mexico	8,000,000
Monaco	451
Morocco	131,000
Mozambique	353,294
Netherlands	5,299,821
Norway	1,020,000
Poland	1,811,726
Portugal	287,617
Republic of Korea	3,659,646
Republic of Moldova	7,426
Romania	1,052,815
Russian Federation	26,357,800
Singapore	413,000
Slovakia	666,645
Slovenia	90,909
Spain	3,228,248
Sri Lanka	57,889
Sweden	2,777,000
Turkey	1,120,000
Ukraine	2,370,900
United Kingdom	6,037,068
Zambia	10,622

Source: Wielenga, K. (2010). *Waste Without Frontiers: Global Trends in the Generation of Transboundary Movements of Hazardous Wastes and Other Wastes*. Prepared for the Secretariat of the Basel Convention.

9.4 Special Categories of Waste: Priority Concerns for Developing Countries

Certain categories of waste are frequently cited as particularly significant concerns for developing countries. Electronic waste, obsolete pesticide stocks and waste from small-scale gold mining are three such categories.

9.4.1 Electronic Waste

Consumer demand for new electronic products such as personal computers and mobile phones with the latest technology is driving a quick turnover of these products on the market. In 2005, the average lifespan of personal computers in developed countries was just two years, and less than two years for mobile phones.²²⁰ The increasing consumption of electronics creates an increasing volume of electronic waste, much of which is being exported to developing countries in large part due to the lower cost associated with waste handling.²²¹

Waste handling/recycling costs for PCs and mobile phones are ten times higher in the US or the EU than in, for example, India or Nigeria.²²² Concern remains high regarding the suspected illegal trade of electronic waste (e-waste) that are being shipped to countries such as Nigeria, Ghana, Pakistan, India and China among others for re-use and repair. Estimates suggest that up to 75 per cent of the e-waste generated in Europe and approximately 80 per cent of the e-waste generated in the United States goes unaccounted for.²²³ One assessment of e-waste in Lagos, Nigeria estimated that anywhere from 25 to 75 per cent of e-waste shipments are not economically viable to repair or marketable for reuse.²²⁴ Thus a significant portion of imported material is considered hazardous waste, yet may not be officially defined as such under the Basel Convention (i.e. requiring disposal whole or in part) since shipments are not pre-tested for functionality prior to export/import.

Electronic devices such as PCs, laptops, mobile phones, televisions and other household appliances and entertainment devices are composed of a number of materials and components, which are in turn comprised of several hundred different chemicals many of which are toxic to human health and the environment. Notable chemicals of concern include heavy metals such as mercury, lead, cadmium, chromium and flame retardants such as polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDEs).²²⁵ Polychlorinated biphenyls (PCBs) in obsolete capacitors and transformers continue to be a problem as well.²²⁶

Increasing consumer demand for electrical/electronic goods and materials, along with rapid technology change and the high obsolescence rate of these electronic and electrical items, have led to the increasing availability of large quantities of obsolete and near-end-of-life electronic products.

In the first quarter of 2010, worldwide shipments of personal computers were estimated to total 84.3 million units, and worldwide sales of mobile phones were estimated to total 314.7 million units.²²⁷ Such devices are replaced by the average consumer within 2 and 4 years, respectively. These trends contribute to a global e-waste generation estimated by a 2009 UNEP report at 40 million tonnes a year.²²⁸ This e-waste burden is expected to rise as BRIICS countries increase their own e-waste. For example compared to 2007 levels, by 2020, South Africa and China are estimated to increase their computer e-waste up to 400 per cent, India by 500 per cent and other African nations such as Uganda and Senegal up to 800 per cent.²²⁹

9.4.2 Obsolete Pesticides

According to FAO, obsolete pesticides include all pesticide products not in current use because they have been banned, have deteriorated or are damaged, are past their expiration date, can not be used for any reason, or are not wanted by the current owner. In Africa, an estimated 20 per cent of the over 27,000 metric tonnes of obsolete pesticide stockpiles consist of POPs that have been banned under the Stockholm Convention.²³⁰ Other important classes of obsolete pesticides in current stockpiles include organophosphates, carbamates, synthetic pyrethroid insecticides, various other fungicides and herbicides as well as organometallics such as arsenic, mercury and tin-based chemicals.²³¹ In addition to stockpiles that began accumulating over 50 years ago, new products are being added continuously. According to an inventory maintained by FAO, there are 537,000 metric tonnes of obsolete pesticides in Africa, Asia, Eastern Europe, Latin America and the Middle East.²³² Those countries with more than 150 metric tonnes are listed in Table 19. The four countries with the highest stockpiles include the Russian Federation (100,000 metric tonnes), Macedonia (38,000 metric tonnes), Ukraine (25,000 metric tonnes) and Mali (14,000).²³³ Countries such as Mali are among the poorest in the world, with an average life expectancy of 37.5 years and only 35 per cent of those in rural areas having access to safe drinking water.²³⁴

Spills and leaks from stockpile containers can contaminate surface waters from runoff or groundwater from leaching through soil. Unsecured storage or open disposal areas have the potential to expose people where they work, live, travel, or play. For example, in the village of Arjo, Ethiopia, family homes where adults prepare food and children play are located a few meters from a pesticide dump site and an unsecured building that stores 5.5 tonnes of obsolete pesticides—including DDT and organophosphates (malathion, pirimiphos-methyl, and fenitrothion)—in drums, boxes, and bags.²³⁵

The Africa Stockpiles programme, a multi-stakeholder programme with participation from intergovernmental organizations, industry, and civil society, is working to reduce obsolete pesticide stockpiles, and their attendant hazards, in Africa.²³⁶

Table 19. Countries with More than 200 Metric Tonnes of Obsolete Pesticides

Region	Country	Year Latest Update	Pesticides Stocks (Metric Tonnes)
Africa	Algeria	1996	900
	Benin	1999	421
	Burkina Faso	2001	275
	Cameroon	2001	283
	Congo, Democratic Republic of the	1998	591
	Côte d'Ivoire	2001	828
	Egypt	1999	591
	Eritrea	2008	500
	Ethiopia	2008	300
	Lesotho	2008	200
	Malawi	2008	311
	Mali	2000	14,001
	Mauritania	1999	297
	Morocco	1994	700
	Niger	2001	207
	République centrafricaine	1994	238
	Rwanda	1998	451
	Senegal	1999	289
	South Africa	2008	700
	Sudan	1998	666
Tanzania	2008	1,500	
Tunisia	1994	1,200	
Uganda	1996	304	
Zambia	1997	360	
Zanzibar	1995	280	
Asia	India	2001	3,346
	Pakistan	2001	2,361
	Vietnam	2001	207
Eastern Europe	Armenia	2006	800
	Azerbaijan	2006	4,000
	Belarus	2006	6,000
	Bulgaria	2006	11,222
	Czech Republic	2006	400
	Estonia	2006	700
	FYR Macedonia	2006	38,000
	Georgia	2006	3,000
	Hungary	2006	314
	Kazakhstan	2006	10,000
	Kyrgyzstan	2006	2,000
	Latvia	2006	2,000
	Lithuania	2006	3,280
	Moldova	2006	6,600
	Poland	2006	9,000
	Romania	2006	1,000
	Russian Federation	2006	100,000
	Slovak Republic	2006	300
	Slovenia	2006	400
	Tajikistan	2006	3,300
Turkmenistan	2006	1,671	
Ukraine	2006	25,000	
Uzbekistan	2006	12,000	

Latin America	Brazil	1999	288
	Colombia	2003	5,436
	Costa Rica	2001	734
	Guatemala	2001	200
	Mexico	-	1,151
	Nicaragua	-	1,031
	Venezuela	2001	1,426
Near East	Iran, Islamic Republic of	1999	1,139
	Iraq	-	232
	Saudi Arabia, Kingdom of	-	241
	Syria	2002	529
	Yemen	1996	2,162

Source: UN Food and Agriculture Organization. Prevention and Disposal of Obsolete Pesticides. Where the Stocks Are. Available from <http://www.fao.org/agriculture/crops/obsolete-pesticides/where-stocks/en/>.

9.4.3 Small Scale Gold Mining

In many developing countries, of the environmental regulations pertinent to mineral activity, most apply to large-scale mines and fail to regulate smaller operations appropriately.²³⁷ Small-scale and artisanal gold mining operations are among the most pressing environmental and public health problems facing developing countries.

It is estimated that at least 100 million people in over 55 countries depend on small scale gold mining—directly or indirectly—for their livelihood, primarily in Africa, Asia and South America.²³⁸ These small-scale operations are estimated to account for 20 to 30 per cent of the world’s gold production.²³⁹ Because of inefficient mining practices, mercury amalgamation in small-scale gold mining results in the use and release of an estimated 650 to 1,000 metric tonnes of mercury per year.²⁴⁰ UNEP estimates that artisanal gold mining is the second largest source of mercury air emissions, accounting for an estimated 17 per cent.²⁴¹

Mercury is now a widespread contaminant in many parts of Africa. In Victoria Fields, Tanzania for example, the upper range of mercury levels in the mine water was 0.019 ppm. (WHO drinking water guidelines, in contrast, are 0.006 ppm).²⁴² High mercury concentrations of more than 48.3 ppm (50 ppm is a critical level for Minamata disease) was found in the hair of the gold miners (the highest value being 953 ppm), four fishermen and their families (highest value of 416 ppm), and four Mwanda people (highest value of 474 ppm).²⁴³ Evidence from Ghana is similar where levels of mercury that are unsafe for human consumption have been reported in vegetation and lake fish surrounding mining towns.²⁴⁴

Other developing countries face similar threats as those in Africa regarding mercury contamination and small scale mining. Researchers have documented elevated levels of mercury in blood as well as neurotoxic effects among small-scale gold miners in Brazil and the Philippines.²⁴⁵

10. Trends Associated with the Environmental Effects of Chemicals

Chemicals can affect all aspects of natural resources: atmosphere, water, soil, and biodiversity. Many of the chemicals described in the first half of this report are well known environmental contaminants in developed countries. Increasing use of these chemicals in developing countries is likely to produce similar patterns of environmental contamination. Section 9, above, provides detailed information on chemical waste in the environment. The present section briefly summarizes information regarding impacts to specific ecosystem resources from chemical contamination in the environment.

10.1 Air Resources

As reviewed above, PRTR data from OECD countries demonstrate that chemical releases to air are significant. There is a need for comparable data on air releases in developing countries. Chemicals that are VOCs are likely to become air contaminants; these are addressed in Section 9, above. Human health effects of industrial chemicals in air are reviewed in the section on health impacts, below.

Air is a vehicle of long-range transport of a wide variety of pollutants, including persistent organic pollutants. Many pollutants are initially emitted to air, and later are deposited to water.

Other atmospheric impacts of air emissions include contributions to formation of acid rain; global warming; and ozone depletion. Acid rain formation and global warming are primarily associated with fossil fuel combustion sources and are not reviewed in this report. Trends related to chemicals contributing to ozone depletion are reviewed below.

Tropospheric ozone is another important source of health impacts. Because fuel combustion by mobile sources is the primary source of tropospheric ozone, this issue is not reviewed in this report.

10.1.1 Ozone Depleting Chemicals

As a result of the 1987 Montreal Protocol, which has achieved universal ratification by 196 countries, the overall quantity of ozone-depleting substances in the lower atmosphere (troposphere) has declined approximately 8 per cent from peak values that occurred during the 1990s.²⁴⁶ These reductions are directly associated with the 95 per cent decrease in the use of ozone-depleting substances from 1986-2008.²⁴⁷ While global emissions of strong ozone-depleting substances such as chlorofluorocarbons (CFCs), halons, carbon tetrachloride and methyl bromide showed continued reductions during 2005-2008, global emissions of hydrochlorofluorocarbons (HCFCs) increased. HCFCs, which are allowed as temporary substitutes under the Montreal Protocol for the longer-lived ozone-depleting substances, accounted for 7.5 per cent of the total tropospheric chlorine in 2008. HCFC-22, which is the most abundant HCFC, increased 4.3 per cent per year during 2007-2008, more than 50 per cent faster than during 2003-2004. HCFC-142b increased 6 per cent per year during 2007-2008. By 2008, emissions for HCFC-142b were twice the magnitude than what was projected based on a scientific assessment in 2006 for the UNEP Ozone Secretariat.²⁴⁸

The increase in emissions of HCFCs was primarily driven by increases in production and consumption of HCFCs among developing countries.²⁴⁹ From 1989-2004, production of HCFCs increased 1,184 per cent among developing countries compared to 5 per cent among industrialized countries.²⁵⁰ Consumption of HCFCs increased from 745 per cent among developing countries compared to a decline of 6 per cent among industrialized countries from 1989-2004.²⁵¹ Although HCFCs have significantly lower ozone depleting potential than CFCs, they are likely to remain in the stratosphere for a long time. Moreover, these chemicals have a very high global warming potential.²⁵²

10.2 Water Resources

Chemicals contaminate water resources through direct discharges to bodies of water, and via deposition of air contaminants to water. Water contamination occurs through both legal and illegal discharges of chemicals used in or produced as byproducts of industrial activities. Chemicals are also released to water through normal use of some consumer products. Disposal of chemicals or products that contain them can lead to direct water contamination through leaching from landfills. Incineration of products containing chemicals can lead to indirect water pollution through deposition from air.

Chemical contamination of water resources, in turn, affects aquatic ecosystems. Some chemicals damage populations of aquatic microorganisms and small invertebrates. Damage to these organisms at low levels of the food chain can disrupt predator-prey relationships, setting off a cascade of adverse effects higher in the food chain.²⁵³ Effects such as eutrophication from the discharge of nitrates and phosphates in agricultural fertilizers to an aquatic system can indirectly impact fish and other aquatic populations by depleting oxygen in the water (See Box 1). Effects of other chemicals can affect the health of aquatic organisms more directly. Hundreds of chemicals are classified with regard to aquatic toxicity under the EU harmonized classifications. According to these classifications, 1,045 chemicals are classified as “very toxic to aquatic life,” 933 are classified as “very toxic to aquatic life with long lasting effects,” 566 are classified as “toxic to aquatic life with long lasting effects,” 406 are classified as “harmful to aquatic life with long lasting effects,” and 252 are classified as “may cause long lasting harmful effects to aquatic life.”²⁵⁴

Chemicals can also affect aquatic vertebrates, including amphibians, reptiles, fish and aquatic mammals. Adverse effects on aquatic animals include cancers, disrupted reproduction, immune dysfunction, damage to cellular structures and DNA, and gross deformities.²⁵⁵ Examples of adverse effects of water contaminants on aquatic vertebrates include feminization of fish, amphibians, and reptiles;²⁵⁶ and developmental delays, acceleration, and malformations in amphibians exposed to agricultural chemicals.²⁵⁷

Persistent organic pollutants can be transported over long distances in air and later be deposited into water resources. These chemicals can then accumulate in aquatic microorganisms and bioconcentrate as they move up the food chain. Mercury, for example, is transformed by aquatic microorganisms into methylmercury and bioaccumulates in fish, sometimes reaching tens of thousands of times the concentration originally found in water.²⁵⁸ Similarly, persistent organic pollutants (POPs) are concentrated as they move up the aquatic food chain, reaching very high levels in fish-eating mammals, such as seals. Chemicals that accumulate in aquatic animals, in turn, bioconcentrate in terrestrial predators such as bears, as well as in fish-eating birds.²⁵⁹ These exposures can lead to a variety of problems in predator species, including thinning of eggshells, disruption of parental behavior, reproductive disorders, and cancers, among other effects.²⁶⁰

Box 1. Chemical Impacts on Fisheries

Fisheries, an important source of protein and of economic value for populations around the world, can be severely affected by chemicals. Persistent organic pollutants can accumulate in fish, especially those high in the food chain. As a result, the value of this otherwise excellent protein source is diminished or lost completely.

Industrial and agricultural run-off can lead to large-scale fish kills, and lower-level chemical contamination of water bodies can decimate fish populations over time. Chemical contamination is also associated with disease in fish populations, including cancers and increased vulnerability to infectious agents.

10.3 Soil Resources

Chemicals contaminate soil in rural as well as urban or industrial settings. The sources of contamination may include atmospheric deposition, dumping of wastes, spills from industrial or waste facilities, mining activities, contaminated water, or pesticides. Plants grown in the soil may concentrate toxic substances such as cadmium and lead. For example, crops irrigated with wastewater in some parts of the world have been found to have elevated levels of heavy metals.²⁶¹ Additional exposure to contaminated soils can be from direct contact, inhalation of dust, or ingestion.

Agricultural chemicals can contribute to the depletion of soil resources. For example, insecticides and fungicides can affect a wide variety of non-target organisms, including beneficial soil microorganisms, decreasing ecosystem resilience and reducing soil fertility. In some instances, chemical-intensive crop production has produced short-term productivity gains that have later been reversed through soil depletion and degradation of water resources. Pesticides can also damage natural predator-prey relationships. The combination of soil and water contamination, effects on non-target species, and in some cases, emergence of pesticide-resistant pests can, in combination, significantly reduce total productivity. Conversely, integrated pest management approaches can boost productivity, providing a range of health, environmental and economic benefits.²⁶²

Other impacts of pesticides include adverse effects on biodiversity and on pollinator and other beneficial insect populations.²⁶³ Adverse effects on pollinators, in turn, can have long-term effects on food security. In addition to these ecosystem effects, studies have found that farming populations in developing and transition countries sometimes experience diminished productivity due to illnesses resulting from pesticide exposures.

10.4 Wildlife Impacts

Persistent and bioaccumulative chemicals are found as widespread contaminants in wildlife, especially those that are high on the food chain. Some of these chemicals cause cancers, immune dysfunction, endocrine disruption and reproductive disorders in wildlife.²⁶⁴ These effects can contribute to species extinction. For example, several studies have indicated that exposure to some pesticides can cause endocrine disruption in amphibians, resulting in a variety of effects that reduce reproductive success.²⁶⁵ Laboratory studies also suggest that the effect of some endocrine disrupting chemicals can be transgenerational, meaning that they affect not only the offspring of exposed organisms, but also subsequent generations.²⁶⁶

Many studies document high levels of persistent organic pollutants in wildlife, including aquatic mammals, polar bears, and fish-eating birds. Dioxins and PCBs are among the chemicals that have been documented at high levels in wildlife. These contaminants cause a variety of diseases and disorders—including cancers, alterations in sexual development, neurological dysfunction, and reproductive failure—and in the case of organochlorine chemicals, such as PCBs and DDT, have been responsible for the near extinction of some species.²⁶⁷ As measures have been undertaken to reduce the presence of these contaminants in the environment, levels have begun to decrease gradually. However, while levels of dioxins and PCBs in wildlife have decreased, levels of brominated flame retardants and perfluorinated compounds have increased. Many temporal trend studies of levels in wildlife in different regions of the world, especially for the perfluorinated compound perfluorooctane sulfonate (PFOS), have shown increasing concentrations over time in a range of wildlife, including fish, bird and bird eggs, ringed seals, and polar bears, among others.²⁶⁸ Extensive measurement of spatial and temporal trends of PBDEs in wildlife document increasing exposure of top predators over time, long-range transport/deposition and accumulation in remote regions, and biomagnification in top predators.²⁶⁹

At the nexus between contamination of animals and contamination of human food sources, some studies have examined levels of POPs in chicken eggs. A study by the International POPs Elimination Network (IPEN), a NGO, documented levels of dioxins, PCBs and hexachlorobenzene in free-range chicken eggs in 17 DCEITs. All of the composite egg samples examined in the study contained high levels of one or more of these persistent organic pollutants.²⁷⁰ More recently, a study in China documented contamination of dust, water, soil and chicken eggs with perfluorinated compounds.²⁷¹

11. Trends Associated with the Human Health Effects of Chemicals

As developing countries and countries with economies in transition account for an increasingly large share of chemical production and consumption, these changes have implications for human health. Having reviewed the changes that are occurring in the global distribution of chemical production, use and disposal, this section reviews the state of knowledge regarding the extent to which chemicals impact human health.

Extensive evidence is available on the human health impacts of a limited number of high-profile chemicals. However, a comprehensive understanding of impacts associated with the majority of chemicals in the global economy or even the smaller subset of high-production chemicals is lacking. In the sections that follow two indicators are used to describe trends: (1) biomonitoring data, and (2) the fraction of specific diseases attributable to chemicals globally. While the SAICM Secretariat in 2009 established biomonitoring data as the primary health indicator for tracking the effectiveness of sound chemicals management programmes,²⁷² comprehensive biomonitoring programmes are primarily confined to developed countries. Long-term biomonitoring data in developed countries and in some developing countries or countries in economic transition are available for only a small number of persistent pollutants. Despite these limitations, available data show important trends that are directly linked to policy decisions about chemicals management in both developed and developing countries.

Only recently has WHO attempted to quantify the disease burden worldwide that can be linked to exposure to chemicals. These health indicators reveal that the magnitude of harm is significant, yet the WHO analysis does not disaggregate its findings for developed and developing countries. Therefore, this section reviews additional data from scientific studies for a selected number of health endpoints to provide key examples of chemical effects on human health in developing countries and countries in economic transition.

11.1 Lack of Information on Health and Environmental Effects of Chemicals

While there is extensive evidence of adverse effects of chemicals on human health and the environment, there are also large data gaps. Of the tens of thousands of chemicals on the market, only a fraction has been thoroughly evaluated to determine their effects on human health and the environment.

The data gaps on chemicals were quantified in several studies in the late 1990s. A report by the European Chemicals bureau indicated that of approximately 2,500 high-production-volume (HPV) chemicals, only 14 per cent had sufficient data to comply with the basic requirements in the European Union's Dangerous Substances Directive; 65 per cent had incomplete data; and 21 per cent had no data at all.²⁷³ In another study, the US Environmental Protection Agency (US EPA) found that of approximately 3,000 substances sold above 1 million pounds per year, only 7 per cent had the minimum data considered to be necessary by the OECD, and that 43 per cent of the substances had no data at all.²⁷⁴ It is reasonable to assume that even less information is available on lower-volume substances.²⁷⁵ While there have been some improvements in data availability over the past decade, these figures continue to be indicative of the magnitude of the problem.²⁷⁶ However, data submission to the European Chemicals Agency under REACH, as well as other OECD activities, will help to fill some of the gaps in the decade ahead. Moreover, voluntary initiatives such as the Global Product Strategy of the International Council of Chemical Associations (ICCA) are helping to translate data required under REACH into easy-to-use safety summaries to ensure greater public access to information on general risk characterization and risk management for chemicals in commerce.²⁷⁷

Other gaps in our knowledge about chemicals and their effects on the environment and health are associated with our lack of knowledge regarding exposure to chemical mixtures. When chemicals are tested for toxicity they are usually studied individually. However, exposure under real-world circumstances is rarely to just one chemical. While more studies are beginning to examine how chemicals interact with genes and other biochemical functions, such as hormones, practical limits in epidemiology often mean that researchers can only examine the interaction of only two or three chemicals at a time.

11.2 Exposure Pathways, Vulnerable and Susceptible Populations

Public health risks associated with chemicals occur via various exposure pathways including ingestion of contaminated water and food, inhalation of contaminated air or dusts, dermal exposure, fetal exposure during pregnancy and the transfer of toxics through breast milk. In addition to identifying health effects of high exposure levels, toxicological research has also revealed mechanisms for a range of diseases whereby very low levels of exposure can influence disease risk. For example, multiple toxicological studies have demonstrated that exposure to low doses of the chemical bisphenol A in utero can cause alterations that increase the risk of diseases such as diabetes, prostate cancer and breast cancer later in life.²⁷⁸ Moreover, the dose of a chemical is not the only factor that significantly influences risk; the timing of exposure is also important. Exposure to chemical toxicants at low levels during periods of rapid growth and cell differentiation (e.g. fetal life through puberty) can be important factors that influence disease risk. Depending on the health outcome, these effects can occur very soon after exposure or much later in life. For example, a recent case-control epidemiologic study observed that girls exposed to DDT during the time of puberty—when mammary cells are more susceptible to deleterious effects of endocrine disrupting chemicals—were five times more likely than controls to develop breast cancer when they reached middle age.²⁷⁹

Individuals living in poverty, the elderly, workers, as well as infants and children (including those in utero) are among those most vulnerableⁱⁱ and susceptibleⁱⁱⁱ to the toxic effects of chemicals. Those living in poverty are more likely to be exposed to higher levels of chemical pollutants as they are more likely to dwell on marginal land (near landfills and polluted sites); to live in substandard housing with aging and deteriorating lead-based paint; to live near chemical-intensive industries; to live near sites where waste is burned and near heavy traffic; and to work in high hazard informal sector jobs.²⁸⁰ Those who are more poorly nourished and who have concurrent disease are also more susceptible to toxic chemicals than those more adequately nourished. For example, deficiency in specific nutritional factors can increase the risk of toxicity associated with exposure to metals, such as arsenic and lead.²⁸¹ Similarly, individuals with impaired respiratory or cardiovascular systems are more susceptible to life-threatening disease exacerbations associated with low-level exposure to particulate matter in air.²⁸²

Research has also made clear that the elderly are particularly susceptible to health effects from a range of chemical contaminants and associated pollution. For example, older adults are more susceptible to the toxic effects of mercury because of declining organ function, and are more susceptible to the carcinogenic effects of contaminants in air, water, food, and consumer products because of impaired DNA repair mechanisms; exposure to specific carcinogens can also promote the growth of existing tumors.²⁸³ Exposure to low levels of lead may increase the risk of high blood pressure among the elderly, especially those with nutritional deficits, and may increase cognitive impairments (e.g. psychomotor speed, manual dexterity, sustained attention, and mental flexibility) as well as psychiatric symptoms (e.g. anxiety, depression and phobic anxiety).²⁸⁴ In addition, both short- and long-term exposure to air pollutants, particularly particulate matter, are clearly linked to cardiovascular effects among older adults, including reduced oxygen supply to the heart and heart attacks, heart failure, stroke, arrhythmia and sudden death, cardiovascular hospitalization and mortality, and blood clots.²⁸⁵

Nearly all workers today are exposed to some sort of chemical hazard because of the ubiquitous use of chemicals in every type of industry, ranging from mining, welding, mechanical and manufacturing work, to office work and other occupations. While significant advances have been made in occupational safety and health globally, workers around the world still face unhealthy and unsafe working conditions. Accidents resulting in exposure as well as chronic health effects from long-term exposure to lower levels remain a global concern. Workers are also frequently required to use chemicals that have received inadequate health and safety testing and for which safe occupational exposure limits have not been identified. Some categories of workers such as migrants, temporary workers and those in the informal sector are more vulnerable to health effects of chemicals given the high levels of exposure they often experience.²⁸⁶

ⁱⁱ Defined as populations of individuals at risk of various health outcomes because they experience more frequent or higher levels of exposure.

ⁱⁱⁱ Defined as populations affected by pollutant concentrations at lower levels than the general population.

For example, migrant workers—who are often at increased risk of exploitation and tend to work in high risk jobs over long hours—bear a disproportionate burden of occupational fatalities, injuries and illnesses as compared to the non-migrant or native workforces.²⁸⁷

The developing fetus, infants and children are also uniquely susceptible to toxic chemicals. Due to their size, children’s exposures to toxic chemicals are disproportionately large compared to adults. In addition, because their metabolic pathways are immature, children are slower to detoxify and excrete many environmental chemicals, and thus toxicants can remain active in their bodies for longer periods of time.²⁸⁸ Furthermore, as mentioned above, during complex processes that occur during rapid growth and development of nervous, respiratory, immune, reproductive, and organ systems, the developing fetus and children’s bodies are less able to repair damage due to toxic exposures.²⁸⁹

Children’s exposures to chemical pollutants are not just through contaminated air, dusts, water or breast milk; they are also occupational. Child labourers often have other important risk factors, such as malnourishment, and are also less likely to wear personal protective equipment to protect themselves from exposure.²⁹⁰ The International Labour Organization (ILO) estimates that in 2008, there were 215 million child labourers between the ages of 5 and 17 and that more than half (115 million) work in hazardous conditions.²⁹¹ The highest incidence rate of children engaged in hazardous work was in sub-Saharan Africa, 15.1 per cent of all children ages 5-17 (38.7 million). The highest total number of children in hazardous work was in Asia (48.2 million).²⁹² Sixty per cent of child labourers overall were involved in agricultural work, underscoring the risks associated with exposure to pesticides and other agricultural chemicals. Children working in the informal sector, such as electronics and battery recycling, as well as scavenging, may be at most risk.²⁹³

11.3 Health Outcomes Associated with Chemical Exposure

Exposure to toxic chemicals can cause or contribute to a broad range of health outcomes, as shown in Table 20, as well as mortality. Some chemicals can irritate the eyes, skin or respiratory tract, causing either reversible or permanent damage. Chemicals can also cause injury to one or more organs of the body, such as the lungs, liver or kidneys. Others may adversely affect the functioning of various systems of the body, including the immune system, respiratory system, cardiovascular system, nervous system, reproductive system and endocrine system. Lastly, chemicals can cause specific chronic diseases, such as cancer, asthma, diabetes, or birth defects. As a result, chemical exposures can contribute to rates of disease and disability, as well as causing deaths.

Table 20. Health Outcomes and Examples of Suspected or Confirmed Linkages to Chemicals

Health effect	Suspected or Confirmed Number of Chemicals (If Examined)	Examples (not comprehensive)
Asthma (via non-respiratory sensitization)	NA ^c	<i>inorganics</i> (chlorine, hydrochloric acid, sulfuric acid); <i>other organics</i> (ethylene oxide); <i>pesticides</i> (acephate, diazinon, malathion, safrotin)
Cancer	1070 ^b	<i>aromatics</i> (benzene); <i>aromatic amines</i> (benzidine, 4,4'-methylenebis 2-chloroaniline); <i>combustion byproducts</i> (2,3,7,8-tetrachlorodibenzo-p-dioxin, polyaromatic hydrocarbons); <i>fibers/dust</i> (asbestos, silica); <i>halogenated compounds</i> (methylene chloride, trichloroethylene); <i>inorganics</i> (sulfuric acid); <i>metals</i> (arsenic, beryllium, cadmium, chromium, lead, nickel); <i>other organics</i> (butadiene, ethylene oxide, formaldehyde); <i>pesticides</i> (chlordane, DDT)
Diabetes	NA ^b	<i>combustion byproducts</i> (2,3,7,8-tetrachlorodibenzo-p-dioxin); <i>metals</i> (arsenic), <i>pesticides</i> (N-2-pyridylmethyl-N'p-nitrophenyl urea)
Organ Damage	466 ^a	<i>aromatics</i> (benzene); <i>halogenated compounds</i> (carbon tetrachloride, pentachloroethane); <i>metals</i> (beryllium, chromium compounds, mercury, nickel and compounds); <i>other organics</i> (methanol, methyl butyl ketone); <i>pesticides</i> (aldrin, DDT, dieldrin, mipafox, leptophos, cyanofenphos)

Table 20. Health Outcomes and Examples of Suspected or Confirmed Linkages to Chemicals

Neurotoxicity	201 ^d	aromatics (benzene, toluene); <u>halogenated compounds</u> (trichloroethylene, vinyl chloride); <u>inorganics</u> (hydrogen sulfide, phosphorus); <u>metals</u> (arsenic and compounds, lead and compounds, manganese and compounds, methylmercury, tin compounds); <u>pesticides</u> (aldrin, carbofuran, chlorpyrifos, coumaphos, diazinon, endosulphan, endrin, fonofos); <u>phthalates</u> (dibutyl phthalate); <u>other organics</u> (caprolactum, cumene, ethylene, ethylene glycol, ethylene oxide, methanol polychlorinated biphenyls)
Reproductive Toxicity (e.g. Impaired Fertility, Birth Defects)	261 ^a	<u>halogenated compounds</u> (1-bromopropane, 2-bromopropane); <u>metals</u> (chromium and compounds, cobalt and compounds, lead and compounds, mercury); <u>phthalates</u> (dibutyl phthalate, di(2-ethylehexyl)phthalate (DEHP), benzylbutylphthalate); other organics (n-hexane); <u>pesticides</u> (1,2-dibromo-3-chloropropane (DBCP), mirex)
Skin Burns/Irritation; Serious Eye Irritation/ Damage; Respiratory Irritation	837 ^a 892 ^a 224 ^a	<u>isocyanates</u> (chlorophenylisocyanate, hexamethylene diisocyanate, methyl isocyanate, methylene bisphenyl isocyanate, naphthylene diisocyanate); <u>other organics</u> (caprolactam, hydroxylamine); <u>pesticides</u> (guazatine, dodemorph, paraquat dichloride, sabadilla)
Skin Sensitizers (e.g. Dermatitis, Allergy)	997 ^a	<u>acid anhydrides</u> (maleic anhydride, phthalic anhydride, trimellitic anhydride); <u>amines</u> (ethylenediamine, triethanolamine); <u>diisocyanates</u> (methylene bisphenyl isocyanate, naphthylene diisocyanate, hexamethylene diisocyanate, toluene diisocyanate); <u>metals</u> (chromium and compounds, nickel and compounds); <u>other organics</u> (formaldehyde, glutaraldehyde)
Respiratory Sensitizers (e.g. Allergy, Allergic Asthma)	114 ^a	

Sources:

^aEuropean Chemical Substance Information System. Table 3.1 Available from <http://esis.jrc.ec.europa.eu/index.php?PGM=cla>. Note: this database is routinely updated.

^bPrüss-Ustün, A., Vickers, C., Haefliger P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health*. 10:9. Table 2.

^cAssociation of Environmental and Occupational Clinics. AOEC Exposure Codes. Available from <http://www.aoecdata.org/ExpCodeLookup.aspx>.

^dGrandjean, P. and Landrigan, P.J.(2006). Developmental neurotoxicity of industrial chemicals. *Lancet*. 368, 2167-2178.

Health effects associated with specific chemicals reviewed in the earlier sections of this report are shown in Table 21. As shown in the table, most of these chemicals are associated with some adverse health effect, although some are significantly more hazardous than others. For example, of the bulk organic chemicals, all of which are used in large quantities globally, two (benzene and butadiene) are classified by IARC in Group 1 (carcinogenic to humans) and thus listed as carcinogenic within the EU system of harmonized classification.

Table 21. Health Effects of Specific Organic and Inorganic Chemicals Discussed in Sections 4 and 5 of This chapter (Production and Consumption Trends)

Chemical category	Chemical	Health Effect
ORGANIC CHEMICALS		
	Methanol	toxic if swallowed, inhaled or if in contact with skin; ^a single exposure can damage organs; ^a burns (flammable); ^a neurotoxic
Olefins	Ethylene	burns (flammable); ^a neurotoxic ^{a, b}
	Propylene	burns (flammable) ^a
	Butadiene	carcinogenic to humans; ^c may cause genetic defects ^a
Aromatics	Xylenes	harmful if inhaled, causes skin irritation; ^a neurotoxic ^b
	Benzene	carcinogenic to humans; ^c neurotoxic; ^b may cause genetic defects, may be fatal if swallowed and enters airways, causes damage to organs through prolonged or repeated exposure, causes eye and skin irritation, burns (flammable) ^a
	Toluene	Burns (flammable), may be fatal if swallowed and enters airways, causes damage to organs through prolonged or repeated exposure, causes skin irritation; ^a neurotoxic, including a developmental neurotoxicity ^b
Chlorinated Compounds	Vinyl chloride monomer	carcinogenic to humans; ^c neurotoxic; ^b burns (flammable) ^a
	Trichloroethylene	probably carcinogenic to humans; ^{* c} neurotoxic; ^b suspected of causing genetic defects, causes eye and skin irritation ^a
	Perchloroethylene	probably carcinogenic to humans; ^c neurotoxic; ^b
	Lindane	neurotoxic; ^b toxic if swallowed, harmful if in contact with skin or inhaled, may cause damage to organs through prolonged or repeated exposure, may cause harm to breast-fed children ^a
Brominated Compounds	Polybrominated diphenyl ethers	thyroid disorders; ^e neurotoxic ^e
Fluorinated compounds	Fluorinated polymers (e.g. PFOA or PFOS)	reproductive toxicant; ^f possibly carcinogenic; ^f may cause increased cholesterol ^{f, g}
INORGANICS		
Basic Inorganics	Sulfuric Acid	carcinogenic to humans (fuming sulfuric acid); ^c asthmagen (reactive airway dysfunction syndrome) ^d
	Ammonia	toxic if inhaled, causes severe skin burns and eye damage, burns (flammable), ^a asthmagen (reactive airway dysfunction syndrome) ^d
	Sulfur	causes skin irritation ^a
	Phosphoric Acid	causes severe skin burns and eye damage ^a
Metals	Cadmium	carcinogenic to humans; ^c suspected of causing genetic defects, may damage fertility or the fetus, fatal if inhaled, causes damage to organs through prolonged or repeated exposure ^a
	Lead	neurotoxic, including a developmental neurotoxicity; ^b causes high blood pressure; harmful if inhaled or swallowed, may cause organ damage with prolonged or repeated exposure ^a
	Mercury	neurotoxic, including developmental neurotoxicity (methyl mercury) ^b fatal if inhaled, swallowed or in contact with skin, causes organ damage with prolonged or repeated exposure ^a

Sources:

^a European Chemical Substance Information System. Table 3.1 Available from <http://esis.jrc.ec.europa.eu/index.php?PGM=cla>.

^b Grandjean, P. and Landrigan, P.J. (2006). Developmental neurotoxicity of industrial chemicals. *Lancet*. 368, 2167-2178.

^c International Agency for Research on Cancer. Agents Classified by the IARC Monographs Volumes, 1-102. Available from <http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf>.

^d Association of Environmental and Occupational Clinics. AOEC Exposure Codes. Available from <http://www.aoecdata.org/ExpCodeLookup.aspx>.

^e US National Toxicology Program. (1986). Toxicology and carcinogenesis studies of decabromodiphenyl oxide (CAS No. 1163-19-5) in F344/N rates and B6C3F1 mice (feed studies). National Toxicology Program Technical Report Series. 309,1-242.

^f US Agency for Toxic Substances and Disease Registry. ToxFAQs for Perfluoroalkyls. Available from <http://www.atsdr.cdc.gov/toxfaqs/faq.asp?id=1116&tid=237>.

^g Webster, G. (October 2011). Potential Human Health Effects of Perfluorinated Chemicals (PFCs). National Collaborating Center for Environmental Health at the British Columbia Centre for Disease Control. Available from http://www.nceh.ca/sites/default/files/Health_effects_PFCs_Oct_2010.pdf.

*Note: In September 2011, the US National Toxicology Program upgraded trichloroethylene to a “known human carcinogen”

11.4 Indicators of Exposure to Chemicals: Human Biomonitoring Data

Humans are exposed to a daily mixture of chemicals as contaminants in air, water, food, consumer products and other media. Human biomonitoring data provide key indicators of human exposure to chemicals. These data can be used to monitor the effectiveness of chemical management programmes over time by measuring changes in human exposure levels, and by revealing sub-populations with disproportionately high levels of exposure.

Research in developed countries has provided detailed information on the presence of industrial chemicals in the human body. Results from these studies can provide an indication of likely results in developing countries where exposure circumstances are similar or more severe. In addition, an increasing amount of data is becoming available from biomonitoring studies in developing countries and countries with economies in transition. As part of its work to support the goals of SAICM, the International Council of Chemical Associations (ICCA) has made efforts to track and document the number of countries engaged in biomonitoring and environmental monitoring efforts.²⁹⁴

Long-term biomonitoring data are available only for a small number of persistent pollutants. However, the available data show important trends that are directly linked to policy decisions about chemicals management.

For example, significant progress has been made in reducing children's blood lead levels, primarily as a result of policies phasing out the use of leaded gasoline. Dramatic declines in children's blood lead levels have been documented following the phaseout of leaded gasoline in the US²⁹⁵ and other developed countries; similar trends have been documented in developing countries and countries with economies in transition, including China, El Salvador, India, Mexico and Thailand.²⁹⁶ While these trends are positive, WHO still estimates that 98 per cent of adults and 99 per cent of children currently affected by exposure to lead live in developing countries and countries in economic transition.^{iv} ²⁹⁷ In addition to leaded gasoline, lead industries are also significant contributors to blood lead levels in these regions. For example, a recent review of biomonitoring studies examined blood lead levels among workers at lead-acid battery manufacturing and recycling plants in developing countries. The study found that average blood lead levels among these workers was 47 µg/dL in battery manufacturing plants and 64 µg/dL in recycling facilities.²⁹⁸ This same review found that mean blood lead levels of children residing near battery plants in developing countries was 19 µg/dL—roughly 13-fold greater than the levels observed among children living near comparable facilities in the United States.²⁹⁹ Recent research indicates that neurobehavioural damage associated with lead can occur at blood lead levels of 5 µg/dl and even lower—levels that were once considered safe.³⁰⁰

An ongoing time-series analysis of dioxins and PCBs in human milk, coordinated by WHO, provides the most systematic information on persistent organic pollutants in humans. The latest inter-country comparison results from this study, published in 2002, compare data on dioxins/furans and PCBs in human milk data across multiple countries.³⁰¹ Results from this analysis for the five countries with the highest and lowest levels of these contaminants are shown in Table 22. The analysis found that median levels of dioxins/furans and PCBs in human milk were generally lower in the Southern Hemisphere (e.g. Fiji, Brazil, and Philippines) and higher in Western Europe (Italy, Germany, Luxembourg) as well as in Egypt and the Ukraine where the highest levels of dioxins/furans and PCBs were identified, respectively.³⁰² The study also demonstrated that over all, median levels of these pollutants are decreasing based on comparisons to earlier data where available. The decrease in concentrations has been on the order of 5 per cent or more per year, highest in countries with the highest initial concentrations.³⁰³

In cooperation with UNEP, WHO has recently expanded the analysis of persistent organic pollutants to assess the experience in a larger number of developing and transition countries. Recent data show that levels of dioxins/furans in Africa (Ghana, Nigeria, Senegal), South America (Chile, Uruguay) and Caribbean countries are relatively low and comparable to developed nations. However, breast milk concentrations of DDT are high, especially in African countries.³⁰⁴ Concentrations were highest in Nigeria and Senegal.³⁰⁵ However, these levels are far lower than levels reported in Zimbabwe in 1991 or Uganda in 1999.³⁰⁶

^{iv} These countries were defined as low and middle income countries in the WHO report.

Table 22. Human Milk Biomonitoring Results for Dioxins/Furans and PCBs: Third WHO-Coordinated Exposure Study

TCDD/F* levels		PCB levels	
Countries with Highest Measured Levels	Concentration in milk (median PCDD/Fs WHO ₁₉₉₈ TEQ pg g ⁻¹ fat (range))	Countries with Highest Measured Levels	Concentration in milk (Median PCBs WHO ₁₉₉₈ TEQ pg g ⁻¹ fat (range))
Egypt	22.3 (14.9-51.5)	Ukraine	20.0 (14.1-22.0)
Netherlands	18.3 (17.1-21.3)	Italy	16.3 (11.0-19.3)
Belgium	16.9 (14.8-19.1)	Czech Republic	12.6 (11.2-14.0)
Luxembourg	15.0 (13.7-16.3)	Germany	13.7 (12.8-14.3)
Germany	12.5 (11.1-12.7)	Luxembourg	13.7 (13.0-14.7)
Countries with Lowest Measured Levels		Countries with Lowest Measured Levels	
Fiji	3.3 (3.2-3.5)	Fiji	1.8 (1.7-1.8)
Brazil	3.9 (2.7-5.3)	Brazil	1.8 (1.3-12.3)
Philippines	3.9 (3.6-4.2)	Philippines	2.4 (2.2-2.5)
Australia	5.6 (5.4-5.8)	Hungry	2.9 (2.4-4.2)
Bulgaria	6.1 (5.1-7.1)	Australia	2.9 (2.5-3.3)

* 2,3,7,8-tetrachlorodibenzo-*p*-dioxin; 2,3,7,8-tetrachlorodibenzofuran.

Source: Van Leeuwen, F.X.R. and Malisch, R. (2002). Results of the third round of the WHO coordinated exposure study on the level of PCBs, PCDDs, and PCDFs in human milk. *Organohalogen Compounds*. 56, 311–316.

Some studies in countries in economic transition show populations experiencing disproportionate risks. For example, contamination with dioxins associated with e-waste recycling in Guiyu, China, has resulted in significantly elevated levels of dioxins measured in human milk, placentas and hair.³⁰⁷ As compared to levels in other countries described in Table 22, levels of dioxins/furans in human milk of women in Guiyu ranked second highest behind Egypt. Mean levels of dioxin and related compounds in human breast milk collected from the residents around the open dumping sites of municipal wastes in India were found to be similarly high and likely due in large part to the daily intake of bovine milk—from animals which fed in the dumping sites.³⁰⁸ In Chapaevsk, an area in Northern Russia that was significantly contaminated by a plant producing agricultural chemicals, mean levels of dioxins and related compounds in human milk, while still high, have declined over a ten year time period as a result of plant operations ceasing and environmental remediation efforts.³⁰⁹

Some additional persistent organic pollutants have come into focus more recently. A growing number of studies, conducted in many regions of the world, document the presence of perfluorinated compounds (PFCs) in human blood and breast milk. For example, studies indicate that in the United States, serum levels of PFCs, particularly perfluorooctane sulfonate (PFOS), are approximately two to threefold higher than in Colombia, Brazil, Poland, Belgium, Malaysia, Korea and Japan; about eight to sixteen-fold higher than in Italy and India;³¹⁰ and more than thirty-fold higher than in Peru.³¹¹ A study by 3M, the principal manufacturer of PFOS in the United States, found some decline in US blood levels of certain perfluorinated compounds over the period 2000 to 2006, following 3M's phaseout of PFOS-based manufacturing.³¹² A recent study found that perfluorinated compounds in blood were ubiquitous among residents of Wenzhou, China.³¹³ Another study examined levels of PFOS and perfluorooctanoic acid (PFOA) in blood in Japan, Republic of Korea, and Vietnam, and found variable trends, with blood levels increasing over time in some cases, declining in others, and remaining constant over time in some cases.³¹⁴ Another study documented the presence of long-chain perfluorinated carboxylic acids in both breast milk and infant formulas in Japan, Republic of Korea, and China.³¹⁵

The national biomonitoring programme of the US Centers for Disease Control and Prevention (CDC) provides a more comprehensive picture regarding the extent of human exposure to chemicals. Of the 212 chemicals included in the CDC's fourth exposure study, all were detected in some portion of the US population.³¹⁶ The CDC biomonitoring programme documents these exposures without attempting to draw conclusions about health impacts. Findings from the study indicate widespread exposure to some industrial chemicals; 90 to 100 per cent of samples assessed had detectable levels of substances including perchlorate, mercury, bisphenol-A, acrylamide, multiple perfluorinated chemicals, and the flame retardant polybrominated diphenyl ether-47 (BDE-47).³¹⁷ Since similarly comprehensive biomonitoring programmes are not being carried out in developing and transition countries, these US data are an important source of information on the extent to which these and other chemicals may be present in the human body.

11.5 The Magnitude of Disease Burden Due to Chemicals

Despite ubiquitous exposure to chemicals in both developed and developing nations, little is known about the total disease burden attributable to chemicals. In 2011, WHO used available data for certain toxic chemicals to calculate the global burden of disease. WHO analyzed health endpoints such as cardiovascular disease, cancers, neuropsychiatric disorders, asthma, chronic obstructive pulmonary disease, respiratory infections, and birth defects.

WHO found that globally in 2004, 4.9 million deaths (8.3 per cent of total) and 86 million disability-adjusted life years (DALYs, which address a blend of death and disease impact) (5.7 per cent of total) were attributable to exposure to selected chemicals for which data were available.³¹⁸ Of special note was the finding that children under age 15 years were a highly susceptible group. These children bore 54 per cent of the global burden, including 80 per cent imposed by lead and 19 per cent of that of acute accidental poisonings.³¹⁹

A subset of the exposures examined by WHO are industrial chemical exposures that could be addressed through the sound chemicals management approach envisioned under SAICM. As shown in Table 23, WHO's analysis shows that this subset of exposures were responsible for at least 964,000 deaths and 21 million DALYs, corresponding to 1.5 per cent of total deaths and 1.4 per cent of the total burden of disease in 2004. These figures include some acute poisonings (excluding self-inflicted injuries) and some chronic health effects associated with lead and with carcinogens and particulates in the workplace.^{v 320}

The WHO study emphasizes that these global estimates are an underestimate of the real burden attributable to chemicals.³²¹ Only a small number of chemicals could be included in the WHO analysis due to limitations in data availability. Critical chemicals not able to be included in the analysis include mercury, dioxins, organic chlorinated solvents, PCBs, and chronic pesticide exposures as well as health impacts from exposure to local toxic waste sites, which are estimated to affect more than 56 million people worldwide.³²² Moreover, it is currently not possible to calculate attributable fractions based on certain important mechanisms by which chemicals exert their toxic effects, such as through the endocrine system.³²³ Though it underestimates the magnitude of death and disability that could be prevented by preventing exposure to hazardous chemicals, even this limited analysis shows that a large number of lives are affected by these exposures. While these estimates are currently of limited value to characterize temporal or smaller geographic trends (i.e., trends within developing countries), there is the potential for WHO to routinely repeat and update this analysis in the future as new biomonitoring data emerge that can help to improve exposure information.

^v The original WHO analysis included disease estimates attributable to chemicals not directly related to chemical management strategies under SAICM. These categories have been omitted for the purpose of the present analysis and include: pesticides involved in self-inflicted injury (186,000 deaths and 4,420,000 DALYs), outdoor air pollutant mixtures (1,152,000 deaths and 8,747,000 DALYs), outdoor air pollutants emitted from ships (60,000 deaths and unknown DALYs), indoor biomass combustion (1,965,000 deaths and 41,009,000 DALYs), second-hand smoke (603,000 deaths and 10,913,000 DALYs) and naturally occurring arsenic in drinking water (9,100 deaths and 125,000 DALYs).

Table 23. Overview of Available Disease Burden Estimates Attributable to Chemicals That Could Be Addressed Through Sound Management of Chemicals (2004)

Chemicals/Group of chemicals	Disease outcomes considered (attributable fraction)	Deaths	DALYs ^a	Main limitations
<i>Chemicals in acute poisoning</i>		<i>526,000 (subtotal)</i>	<i>9,666,000 (subtotal)</i>	
Chemicals (including drugs) involved in unintentional acute poisonings (e.g. methanol, diethylene glycol, kerosene, pesticides, etc)	Unintentional poisonings (71%)	240,000 ^a	5,246,000 ^a	Limited to preventable poisonings.
Chemicals involved in unintentional occupational poisonings	Unintentional poisonings (occupational) (8.6%)	30,000 ^b	643,000 ^b	
<i>Chemicals in occupational exposures (longer-term effects)</i>		<i>581,000 (subtotal)</i>	<i>6,763,000 (subtotal)</i>	
Asbestos	Malignant mesothelioma (NA); trachea, bronchus, lung cancer (0.3%); asbestosis (NA)	107,000 ^c	1,523,000 ^c	
Occupational lung carcinogens (arsenic, asbestos, beryllium, cadmium, chromium, diesel exhaust, nickel, silica)	Trachea, bronchus, lung cancer (8.6%)	111,000	1,011,000	Only 8 chemicals or mixtures classified as carcinogenic or probably carcinogenic to humans taken into account.
Occupational leukaemogens (benzene, ethylene oxide, ionizing radiation)	Leukemia (2.3%)	7,400 ^d	113,000 ^d	Only 2 of the chemicals or chemical mixtures classified as carcinogenic or probably carcinogenic taken into account.
Occupational particulates – causing Chronic obstructive pulmonary disease (COPD) (dusts, fumes/gas)	COPD (13%)	375,000 ^e	3,804,000 ^e	
Occupational particulates – other respiratory diseases than COPD (silica, asbestos and coal mine dust)	Asbestosis (NA); silicosis (NA); pneumoconiosis (NA)	29,000	1,062,000	
<i>Single chemicals with mostly longer term effects</i>		<i>143,000 (subtotal)</i>	<i>8,977,000 (subtotal)</i>	
Lead	Mild retardation; cardiovascular diseases	143,000	8,977,000	
Total^f	All considered diseases	964,000 (1.6%)	20,986,000 (2.2%)	

Source: Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health*. 10:9. Table 3. Original table modified based on consultation with the authors.

^aDALYS are “disability-adjusted life years”, a weighted measure of years of life lost due to premature death and years lived with disability. Only outcomes qualified as strong evidence were considered.

^a Estimate not compared to counterfactual exposure, which is however estimated to be negligible using a theoretical minimum exposure given available management options for concerned chemicals.

^b Already included in total unintentional acute poisonings and therefore not included again in the total

^c Lung cancer and asbestosis caused by asbestos are also considered in occupational lung carcinogens and particulates and this part of the burden is therefore not counted twice in the total.

^d Also includes a small fraction of leukemia caused by ionizing radiation.

^e Parts of the particulates are organic in nature, and the estimate therefore includes a small fraction that is not directly related to chemicals.

^f Total is corrected for double counting (chemicals considered in more than one estimate); not all disease burdens are additive, and joint exposures could lead to slight overestimate.

11.6 Significant Health Effects Associated with Chemicals

11.6.1 Acute Poisonings

As shown in Table 23, above, WHO estimates that there were 526,000 deaths (9,666,000 DALYs) from chemical poisoning worldwide in 2004. This figure includes pesticide poisonings as well as other chemicals.³²⁴

Acute chemical poisoning data are highly variable and depend on the surveillance infrastructure in place in individual countries or regions. For example, in OECD countries with Poison Center networks, data may be quite complete and trends can be estimated over months or years. The ability to track such poisoning is much less comprehensive in developing countries and countries with economies in transition. Moreover, the full extent of acute poisonings from toxic chemicals in developing and transition nations is difficult to estimate, in part because of the well-known problem of underreporting (both for acute non-fatal poisoning, and for deaths due to accidental or intentional ingestion of toxic chemicals).

Pesticide poisonings are an important subcategory of poisonings. The reasons for these poisonings are varied and include, among others, occupational exposure, bystander exposure from pesticide drift, food and water contamination, and self harm. WHO acknowledges that there are no reliable estimates of pesticide poisonings and existing estimates likely significantly underestimate the global burden.³²⁵ For example, one study in Central America revealed a 98 per cent rate of underreporting, 76 per cent of these additional poisoning incidents being work-related.³²⁶ Similarly, a surveillance study in South Africa found a tenfold increase of pesticide poisoning rates compared to routine reporting methods.³²⁷ The most commonly cited estimations regarding cases of pesticide poisonings are from a WHO task force published in 1990, suggesting that annually, unintentional pesticide poisonings affect one million individuals each year while pesticide poisonings associated with self harm affect an additional two million individuals annually.³²⁸ Ninety-nine per cent of these poisonings occur in low- and middle-income countries. The authors note that this necessarily reflects only a fraction of the real problem and estimate that there could be as many as 25 million agricultural workers in the developing and transition world suffering some form of occupational pesticide poisoning each year, though most incidents are not recorded and most patients do not seek medical attention. One of the conclusions this author reaches is that in some developing and transition countries, acute pesticide poisoning may be as serious a public health concern as are communicable diseases.³²⁹ This global burden is also consistent with a 2004 World Bank report that revealed that the poorest nations use the most hazardous pesticides.³³⁰ More recently, WHO researchers estimated that in 2002, 186,000 deaths from self-harm were due to pesticides (Table 23). Examples of recent poisoning incidents in developing and transitional countries are outlined in Box 2.

Box 2. Poisoning Events: Recent Examples in Developing and Transition Countries

In March and April 2010, Médecins Sans Frontières (MSF) informed the Zamfara State Ministry of Health in Nigeria of an increasing number of childhood deaths and illness in villages in the two Local Government Areas of Bukkuyum and Anka. Working with national and state authorities, MSF, the World Health Organization, subsequent health investigations by the United States Centers for Disease Control, and environmental assessments by a team sent by the Blacksmith Institute confirmed severe lead poisoning in more than 100 children as a result of processing lead-rich ore for gold extraction. Between March and June 2010, a total of 355 cases of lead poisoning were discovered, 46% of which were fatal. Lead concentrations in soil were at levels several orders of magnitude higher than limits set by environmental agencies in the United States and Europe.³³¹

Additional examples of recent poisonings are described below.

Africa	
Angola	In 2007, an outbreak of acute neurologic disease among 467 individuals in the Cacuaco municipality was attributed to poisoning with sodium bromide (a chemical commonly used in the oil drilling industry in Angola). ³³²
Ivory Coast	In 2006, 8 deaths and about 85,000 health-related consultations resulted from the dumping of petrochemical toxic waste in a suburb of Abidjan (2006). ³³³
Senegal	Between November 2007 and March 2008, 18 children died from lead poisoning in a community located in the suburbs of Dakar that was engaged in the recycling of used lead-acid batteries. ³³⁴
Tanzania	An NGO survey of 120 farmers in Ngarenanyuki revealed that during the farming season from December 2006 to March 2007, 69 per cent had experienced pesticide poisoning; 22 per cent had experienced poisoning symptoms more than three times during the season. ³³⁵ Poisonings most commonly occurred after using profenofos, mancozeb and endosulfan.
Asia	
Bangladesh	In 2010, an annual government survey revealed that pesticide-related poisoning is a leading cause of death in Bangladesh. ³³⁶
China	In 2011, tests revealed that 26 adults and 103 children had severe lead poisoning, while 494 others had moderate poisoning as a result of exposure to lead materials from tinfoil processing in the town of Yangxunqiao in eastern China. ³³⁷ In 2007, blood serum levels of PBDE (deca-PBDE, isomer BDE-209) among workers at the e-waste recycling operations in Guiyu exceeded levels previously reported for those occupationally exposed by a factor of 50-200; one worker had the highest levels ever reported. ³³⁸
India	In 2005, there were 323 separate incidents of ill health reported among 97 cotton farmers living in three villages in the Andhra Pradesh state over a five month growing season. 83.6 per cent of these incidents were associated with signs of mild to severe pesticide poisoning. ³³⁹
Vietnam	In 2007, blood tests of 190 rice farmers in the Mekong Delta revealed that over 35 per cent experienced acute pesticide poisoning, and 21 per cent were chronically poisoned. ³⁴⁰
Latin America	
Bolivia	In Cochabamba during 2007/2008 pesticide poisonings increased by 30 per cent (274 cases); 56 per cent of those poisoned were women from rural areas. ³⁴¹
Peru	Hundreds of people fell ill from mercury poisoning when a mining company truck in 2000 dumped mercury along the road in the province of Cajamarca. ³⁴²

11.6.2 Chronic Disease

While chronic diseases such as cancer, cardiovascular disease and asthma have traditionally affected mostly high-income populations, developing countries are experiencing a shift from primarily infectious diseases to primarily chronic illnesses.³⁴³ Rates of morbidity and mortality from chronic diseases are now higher than infectious diseases in every region except Africa, where the rate of such diseases is quickly rising.³⁴⁴ By 2030, chronic diseases are projected to cause nearly five times as many deaths as infectious diseases worldwide, including in developing countries and countries in economic transition.³⁴⁵ As life expectancies increase with improvements in medical care and public health interventions such as improved sanitation, human health is increasingly affected by disease risk factors associated with industrialization.³⁴⁶ Exposure to toxic chemicals is among the important contributors to a variety of chronic diseases, which also include lifestyle and dietary risk factors.

Three important categories of chronic diseases associated with toxic chemicals are briefly reviewed below: cancer, reproductive and developmental disorders and cardiopulmonary diseases, including impacts of respiratory sensitizers. A comprehensive discussion of all the health endpoints noted in Table 20 is beyond the scope of this report. For example, this section includes information on respiratory sensitization but does not summarize the literature on dermal sensitization; and while some neurotoxicants are reviewed in the section on developmental disorders, neurotoxic effects in adults are not reviewed.

11.6.2.1 Cancer

Studies link a variety of chemicals to cancer. As shown above in Table 20, 198 chemicals with EU harmonized classifications have been classified as “may” cause or “suspected” of causing cancer. Much of this evidence is based on comprehensive reviews by IARC. IARC has only evaluated 941 agents and exposure circumstances for carcinogenicity. However, the majority of the over 400 chemicals/exposure circumstances classified by IARC as carcinogenic, probably carcinogenic or possibly carcinogenic (group 1, group 2A and group 2B, respectively) are chemicals used in the material economy.³⁴⁷ Based on a recent review of the IARC monographs, the majority of group 1- group 2B carcinogens are industrial/occupational carcinogens.³⁴⁸ In their review, these researchers identified: 28 definite (group 1) human occupational/industrial carcinogens; 27 probable (group 2A) human occupational/industrial carcinogens; 113 possible (group 2B) human occupational/industrial carcinogens; and 18 occupations and industries that possibly, probably, or definitely entail excess risk of cancer (IARC groups 1, 2A, and 2B).

For a particular person, single cancer risk factors act within multidimensional causal webs reflecting cumulative interaction among risks across an individual’s life.³⁴⁹ Science has yet to reveal the full range of mechanisms (e.g., inflammation, DNA damage, gene suppression or over-expression, or epigenetic changes) by which diet, genetic inheritance, lifestyle factors, and industrial agents in our workplaces and environment, among other cancer risks, contribute to the initiation, promotion, and progression of an individual’s cancer. Thus efforts to understand the magnitude of cancer attributable to chemicals in the environment and in workplaces fall short of enumerating the full burden.

Recent WHO estimates suggest that 8.6 per cent of deaths from cancers of the lung, bronchus and trachea are attributable to chemicals in workplaces, yet only a small set of chemicals were examined (Table 23).³⁵⁰ Similarly, an estimated 2.3 per cent of leukemia deaths were also attributed to occupational chemical exposures (Table 23).³⁵¹ The most widely cited estimation, attributing 2 per cent of cancer deaths to environmental exposures, is from a 1981 analysis.³⁵² However, in 2010, the US President’s Cancer Panel found that the true burden of environmentally (including occupational) induced cancer has been grossly underestimated.³⁵³ The Panel highlighted several methodological limitations that impact the validity of existing calculations—critiques that mirror those in the peer-reviewed literature and by WHO researchers in their most recent calculations.³⁵⁴ These limitations include the following: (a) Calculations are based on single agents, ignoring the fact that individuals are exposed to a combination of multiple industrial carcinogens; (b) Attributable fractions do not account for synergistic effects that can intensify the impact of exposures; (c) Industrial carcinogens are more diverse and numerous than previously assessed; and (d) Cancer causation mechanisms include endocrine

disruption and epigenetic effects. In addition, there is a need to take account of exposure during key developmental periods of vulnerability, and to account for the effects of low doses.

Cancer data, including both incidence and mortality, are available in many countries throughout the world. As shown in Table 24, overall age-adjusted cancer rates for males and females in developed countries are significantly higher than those in the less developed world. Because cancer is a disease of long latency, chemical exposures that occur today may produce cancers decades later. As life expectancy increases among developing nations, rates of cancer are also expected to rise.³⁵⁵ By 2050, nearly two-thirds of incident cases of cancer are expected to occur in low-income countries.³⁵⁶ Examples of recent studies of chemicals associated with cancer in developing countries and those in economic transition are described in Box 3.

Table 24. Age-Adjusted Cancer Incidence (cases per 100,000), 2008

	Men	Women
More developed regions	299.2	226.3
Less developed regions	160.3	138.0
Specific countries/regions		
Eastern Africa	121.2	125.3
Middle Africa	88.1	96.7
Northern Africa	109.2	98.9
Southern Africa	235.9	161.1
Western Africa	92.0	123.5
Brazil	190.4	158.1
China	211.0	152.4
European Union (EU-27)	308.0	233.3
India	92.9	105.5
Indonesia	145.9	144.6
Japan	247.3	167.6
Russia	247.1	178.9
South Africa	254.8	170.1
United States	335.0	274.4

Source: International Agency for Research on Cancer. GLOBOCAN 2008. Available from <http://globocan.iarc.fr/>.

Box 3. Studies of Cancer Associated with Chemical Exposure: Examples from Developing Countries and Countries in Economic Transition

There is a vast literature on the links between chemical exposures and cancers. Many of the key studies have been conducted in developed countries; however, there is an expanding literature on developing countries despite the difficulty in conducting epidemiologic studies in many high-risk populations. This table provides a sampling of a few examples from developing countries and countries with economies in transition.

Country	Example
China	In Shanghai, researchers studying a cohort of female textile workers revealed that long-term exposure (20 years or longer) to chemical dye and dye intermediates resulted in nearly 4-fold elevation in colon cancer risk and a 2-fold elevation in rectal cancer risk. ³⁵⁷ In another study of female textile workers, investigators identified an elevated risk of nasopharyngeal cancer from exposure to dyes and inks as well as to bases and caustics. ³⁵⁸
Ecuador	In San Carlos, a small Amazonian village that has experienced significant ecological damage associated with oil extraction, researchers observed over a 2-fold higher than expected risk of cancer (all types) among males. The analysis of water used for drinking, washing, and bathing showed a severe exposure to total petroleum hydrocarbons by the residents, with samples ranging from 10 to 288 times higher than levels permitted by the European Community regulations. ³⁵⁹
India	In Kashmir, researchers observed more than a 10-fold risk of malignant brain tumors among individuals who worked as orchard farm workers or lived/played among the orchards and experienced high levels of exposure to multiple neurotoxic and carcinogenic pesticides for more than 10 years. ³⁶⁰

For a recent review of the literature see: Clapp, R.C., Jacobs, M., Loechler, E.L. (2008). "Environmental and occupational causes of cancer; new evidence 2005-2007". *Reviews on Environmental Health*, 23, 1-37

11.6.2.2 Reproductive and Developmental Disorders

Studies of reproductive effects have traditionally focused on the role of chemicals in causing infertility, premature death (including spontaneous abortion) or negative birth outcomes such as low birth weight or congenital malformations. These effects are the principal basis of knowledge and evidence used to classify chemicals as reproductive toxicants. As shown earlier in Table 20, there are 122 chemicals classified as "may" cause or "suspected" of causing reproductive toxicity based on the EU harmonized classification system. While there are many studies published on this topic, the following provide a few key example of chemicals associated with specific reproductive toxicant effects: pesticides such as 1,2-dibromo-3-chloropropane (DBCP) are associated with sterility³⁶¹ while other pesticides such as DDT have been linked to preterm birth;³⁶² phthalates such as dibutyl phthalate and DEHP are associated with reduced sperm count and motility;³⁶³ metals such as cadmium have also been linked to reduced sperm motility as well as to gynecological disorders such as endometriosis; perfluorinated chemicals such as perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA) have been linked to low birth weight and low body mass³⁶⁴ as well as reduced sperm count and quality;³⁶⁵ and solvents such as trichloroethylene have been strongly linked to congenital heart malformations.³⁶⁶ Examples of recent studies of chemicals associated with reproductive and developmental health effects in developing countries and those in economic transition are described in Box 4.

Box 4. Studies of Reproductive and Developmental Health Effects Associated with Chemicals: Examples from Developing Countries and Countries in Economic Transition

Conception, pregnancy and fetal and child development are complex processes that research has shown can be adversely affected by industrial chemicals. This table provides a sampling of a few examples from developing countries and countries with economies in transition.

Health Outcome	Country	Example
Reproductive effects	China	Reduced sperm concentration was significantly associated with the urine phthalate metabolite, monomethyl phthalate among a cohort of Chinese men from Chongqing exposed to phthalates in the general environment. ³⁷⁶
	China	In rural China, elevated placental concentrations of several persistent organic pollutants, including o,p'-DDT and metabolites, -HCH, and PAHs were associated with increased risks of neural tube defects. Strong associations were observed for exposure to PAHs—placental concentrations above the median were associated with a 4.52-fold increased risk for any neural tube defect. ³⁷⁷
	Sudan	In central Sudan, hospital- and community-based case control studies revealed a consistent and significant 2-fold elevated risk of perinatal mortality associated with pesticide exposure. The risk was over 3-fold among women engaged in farming. ³⁷⁸
Developmental Disorders	Mexico	A group of children exposed to high levels of pesticides in an agricultural area showed neurodevelopmental deficits (diminished short-term memory, hand-eye coordination, and drawing ability) compared with children living in otherwise similar communities but with low or no pesticide exposure. ³⁷⁹
	Ecuador	Ecuadorean school children whose mothers were exposed to organophosphates and other pesticides during pregnancy demonstrated visuospatial deficits compared with their unexposed peers. ³⁸⁰
	Ecuador	Families living in La Victoria are involved in producing ceramic roof tiles or ceramic objects glazed with lead salts made from melting batteries. Children as young as 6 years of age are engaged in the trade. A small study found very high blood levels in children aged 6-15 years (23 µg/dl to 124 µg/dl, with a mean of 70 µg/dl). Half of the children had repeated one or more years of school. ³⁸¹

Note: There is a vast literature on all these health endpoints, yet much of the evidence comes from developed countries; for a recent review of the literature see: Stillerman, K.P., Mattison, D.R., Giudice, L.C. et al. (2008). "Environmental exposures and adverse pregnancy outcomes: a review of the science." *Reproductive Sciences*, 15, 631-650.

There is extensive evidence that *in utero* exposure to various chemicals has adverse effects on fetal brain and neurological development, with lasting effects on intelligence and behavior.³⁶⁷ Chemicals including lead, methyl mercury, polychlorinated biphenyls, arsenic and toluene are recognized causes of neurodevelopmental disorders and subclinical brain dysfunction.³⁶⁸ Exposure to these chemicals during early fetal development can cause brain injury at doses much lower than those affecting adult brain function.³⁶⁹ A recent US National Academy of Sciences study concluded that 3 per cent of developmental disabilities among US children are the direct result of environmental exposure to chemicals while another 25 per cent arise through interactions between exposures in the environment and genetic susceptibility.³⁷⁰

One particular developmental toxicant that is of concern is lead. Recent research indicates that lead is associated with neurobehavioural damage at blood levels of 5 µg/dl and even lower—levels that were once considered safe.³⁷¹ The Joint FAO/WHO Expert Committee on Food Additives re-evaluated lead in June 2010 and withdrew the provisional tolerable weekly intake guideline value on the grounds that it was inadequate to protect against IQ loss.³⁷² Blood lead levels vary widely from country to country and region to region. Developed countries that have banned the use of lead

in gasoline and household paint have observed dramatic declines in blood lead levels, demonstrating the effectiveness of policy-level chemicals management interventions to improve population health.³⁷³ Today, the highest blood lead levels and the largest burden of disease from exposures to lead are seen in low-income countries, especially in areas where there are industrial uses of lead (such as smelters, mines, refineries or the informal/cottage industry sector) and/or where leaded gasoline is still used.³⁷⁴ Over all, WHO estimates that 98 per cent of adults and 99 per cent of children affected by exposure to lead live in developing countries and countries in economic transition.^{vi 375}

11.6.2.3 Cardiopulmonary Effects

Exposure to air pollutants has been linked to a range of cardiovascular and respiratory outcomes. Exposure can occur in the workplace or through ambient air pollution.

Industrial operations as well as mobile vehicles emit complex mixtures of air pollutants. Research suggests that exposure to fine particulate matter has the greatest effect on human health. Toxic, reactive and irritating chemicals such as acids, metals and nitrates can be adsorbed onto the surfaces of fine particles. These particles are carried deep into the lung as their size evades the defenses of the respiratory system. Most fine particulate matter comes from fuel combustion, both from mobile sources and from stationary sources such as power plants. Globally, approximately 5 per cent of cardiopulmonary deaths and 3 per cent of respiratory infection deaths are attributed to ambient air pollution.³⁸² Particulate matter is the most significant contributor to these effects, but other forms of chemical pollution play a role as well. The percentage of the overall effect that can be attributed to factors other than particulate matter is not known. Particulate matter pollution is an environmental health problem that affects people worldwide, but middle-income countries disproportionately experience this burden.³⁸³

Asthma. In the case of respiratory illnesses such as asthma, 57 chemicals with EU harmonized classifications have been classified as respiratory sensitizers (Table 20). However, organizations such as the Association of Occupational and Environmental Clinics have identified over a hundred industrial chemicals capable of causing asthma primarily as a result of occupational exposures, including a number of diisocyanates, acid anhydrides, formaldehyde, cleaning agents such as glutaraldehyde, and some organophosphate pesticides.³⁸⁴ Occupational asthma is the most common occupational lung disease in developed countries, and is the second most common occupational lung disease in developing countries.³⁸⁵ Globally, the median proportion of adult cases of asthma attributable to occupational exposure is between 10 per cent and 15 per cent.³⁸⁶ Moreover, these same irritant and allergenic chemicals are capable of exacerbating an individual's asthma that was originally caused by another host of factors.

Approximately 300 million people globally currently have asthma, and estimates suggest that asthma prevalence increases globally by 50 per cent every decade.³⁸⁷ The highest asthma prevalence rates are in developed countries. However, over 80 per cent of asthma deaths occur in low and lower-middle income countries.³⁸⁸ Moreover, some developing countries and countries in economic transition are experiencing sharp rises in asthma prevalence in parallel with increasing industrialization and urbanization. High prevalences have been reported in Peru, Costa Rica and Brazil.³⁸⁹ In Africa, South Africa has the highest asthma prevalence.³⁹⁰ The greatest burden in terms of increasing asthma prevalence worldwide is projected to occur in China and India, due to their population size and the rate of economic development with associated environmental and lifestyle changes.³⁹¹ As noted above, fine particulate matter resulting from fuel combustion at both mobile and stationary sources is the most significant contributor, while other forms of chemical pollution also play a role.

Other respiratory disorders. In addition to causing lung cancer, workplace exposure to microscopic airborne particles comprised of a range of chemicals (e.g., silica and asbestos) can cause chronic obstructive pulmonary disease (COPD), silicosis, asbestosis and pneumoconiosis. These diseases can take decades to develop, so even in countries where the risk has been recognized and controlled, reductions in disease burden has been slow.³⁹² In developing countries, trends are mostly unknown, but according to a recent WHO report, the problem is considered to be substantial.³⁹³

^{vi} These countries were defined as "low and middle income countries" in the WHO report.

As shown above in Table 23, WHO estimates suggest that occupational exposure to airborne particulates is estimated to cause 13 per cent of deaths due to COPD. Additionally, an estimated 29,000 deaths are due to silicosis, asbestosis and pneumoconiosis caused by silica, asbestos and coal dust exposure (Table 23).

Examples of recent studies examining cardiopulmonary effects in countries in economic transition are shown in Box 5.

**Box 5. Studies of Cardiopulmonary Health Effects Associated with Chemicals:
Examples of Studies in Developing Countries and Countries in Economic Transition**

Exposure to chemical air pollutants has been linked to a range of cardiovascular and respiratory outcomes that are significant contributors to morbidity and mortality globally. Both airborne chemicals in the workplace and pollutants in the general environment are of concern. The table below provides examples for a range of cardiopulmonary outcomes based on studies or surveillance programmes in developing countries or countries with economies in transition.

Health Outcome	Country	Example
Asthma	Brazil	17.8 per cent of occupational asthma cases reported between 1995 and 2000 to a joint registry from five public clinics in São Paulo were caused by isocyanates. ³⁹⁴
Asthma	South Africa	19.5 per cent of occupational asthma reported to the Surveillance of Work-related and Occupational Respiratory Diseases programme is caused by isocyanates. ³⁹⁵
Cardiovascular Disease	India	In New Delhi, the prevalence of hypertension—a significant risk factor of deleterious cardiovascular events—was nearly 4 times higher than prevalence in a control population from rural areas.
Cardiopulmonary	China	In Guangzhou, researchers demonstrated that exposure to ambient fine particulate matter was associated with cardiorespiratory diseases and increased mortality from all causes. ³⁹⁶
Asbestos-related pulmonary disease	India	Studies conducted by the Indian National Institute of Occupational Health have shown a high prevalence of asbestosis among workers employed in asbestos mining and milling, asbestos textile and asbestos cement industries. ³⁹⁷

12. Conclusion

As described in this report, developing countries and countries with economies in transition are home to an increasing share of global production and consumption of chemicals. Growth in chemical production and use has slowed in the developed countries that previously dominated the market, and has accelerated in countries with economies in transition. These countries with economies in transition are, increasingly, the drivers of global expansion in production and use of chemicals. These changes can be observed with regard to chemicals used in industry, chemicals used in agriculture, and chemicals that are incorporated into products.

Detailed data on waste are lacking due to the absence of pollution release and transfer registries in developing and transition countries. PRTRs data from OECD countries show that large amounts of chemical waste continue to be generated in those countries for which data are available; and a wide variety of studies demonstrate that chemical releases are a global problem. Examples include releases of pesticides, of heavy metals, and of a wide variety of industrial chemicals into air, water, and soil. Special categories of waste of particular concern in developing and transition countries include electronic waste, obsolete pesticide stocks, and pollution associated with mining activities.

The increasing production, use and disposal of chemicals have significant implications for the environment and human health. Effects on ecosystem resources include contamination of air, water, and soil, with adverse impacts on food sources and wildlife as well as human health effects. Wildlife effects range from loss of beneficial insects, including pollinators, to malformations and reproductive disorders in a wide variety of animals. Human health effects include acute poisonings as well as chronic diseases including cancer, reproductive and developmental disorders, and cardiopulmonary effects. As the health of populations in developing and countries in economic transition are increasingly affected by disease risk factors associated with industrialization, the burden of disease and disability associated with exposure to toxic chemicals in these regions is likely to continue to climb.

In this context, it is necessary to consider policy approaches to ensure that chemicals are produced and used in ways that minimize impacts on health and the environment. Each of the three distinct aspects of the growing presence of chemicals in developing countries and countries with economies in transition – chemicals in industry, in agriculture, and in products – presents its own set of challenges for sound management of chemicals.

SAICM and the multilateral environmental agreements now provide a broad framework for promoting the sound management of chemicals, including pollution prevention and adoption of safer alternatives, and many countries have developed a range of legal, economic, technical and voluntary instruments and approaches for managing chemicals. Many multinational firms and NGOs also have developed new methods and tools to assist in these efforts. More work still needs to be done by governments and corporations to develop comprehensive policies that address chemical management across chemical and product life cycles. Furthermore, there is a need for additional investment in the resources needed for sound chemicals management in developing countries and countries with economies in transition. These needs are discussed in detail in Chapter II and Chapter III of the Global Chemicals Outlook.

Endnotes

- ¹ Organisation for Economic Cooperation and Development (2001). *OECD Environmental Outlook for the Chemicals Industry*. Paris: OECD
- ² United Nations Environment Programme, Strategic Approach to International Chemicals Management (2009). *Report of the International Conference on Chemicals Management on the Work of its Second Session*. Available from <http://www.saicm.org/documents/iccm/ICCM2/Meeting%20Report/ICCM2%20report%20advance%20Eng%2023%20Jun%2009.doc>.
- ³ American Chemistry Council (2011). *2011 Guide to the Business of Chemistry*. Washington: ACC.
- ⁴ American Chemistry Council (2011). *2011 Guide to the Business of Chemistry*. Washington: ACC.
- ⁵ American Chemistry Council (2011). *2011 Guide to the Business of Chemistry*. Washington: ACC.
- ⁶ American Chemistry Council (2011). *2011 Guide to the Business of Chemistry*. Washington: ACC. Page 38.
- ⁷ American Chemistry Council (2011). *2011 Guide to the Business of Chemistry*. Washington: ACC. Page 6.
- ⁸ As defined under REACH, an article is “an object which during production is given a special shape, surface or design which determines its function to a greater degree than its chemical composition.” Registration, Evaluation, and Authorization of Chemicals (REACH), Title 1, Chapter 2, Article 3: Definitions. Available via REACHOnline at http://www.reachonline.eu/REACH/EN/REACH_EN/article3.html.
- ⁹ European Chemical Agency (ECHA) *List of Pre-Registered Substances*. Available from <http://apps.echa.europa.eu/preregistered/pre-registered-sub.aspx>. Helen McCarthy (European Commission), personal communication, 21 December, 2011.
- ¹⁰ United States Government Accountability Office (GAO) (2009). *Chemical Regulation: Observations on Improving the Toxic Substances Control Act*. Testimony before the Committee on Environment and Public Works, US Senate. Available from <http://www.gao.gov/assets/130/123792.pdf>.
- ¹¹ Organisation for Economic Development (OECD) (2001). *OECD Environmental Outlook for the Chemicals Industry*. Available from <http://www.oecd.org/env/chemicalsafetyandbiosafety/2375538.pdf>. OECD drew these figures from a 1999 report by the Chemical Manufacturers’ Association.
- ¹² American Chemistry Council (2011). *2011 Guide to the Business of Chemistry* (ACC, 2011), Table 4.1, page 44.
- ¹³ American Chemistry Council (2009). *2011 Guide to the Business of Chemistry* (ACC, 2011), Table 4.8, page 51. ACC developed these figures using 2007 as its reference year.
- ¹⁴ American Chemistry Council (2009). *2011 Guide to the Business of Chemistry* (ACC, 2011), Table 4.8, page 51.
- ¹⁵ The European Chemical Industry Council (CEFIC) (2011). *Facts and Figures 2011*. The European Chemical Industry in a Worldwide Perspective, page 5. Available from <http://www.cefic.org/Facts-and-Figures/>. Figures converted from Euros to dollars using the following conversion: 1 Euro = 1.32 dollars in December 2010.
- ¹⁶ The European Chemical Industry Council (CEFIC) (2011). *Facts and Figures 2011*. The European Chemical Industry in a Worldwide Perspective. Available from <http://www.cefic.org/Facts-and-Figures/>.
- ¹⁷ Organisation for Economic Development (OECD) (2012). *OECD Environmental Outlook to 2050: The Consequences of Inaction*. Paris.
- ¹⁸ The European Chemical Industry Council (CEFIC) (2011). *Facts and Figures 2011*. The European Chemical Industry in a Worldwide Perspective. Available from <http://www.cefic.org/Facts-and-Figures/>.
- ¹⁹ Hotter, L.H. (2004). Integrated chemical management: dream or reality in the developing world? *UNEP Industry and Environment*, April, 19-21.

- ²⁰ Hotter, L.H. (2004). Integrated chemical management: dream or reality in the developing world? *UNEP Industry and Environment*, April, 19-21.
- ²¹ Manda, N., Mohamed-Katerere J. (2006). *Africa Environment Outlook 2: Our Environment, Our Wealth*. Chapter 11: Chemicals. United Nations Environment Programme, 2006. Available from <http://www.unep.org/dewa/Africa/publications/AEO-2/content/index.htm>.
- ²² Organisation for Economic Cooperation and Development (2001). *OECD Environmental Outlook for the Chemicals Industry*.
- ²³ Organisation for Economic Development (OECD) (2012). *OECD Environmental Outlook to 2050: The Consequences of Inaction*. Paris.
- ²⁴ Organisation for Economic Cooperation and Development (2001). *OECD Environmental Outlook for the Chemicals Industry*.
- ²⁵ Organisation for Economic Development (OECD) (2012). *OECD Environmental Outlook to 2050: The Consequences of Inaction*. Paris.
- ²⁶ Swift, T.K., Gilchrist Moore, M., Bhatia, S. et al. (2011). *Mid-Year 2011 Situation & Outlook*. American Chemistry Council.
- ²⁷ Swift, T.K., Gilchrist Moore, M., Bhatia, S. et al. (2011). *Mid-Year 2011 Situation & Outlook*. American Chemistry Council.
- ²⁸ Swift, T.K., Gilchrist Moore, M., Bhatia, S. et al. (2011). *Mid-Year 2011 Situation & Outlook*. American Chemistry Council.
- ²⁹ Swift, T.K., Gilchrist Moore, M., Bhatia, S. et al. (2011). *Mid-Year 2011 Situation & Outlook*. American Chemistry Council.
- ³⁰ Swift, T.K., Gilchrist Moore, M., Bhatia, S. et al. (2011). *Mid-Year 2011 Situation & Outlook*. American Chemistry Council.
- ³¹ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ³² Organisation for Economic Co-operation and Development (2010). *Emissions Scenario Document for Chemicals Used in the Electronics Industry*. Series on Emission Scenario Documents No.25. Available from <http://www.oecd.org/dataoecd/39/3/46021581.pdf>. Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord.
- ³³ Beall, C., Bender, T.J., Cheng, H. et al. (2005). Mortality among semiconductor and storage device-manufacturing workers. *Journal of Occupational and Environmental Medicine*, 47, 996-1014. Clapp, R.W. (2006). Mortality among US Employees of a Large Computer Manufacturing Company: 1969-2001. *Environmental Health*, 5: 30. Available from <http://www.ehjournal.net/content/5/1/30>. Lin, C.C., Wang, J.D., Hsieh, G.Y., Chang, Y.Y., Chen, P.C. (2008). Increased risk of death with congenital anomalies in the offspring of male semiconductor workers, *International Journal of Occupational and Environmental Health* 14:112-116. 15. LaDou, J., Bailar, J.C. 3rd. (2007). Cancer and reproductive risks in the semiconductor industry, *International Journal of Occupational and Environmental Health* 13:376-385
- ³⁴ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ³⁵ BCC Research (January 2011). *Electronic Chemicals and Materials: The Global Market*. Available from <http://www.bccresearch.com/report/electronic-chemicals-materials-smc043b.html#>. ³⁶ Hackett, M., Funada, C., Inoguchi, Y. et al. (June 2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.

- ³⁷ BCC Research (2011). *Electronic Chemicals and Materials: The Global Market*. Available from <http://www.bccresearch.com/report/electronic-chemicals-materials-smc043b.html#>. Hackett, M., Funada, C., Inoguchi, Y. et al. (June 2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ³⁸ BCC Research (2011). *Electronic Chemicals and Materials: The Global Market*. Available from <http://www.bccresearch.com/report/electronic-chemicals-materials-smc043b.html#>.
- ³⁹ Hackett, M., Funada, C., Inoguchi, Y. et al. (2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ⁴⁰ United Nations Environment Programme, DTIE/Chemicals Branch (2011). *The Chemicals in Products Project: Case Study of the Textiles Sector*. Available from http://www.chem.unep.ch/unepsaicm/cip/Documents/CaseStudies/CiP%20textile%20case%20study%20report_21Feb2011.pdf.
- ⁴¹ The Freedonia Group (2008). *World Textile Chemicals: Industry Study with Forecasts to 2012 and 2017*.
- ⁴² Hackett, M., Funada, C., Inoguchi, Y. et al. (2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ⁴³ Hackett, M., Funada, C., Inoguchi, Y. et al. (2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ⁴⁴ Hackett, M., Funada, C., Inoguchi, Y. et al. (2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ⁴⁵ Hackett, M., Funada, C., Inoguchi, Y. et al. (2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ⁴⁶ Hackett, M., Funada, C., Inoguchi, Y. et al. (2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ⁴⁷ Hackett, M., Funada, C., Inoguchi, Y. et al. (2011). *Overview of the Specialty Chemicals Industry*. SRI Consulting.
- ⁴⁸ US Geological Survey (2011). *Mineral Commodity Summaries*. US Department of Interior. Available from <http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf>.
- ⁴⁹ US Geological Survey (2011). *Mineral Commodity Summaries*. US Department of Interior. Available from <http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf>.
- ⁵⁰ The Freedonia Group (2010). *World Cement: Industry Study with Forecasts for 2013 and 2018*.
- ⁵¹ The Freedonia Group (2010). *World Cement: Industry Study with Forecasts for 2013 and 2018*.
- ⁵² The Freedonia Group (2010). *World Cement: Industry Study with Forecasts for 2013 and 2018*.
- ⁵³ Organisation for Economic Cooperation and Development (2001). *OECD Environmental Outlook for the Chemicals Industry*.
- ⁵⁴ Devanney, M. T. (2011). *Chemical Economics Handbook Marketing Research Report: Ethylene*. SRI Consulting.
- ⁵⁵ Will, R.K. (2009). *Chemical Economics Handbook Marketing Research Report: Fluorspar and Inorganic Fluorine Compounds*. SRI Consulting.
- ⁵⁶ Rothman, D.S. (1998). *Environmental Kuznets curves – real progress or passing the buck? A case for consumption based approaches*. *Ecological Economics*. 25, 177-194.
- ⁵⁷ Organisation for Economic Cooperation and Development (2001). *OECD Environmental Outlook for the Chemicals Industry*.
- ⁵⁸ Kiriya, N. (2010). *Trade and Innovation: Report on the Chemicals Sector*. OECD Trade Policy Working Papers, No. 103.
- ⁵⁹ Royal Society of Chemistry (2009). 2009 marks the start of the great divide. *Chemistry World*.
- ⁶⁰ Governing Council of the United Nations Environment Programme (2009). *Financing the Chemicals and Wastes Agenda* (Document presented at the Eleventh Special Session of the Governing Council/Global Ministerial Environment Forum, Bali, 24-26 February, 2010).

- ⁶¹ Davis, S. (2011). *Chemical Economics Handbook Product Review: Petrochemical Industry Overview*. SRI Consulting.
- ⁶² Guillermo, S.A. (2011). *Chemical Economics Handbook Marketing Research Report: Methanol*. SRI Consulting.
- ⁶³ For many chemicals, the *Chemical Economics Handbook* provides both “consumption” and “apparent consumption” figures. Where available, this table shows “consumption” figures. For methanol and ethylene, it shows “apparent consumption” because “consumption” figures are unavailable.
- ⁶⁴ Guillermo, S.A. (2011). *Chemical Economics Handbook Marketing Research Report: Methanol*. SRI Consulting.
- ⁶⁵ Devanney, M.T. (2011). *Chemical Economics Handbook Marketing Research Report: Ethylene*. SRI Consulting.
- ⁶⁶ Giacobbe, G.B. (2011). *Chemical Economics Handbook Marketing Research Report: Propylene*. SRI Consulting.
- ⁶⁷ Davis, S. (2009). *Chemical Economics Handbook: Butadiene*. SRI Consulting.
- ⁶⁸ Guillermo, S.A. and Yoneyyama, M. (September 2010). *Chemical Economics Handbook Marketing Research Report: Xylenes*. SRI Consulting.
- ⁶⁹ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.
- ⁷⁰ Davis, S. and Yoneyyama, M. (February 2010). *Chemical Economics Handbook Marketing Research Report: Toluene*. SRI Consulting.
- ⁷¹ Guillermo, S.A. (2011). *Chemical Economics Handbook Marketing Research Report: Methanol*. SRI Consulting.
- ⁷² Data include the Caribbean.
- ⁷³ Devanney, M.T. (2011). *Chemical Economics Handbook Marketing Research Report: Ethylene*. SRI Consulting.
- ⁷⁴ Giacobbe, G.B. (2011). *Chemical Economics Handbook Marketing Research Report: Propylene*. SRI Consulting.
- ⁷⁵ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Butadiene*. SRI Consulting.
- ⁷⁶ Data include Argentina, Brazil, Chile and Venezuela.
- ⁷⁷ Guillermo, S.A. and Yoneyyama, M. (September 2010). *Chemical Economics Handbook Marketing Research Report: Xylenes*. SRI Consulting.
- ⁷⁸ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.
- ⁷⁹ Data include Iran, Iraq, Israel, Qatar, Saudia Arabia and Turkey.
- ⁸⁰ Data include Argentina, Brazil, Chile, Colombia and Venezuela.
- ⁸¹ Data include India, Indonesia, Malaysia, Singapore, Thailand and other Southeast Asian countries.
- ⁸² Davis, S. and Yoneyyama, M. (February 2010). *Chemical Economics Handbook Marketing Research Report: Toluene*. SRI Consulting.
- ⁸³ Data include Indonesia, Malaysia, the Philippines and Singapore.
- ⁸⁴ These figures represent “actual consumption,” not “apparent consumption.” Davis, S. (May 2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.
- ⁸⁵ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.
- ⁸⁶ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.
- ⁸⁷ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.
- ⁸⁸ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.
- ⁸⁹ Davis, S. (2009). *Chemical Economics Handbook Marketing Research Report: Benzene*. SRI Consulting.

- ⁹⁰ International Agency for Research on Cancer (IARC). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Agents Classified by the IARC Monographs, Volumes 1-102, Available from <http://monographs.iarc.fr/ENG/Classification/index.php>,
- ⁹¹ Suresh, B. (2009). *Chemical Economics Handbook Marketing Research Report: Sulfuric Acid*. SRI Consulting. Updated figures for 2010 provided by Bala Suresh, personal communication, November 23, 2011.
- ⁹² Schlag, S. and Funada, C. (2009). *Chemical Economics Handbook Marketing Research Report: Lime/Limestone*. SRI Consulting.
- ⁹³ Suresh, B. (2009). *Chemical Economics Handbook Marketing Research Report: Sulfuric Acid*. SRI Consulting. Updated figures for 2010 provided by Bala Suresh, personal communication, November 23, 2011.
- ⁹⁴ Glauser, J. and Kumamoto, T. (2010). *Chemical Economics Handbook Marketing Research Report: Ammonia*. SRI Consulting.
- ⁹⁵ Suresh, B. (2009). *Chemical Economics Handbook Marketing Research Report: Sulfur*. SRI Consulting. Updated figures for 2010 provided by Bala Suresh, personal communication, November 23, 2011.
- ⁹⁶ Schlag, S. (2010). *Chemical Economics Handbook Marketing Research Report: Wet-Process Phosphoric Acid*. SRI Consulting.
- ⁹⁷ The first chemicals listed as POPs under the Stockholm Convention were aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, PCBs, and polychlorinated dibenzo-p-furans and polychlorinated dibenzofurans (PCDD/PCDF). Additional chemicals were added to the list more recently: alpha-hexachlorocyclohexane; beta hexachlorocyclohexane; chlordecone; technical endosulfan and its related isomers; hexabromobiphenyl; hexabromodiphenyl ether and heptabromodiphenyl ether (commercial octabromodiphenyl ether); lindane; pentachlorobenzene; perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride; and tetrabromodiphenyl ether and pentabromodiphenyl ether (commercial pentabromodiphenyl ether). See <http://chm.pops.int/Implementation/NewPOPs/TheNewPOPs/tabid/672/Default.aspx> for information on the new POPs.
- ⁹⁸ Beal, M. and Linak, M. (2011). *Chemical Economics Handbook Marketing Research Report: Chlorine/Sodium Hydroxide*. SRI Consulting.
- ⁹⁹ Glauser, J. (2009). *Chemical Economics Handbook Marketing Research Report: Bromine*. SRI Consulting.
- ¹⁰⁰ Will, R.K. (2009). *Chemical Economics Handbook Marketing Research Report: Fluorspar and Inorganic Fluorine Compounds*. SRI Consulting.
- ¹⁰¹ Beal, M. and Linak, M. (2011). *Chemical Economics Handbook Marketing Research Report: Chlorine/Sodium Hydroxide*. SRI Consulting.
- ¹⁰² Glauser, J. (2009). *Chemical Economics Handbook Marketing Research Report: Bromine*. SRI Consulting.
- ¹⁰³ Will, R.K. (2009). *Chemical Economics Handbook Marketing Research Report: Fluorspar and Inorganic Fluorine Compounds*. SRI Consulting.
- ¹⁰⁴ Linak, E. (2009). *Chemical Economics Handbook Product Review: Vinyl Chloride Monomer*. SRI Consulting.
- ¹⁰⁵ Glauser, J. and Ishikawa, Y. (2008). *Chemical Economics Handbook Marketing Research Report: C₂ Chlorinated Solvents*. SRI Consulting.
- ¹⁰⁶ Rosenthal, E. and Wiser, G. (2008). Thought starter: International transport of lead and cadmium via trade: an international concern? Center for International Environmental Law. *Intergovernmental Forum on Chemical Safety Sixth Session – Forum VI*. Dakar, Senegal. Available from http://www.ciel.org/Publications/PbCd_ThoughtStarter_Mar08.pdf.
- ¹⁰⁷ European Commission, Directorate General for Environment. (February 2004). *Mercury Flows in Europe and the World: The Impact of Decommissioned Chlor-Alkali Plants*. Available from <http://ec.europa.eu/environment/chemicals/mercury/pdf/report.pdf>.

- ¹⁰⁸ Guberman, D.E. (2011). *2009 Minerals Yearbook: Lead*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/lead/myb1-2009-lead.pdf>.
- ¹⁰⁹ International Lead and Zinc Study Group. Lead and Zinc Statistics: World Refined Lead Supply and Usage 2006 – 2011. Available from <http://www.ilzsg.org/static/statistics.aspx?from=2>.
- ¹¹⁰ Smith G.R. and Guberman, D.E. (2011). Lead. *Mineral Commodity Summaries*. US Geological Survey. 90-91. Available from <http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf>.
- ¹¹¹ Guberman, D.E. (2011). *2009 Minerals Yearbook: Lead*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/lead/myb1-2009-lead.pdf>.
- ¹¹² Guberman, D.E. (2011). *2009 Minerals Yearbook: Lead*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/lead/myb1-2009-lead.pdf>.
- ¹¹³ Guberman, D.E. (2011). *2009 Minerals Yearbook: Lead*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/lead/myb1-2009-lead.pdf>.
- ¹¹⁴ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf.
- ¹¹⁵ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf.
- ¹¹⁶ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf.
- ¹¹⁷ Brooks, W.E. (2010). *2009 Minerals Yearbook: Mercury*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/myb1-2009-mercu.pdf>.
- ¹¹⁸ European Commission, Directorate General for Environment (2004). *Mercury Flows in Europe and the World: The Impact of Decommissioned Chlor-Alkali Plants*. Available from <http://ec.europa.eu/environment/chemicals/mercury/pdf/report.pdf>.
- ¹¹⁹ Brooks, W.E. (2010). *2009 Minerals Yearbook: Mercury*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/myb1-2009-mercu.pdf>.
- ¹²⁰ Brooks, W.E. (2010). *2009 Minerals Yearbook: Mercury*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/myb1-2009-mercu.pdf>.
- ¹²¹ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf. Consumption data are summarized in Table 3.4, pages 20-21.
- ¹²² Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf. Consumption data are summarized in Table 3.4, pages 20-21.
- ¹²³ Brooks, W.E. (2010). *2009 Minerals Yearbook: Mercury*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/myb1-2009-mercu.pdf>.

- ¹²⁴ European Commission, Directorate General for Environment (2004). *Mercury Flows in Europe and the World: The Impact of Decommissioned Chlor-Alkali Plants*. Available from <http://ec.europa.eu/environment/chemicals/mercury/pdf/report.pdf>.
- ¹²⁵ Brooks, W.E. (2010). *2009 Minerals Yearbook: Mercury*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/myb1-2009-mercu.pdf>.
- ¹²⁶ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf. Projected consumption figures for 2020 are summarized in Tables 4.3–4.5, pages 59-60.
- ¹²⁷ US Geological Survey (2011). Cadmium. *Mineral Commodity Summaries*. 36-37. Available from <http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf>.
- ¹²⁸ United Nations Environment Programme, Chemicals Branch (2010). *Final Review of Scientific Information on Cadmium*. Available from http://www.unep.org/hazardoussubstances/Portals/9/Lead_Cadmium/docs/Interim_reviews/UNEP_GC26_INF_11_Add_2_Final_UNEP_Cadmium_review_and_appendix_Dec_2010.pdf.
- ¹²⁹ United Nations Environment Programme, Chemicals Branch (2010). *Final Review of Scientific Information on Cadmium*. Available from http://www.unep.org/hazardoussubstances/Portals/9/Lead_Cadmium/docs/Interim_reviews/UNEP_GC26_INF_11_Add_2_Final_UNEP_Cadmium_review_and_appendix_Dec_2010.pdf.
- ¹³⁰ US Geological Survey (2011). Cadmium. *Mineral Commodity Summaries*. 36-37. Available from <http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf>.
- ¹³¹ Tolcin, A.C. (2011). *2010 Minerals Yearbook: Cadmium*. US Geological Survey.
- ¹³² Tolcin, A.C. (2011). *2010 Minerals Yearbook: Cadmium*. US Geological Survey.
- ¹³³ United Nations Environment Programme, Chemicals Branch (2010). *Final Review of Scientific Information on Cadmium*. Available from http://www.unep.org/hazardoussubstances/Portals/9/Lead_Cadmium/docs/Interim_reviews/UNEP_GC26_INF_11_Add_2_Final_UNEP_Cadmium_review_and_appendix_Dec_2010.pdf.
- ¹³⁴ United Nations Environment Programme, Chemicals Branch (2010). *Final Review of Scientific Information on Cadmium*. Available from http://www.unep.org/hazardoussubstances/Portals/9/Lead_Cadmium/docs/Interim_reviews/UNEP_GC26_INF_11_Add_2_Final_UNEP_Cadmium_review_and_appendix_Dec_2010.pdf.
- ¹³⁵ US Geological Survey (2011). Aluminum. *Mineral Commodity Summaries*. 16-17. Available from <http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf>.
- ¹³⁶ US Geological Survey (2011). Nickel. *Mineral Commodity Summaries*. 108-109. Available from <http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcs2011.pdf>.
- ¹³⁷ Brooks, W.E. (2011). *2010 Minerals Yearbook: Arsenic*. US Geological Survey.
- ¹³⁸ Brooks, W.E. (2011). *2010 Minerals Yearbook: Arsenic*. US Geological Survey.
- ¹³⁹ World Health Organization. Health Topics: Arsenic. Available from <http://www.who.int/topics/arsenic/en/>.
- ¹⁴⁰ Paul, J. and Campbell, C. (2011). *Investigating Rare Earth Element Mine Development in EPA Region 8 and Potential Environmental Impacts*. United States Environmental Protection Agency. Available from <http://www.epa.gov/region8/mining/ReportOnRareEarthElements.pdf>.
- ¹⁴¹ US Geological Survey (2011). Asbestos Statistics and Information. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/asbestos/>.
- ¹⁴² Chrysotile Institute (2011). Overview: Chrysotile and Asbestos Amphiboles: Two Different Fibre Types. Available from <http://www.chrysotile.com/en/chrysotile/overview/default.aspx>.

- ¹⁴³ International Agency for Research on Cancer (IARC). Agents Classified by the *IARC Monographs*, Volumes 1-102. Available from <http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf>.
- ¹⁴⁴ Virta, R.L. (August 2011). *2010 Minerals Yearbook: Asbestos*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/asbestos/myb1-2010-asbes.pdf>.
- ¹⁴⁵ US Geological Survey. Asbestos Statistics and Information (2011). Available from <http://minerals.usgs.gov/minerals/pubs/commodity/asbestos/>. Per cent change calculated using figures in the yearly Mineral Commodity Summaries.
- ¹⁴⁶ United Nations Commodity Trade Statistics Database (UN Comtrade) (2011). Available from <http://comtrade.un.org/db/ce/ceSnapshot.aspx?px=H2&cc=2524>.
- ¹⁴⁷ United Nations Commodity Trade Statistics Database (UN Comtrade) (2011). Available from <http://comtrade.un.org/db/ce/ceSnapshot.aspx?cc=2524&px=HS&y=2009&rg=1>.
- ¹⁴⁸ United Nations Commodity Trade Statistics Database (UN Comtrade) (2011). Available from <http://comtrade.un.org/db/dqBasicQueryResults.aspx?px=H2&cc=2524&y=2009>. Search terms: Selected classification: HS2002; Selected commodities: 2524 (Asbestos); Selected reporters: All; Selected years: 2009; Selected partners: All; Selected trade flows: All.”
- ¹⁴⁹ World Health Organization (2010). Asbestos: Elimination of Asbestos-Related Diseases. Fact Sheet No. 343. Available from <http://www.who.int/mediacentre/factsheets/fs343/en/index.html>.
- ¹⁵⁰ World Health Organization (2006) Elimination of Asbestos-Related Diseases. Geneva: World Health Organization. Available from http://whqlibdoc.who.int/hq/2006/WHO_SDE_OEH_06.03_eng.pdf.
- ¹⁵¹ Burki, T. (2010) Health Experts Concerned over India’s Asbestos Industry. *The Lancet* 375:9715, 626-627.
- ¹⁵² Food and Agriculture Organization of the United Nations (2010). *Current World Fertilizer Trends and Outlook to 2014*.
- ¹⁵³ Croplife International (2010). *Facts and Figures: The Status of Global Agriculture*. Available from [http://www.croplife.org/files/documentspublished/1/en-us/PUB-BR/5743_PUB-BR_2010_11_23_Facts_and_figures_-_The_status_of_global_agriculture_\(2010\).pdf](http://www.croplife.org/files/documentspublished/1/en-us/PUB-BR/5743_PUB-BR_2010_11_23_Facts_and_figures_-_The_status_of_global_agriculture_(2010).pdf).
- ¹⁵⁴ Freedonia Group (2010). *World Pesticides to 2014 - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders*. Study #2664.
- ¹⁵⁵ Freedonia Group (2010). *World Pesticides to 2014 - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders*. Study #2664.
- ¹⁵⁶ Food and Agriculture Organization of the United Nations. *FAOSTAT* (online database). Available from <http://faostat.fao.org/site/424/default.aspx#ancor>.
- ¹⁵⁷ Marash, S., Gubler, R., Yagi, K. (2002). *Chemical Economics Handbook Marketing Research Report: Herbicides*. SRI Consulting.
- ¹⁵⁸ International Service for the Acquisition of Agri-Biotech Applications (ISAAA) (2010). *Global Status of Commercialized Biotech/GM Crops: 2010*.
- ¹⁵⁹ Benbrook, C. (2009). *Impacts of Genetically Engineered Crops on Pesticide Use: The First Thirteen Years*. The Organic Center.
- ¹⁶⁰ Marash, S., Gubler, R., Yagi, K. (2002). *Chemical Economics Handbook Marketing Research Report: Herbicides*. SRI Consulting.
- ¹⁶¹ Calderoni, P. (2000). *Chemical Economics Handbook Marketing Research Report: Pesticide Industry Overview*. SRI Consulting.

- ¹⁶² Marash, S., Sesto, B., Yokose, K. (2003). *Chemical Economics Handbook Marketing Research Report: Fungicides*. SRI Consulting.
- ¹⁶³ Freedonia Group (2010). *World Pesticides to 2014 -- Demand and Sales Forecasts, Market Share, Market Size, Market Leaders*. Study #2664. Note: data from Table: *Africa/Mideast: Pesticide Demand by Type (million dollars), 1999-2019*. Available for purchase at <http://www.freedoniagroup.com/World-Pesticides.html>.
- ¹⁶⁴ Freedonia Group (2010). *World Pesticides to 2014 -- Demand and Sales Forecasts, Market Share, Market Size, Market Leaders*. Study #2664. Note: data from Table: *Africa/Mideast: Pesticide Demand by Type (million dollars), 1999-2019*. Available for purchase at <http://www.freedoniagroup.com/World-Pesticides.html>.
- ¹⁶⁵ Freedonia Group (2010). *World Pesticides to 2014 -- Demand and Sales Forecasts, Market Share, Market Size, Market Leaders*. Study #2664. Note: data from Table: *Africa/Mideast: Pesticide Demand by Type (million dollars), 1999-2019*. Available for purchase at <http://www.freedoniagroup.com/World-Pesticides.html>.
- ¹⁶⁶ Pesticide Action Network Asia Pacific (2010). *Communities in Peril: Global Report on Health Impacts of Pesticides Use in Agriculture*. Available from <http://www.pan-uk.org/publications/communities-in-peril>.
- ¹⁶⁷ Zhang W.J., Jiang F.B., Ou J.F. (2011). Global pesticides consumption and pollution: with China as a focus. *Proceedings of the International Academy of Ecology and Environmental Sciences*, 1, 125-144. Available from <http://www.iaees.org/publications/journals/piaees/articles/2011-1%282%29/Global-pesticide-consumption-pollution.pdf>.
- ¹⁶⁸ Freedonia Group (2010). *World Pesticides to 2014 -- Demand and Sales Forecasts, Market Share, Market Size, Market Leaders*. Study #2664. Note: data from Table: *South Africa: Pesticide Demand by Type, 1999-2019*. Available for purchase at <http://www.freedoniagroup.com/World-Pesticides.html>.
- ¹⁶⁹ American Chemistry Council (2009). *2009 Guide to the Business of Chemistry*.
- ¹⁷⁰ Procter and Gamble (P&G) statement on APEC meeting, *APEC Represents 'Huge Growth Opportunity'*, November 7, 2011. RSS feed from PG.com.
- ¹⁷¹ As defined under REACH, an article is "an object which during production is given a special shape, surface or design which determines its function to a greater degree than its chemical composition."
- ¹⁷² Massey, R., Becker, M., Hutchins J. (2008). *Toxic Substances in Articles: The Need for Information*. Swedish Chemicals Agency. United Nations Environment Programme, DTIE/Chemicals Branch (January 2011). *The Chemicals in Products Project: Case Study of the Textiles Sector*. Available from http://www.chem.unep.ch/unepsaicm/cip/Documents/CaseStudies/CIP%20textile%20case%20study%20report_21Feb2011.pdf. Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>. Wilt, C.A., Monaco, J.K., Geibig, J.R. et al. (February 2011). *Identification and Analysis of Product/Chemicals Exchange Information within the Building Product Sector*. Center for Clean Products. Available from http://www.chem.unep.ch/unepsaicm/cip/Documents/CaseStudies/UNEP%20Case%20Study%20on%20CiP%20in%20Building%20Products_Merged.pdf. Dannwolf, U., Ulmer, F., Cooper, J. et al. (February 2011). *Chemicals in Products: Toys Sector Case Study for UNEP*. Dialogic and Dekra. Available from http://www.chem.unep.ch/unepsaicm/cip/Documents/CaseStudies/UNEP%20CiP_Toys%20case%20study_Final%20report%202.pdf.
- ¹⁷³ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ¹⁷⁴ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.

- ¹⁷⁵ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ¹⁷⁶ Rosenthal, E. and Wiser, G. (September 15-19). Thought starter: International transport of lead and cadmium via trade: an international concern? Center for International Environmental Law. *Intergovernmental Forum on Chemical Safety Sixth Session – Forum VI*. Dakar, Senegal. Available from http://www.ciel.org/Publications/PbCd_ThoughtStarter_Mar08.pdf.
- ¹⁷⁷ Massey, R., Becker, M., Hutchins J. (2008). *Toxic Substances in Articles: The Need for Information*. Swedish Chemicals Agency.
- ¹⁷⁸ European Commission, Institute for Health and Consumer Protection, Toxicology and Chemical Substance, European Chemicals Bureau (2008). BIS (2-ETHYLHEXYL) PHTHALATE (DEHP), Summary Risk Assessment Report. Available from http://ecb.jrc.ec.europa.eu/documents/Existing-Chemicals/RISK_ASSESSMENT/SUMMARY/dehpsum042.pdf.
- ¹⁷⁹ Swedish Chemicals Agency (2011). *Antibakteriella ämnen läcker från kläder vid tvätt*. Sundyberg: Swedish Chemicals Agency. Available from http://www.kemi.se/Documents/Publikationer/Trycksaker/PM/PM4_11.pdf.
- ¹⁸⁰ Dunagan S.C. et al. (2011). Toxics use reduction in the home: lessons learned from household exposure studies. *Journal of Cleaner Production* 19:5, 438-444.
- ¹⁸¹ Zota, R.A. et al. (2008). Elevated house dust and serum concentrations of PBDEs in California: unintended consequences of furniture flammability standards? *Environmental Science and Technology* 42:21, 8158–8164.
- ¹⁸² Grandjean, P. and Landrigan, P.J. (2006). Developmental neurotoxicity of industrial chemicals. *Lancet*. 368, 2167-2178. European Chemical Substance Information System. Table 3.1 Available from <http://esis.jrc.ec.europa.eu/index.php?PGM=cla>. United Nations Environment Programme (UNEP) (August 2008). “UNEP-WHO Guidance Document on Identifying Populations at Risk from Mercury Exposure.” Available from <http://www.unep.org/hazardoussubstances/Mercury/MercuryPublications/GuidanceTrainingmaterialToolkits/GuidanceforIdentifyingPopulationsatRisk/tabid/3616/language/en-US/Default.aspx>.
- ¹⁸³ See for example, Idaho Department of Environmental Quality (2008). Mercury Switches in Automobiles: Information for the Auto Services Sector. Available from http://www.deq.state.id.us/multimedia_assistance/auto_repair_shops/mercury_switches_autos_fs.pdf on Sept. 24.
- ¹⁸⁴ International Agency for Research on Cancer. Agents Classified by the IARC Monographs Volumes, 1-102. Available from <http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf>.
- ¹⁸⁵ Swedish Chemicals Agency (2003). *HA Oils in Automotive Tyres: Prospects of a National Ban*.
- ¹⁸⁶ Grandjean, P. and Landrigan, P.J. (2006). Developmental neurotoxicity of industrial chemicals. *Lancet*. 368, 2167-2178. European Chemical Substance Information System. Table 3.1 Available from <http://esis.jrc.ec.europa.eu/index.php?PGM=cla>. US Agency for Toxic Substances and Disease Registry. (August 2007) “ToxFAQs™ for Lead. Available from <http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=93&tid=22>.
- ¹⁸⁷ Bleiwas, D.I. (2006). *Stocks and Flows of Lead-Based Wheel Weights in the United States*. US Geological Survey. Open-File Report 2006–1111. Available from <http://pubs.usgs.gov/of/2006/1111/2006-1111.pdf>.
- ¹⁸⁸ European Chemical Substance Information System. Table 3.1 Available from <http://esis.jrc.ec.europa.eu/index.php?PGM=cla>. International Agency for Research on Cancer. Agents Classified by the IARC Monographs Volumes, 1-102. Available from <http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf>.
- ¹⁸⁹ US National Toxicology Program (1986). Toxicology and carcinogenesis studies of decabromodiphenyl oxide (CAS No. 1163-19-5) in F344/N rates and B6C3F1 mice (feed studies). *National Toxicology Program Technical Report Series*. 309,1-242.

- ¹⁹⁰ See for example: US Government Accountability Office (2008). *Electronic Waste: EPA Needs to Better Control Harmful U.S. Exports through Stronger Enforcement and More Comprehensive Regulation*. Available from <http://www.gao.gov/new.items/d081044.pdf>.
- ¹⁹¹ Guberman, D.E. (2011). *2009 Minerals Yearbook: Lead*. US Geological Survey. Available from <http://minerals.usgs.gov/minerals/pubs/commodity/lead/myb1-2009-lead.pdf>.
- ¹⁹² Gottesfeld, P. and Pokhrel, A.K. (2011). Review: Lead exposure in battery manufacturing and recycling in developing countries and among children in nearby communities. *Journal of Occupational and Environmental Hygiene*, 8, 520-32.
- ¹⁹³ US Agency for Toxic Substances and Disease Registry (2002). Public Health Statement for Di(2-ethylhexyl)phthalate (DEHP). Available from <http://www.atsdr.cdc.gov/toxprofiles/phs9.html#bookmark05>. Duty, S.M., Silva, M.J., Barr, D.B. et al. (2003). Phthalate exposure and human semen parameters. *Epidemiology*, 14, 269–277. National Toxicology Program, Report on Carcinogens, 12th Edition (2011). Chapter on di(2-ethylhexyl)phthalate, Available from <http://ntp.niehs.nih.gov/ntp/roc/twelfth/profiles/DiethylhexylPhthalate.pdf>.
- ¹⁹⁴ See for example, Kumar, A., and Pastore, P. (2006). *Toying with Toxics: An Investigation of Lead and Cadmium in Soft Toys in Three Cities in India*. Toxics Link. US Centers for Disease Control and Prevention. Lead recalls: Toys. Available from <http://www.cdc.gov/nceh/lead/Recalls/toys.htm>.
- ¹⁹⁵ Commission for Environmental Cooperation. Taking Stock: North American Pollutant Release and Transfers. Available from <http://takingstock.cec.org/QueryBuilder.aspx#report=Facility|year=2009|chemicalsmedia=TotalReleaseTransfers|naics=3|menu=adv>.
- ¹⁹⁶ Commission for Environmental Cooperation. Taking Stock: North American Pollutant Release and Transfers. Available from <http://www.cec.org/TakingStock/QueryBuilder.aspx#report=Facility|year=2006|country=-1|state=0|common=0|chemTypeld=z|chemical=-1|industry=0|naics=3|unit=Kilograms|menu=wiz>.
- ¹⁹⁷ Organisation for Economic Cooperation and Development. Center for PRTR Data. Available from http://www.oecd.org/env_prtr_data/.
- ¹⁹⁸ Commission for Environmental Cooperation. Taking Stock: North American Pollutant Release and Transfers. Available from <http://www.cec.org/TakingStock/QueryBuilder.aspx#report=Facility|year=2006|country=-1|state=0|common=0|chemTypeld=z|chemical=-1|industry=0|naics=3|unit=Kilograms|menu=wiz>.
- ¹⁹⁹ Organisation for Economic Cooperation and Development. Center for PRTR Data. Available from http://www.oecd.org/env_prtr_data/.
- ²⁰⁰ Commission for Environmental Cooperation. Taking Stock: North American Pollutant Release and Transfers. Available from <http://takingstock.cec.org/QueryBuilder.aspx#report=Facility|year=2009|chemicalsmedia=TotalReleaseTransfers|naics=3|menu=adv>.
- ²⁰¹ Schulz, R. (2001). Rainfall-induced sediment and pesticide input from orchards into the Lourens River, Western Cape, South Africa: importance of a single event. *Water Research*, 35, 1869-1876.
- ²⁰² The Stockholm Convention identifies cement kilns firing hazardous waste as a source category for hexachlorobenzene, pentachlorobenzene, polychlorinated biphenyls, and polychlorinated dibenzo-*p*-dioxins and dibenzofurans. United Nations Environment Programme. Stockholm Convention on Persistent Organic Pollutants. Available from <http://chm.pops.int/Convention/ConventionText/tabid/2232/Default.aspx>.
- ²⁰³ Adejumo, J.A., Obioh, I.B., Oguniola, O.J. et al. (1994). The atmospheric deposition of major, minor and trace elements within and around three cement factories. *Journal of Radioanalytical and Nuclear Chemistry*, 179, 195-204.
- ²⁰⁴ Li, H., Yu, L., Sheng, G. et al. (2007). Severe PCDD/F and PBDD/F pollution in air around an electronic waste dismantling area in China. *Environmental Science and Technology*, 41, 5641-5646.

- ²⁰⁵ Deng, W.J., Zheng, J.S., Bi, X.H. et al. (2007). Distribution of PBDEs in air particles from an electronic waste recycling site compared with Guangzhou and Hong Kong, South China. *Environment International*, 33, 1063–1069.
- ²⁰⁶ Ha, N.N., Agusa, T., Ramu, K. et al. (2009). Contamination by trace elements at e-waste recycling sites in Bangalore, India. *Chemosphere*, 76, 9-15.
- ²⁰⁷ Arctic Monitoring and Assessment Programme and the United Nations Environment Programme (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf.
- ²⁰⁸ Liu, H., Probst, A., Liao, B. (2005). Metal contamination of soils and crops affected by the Chenzhou lead/zinc mine spill (Hunan, China). *The Science of the Total Environment*, 339, 153-166.
- ²⁰⁹ United Nations Environment Programme (2002). Consideration of the Implementation of the Basel Convention: Technical Matters: Preparation of Technical Guidelines. *Sixth Meeting of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*, Geneva. Available from http://archive.basel.int/meetings/cop/cop6/cop6_23e.pdf#annex.
- ²¹⁰ Kannan, K., Tanabe, S., Iwata, H. et al. (1995). Butyltins in muscle and liver of fish collected from certain Asian and Oceanian countries. *Environmental Pollution*, 90, 279-290.
- ²¹¹ Shaik, B., Premisingh, M.G., Ravikumar, B.T. et al. (2007). Heavy metal content of suspended particulate matter at world's largest ship-breaking yard, Alang-Sosiya, India. *Water, Air & Soil Pollution*, 178, 373-384.
- ²¹² Tewari, A.L., Joshi, H.V., Trivedi, R.H. et al. (2001). The effect of ship scrapping industry and its associated wastes on the biomass production and biodiversity of biota in insitu condition at Alang. *Marine Pollution Bulletin*, 42, 462-469.
- ²¹³ Binn, J.A., Maconahie, R.A., Tanko, A.I. (2003). Water, land and health in urban and peri-urban food production: The case of Kano, Nigeria. *Land Degradation and Development*, 14, 431-444.
- ²¹⁴ United Nations Environment Programme (1994). *The Textile Industry and the Environment*. UNEP Technical Report Series No. 16.
- ²¹⁵ Caneiro, P.A., Umbuzeiro, G.A., Olivera, D.P. et al. (2010). Assessment of water contamination caused by a mutagenic textile effluent/dyehouse effluent bearing disperse dyes. *Journal of Hazardous Materials*, 174, 694-699.
- ²¹⁶ Bhanarkar, A.D., Rao, D.G., Gajghate, P. et al. (2005). Inventory of SO₂, PM and toxic metals emissions from industrial sources in Greater Mumbai, India. *Atmospheric Environment*, 39, 3851-3864.
- ²¹⁷ Butt, M.S., Sharif, K., Bajwa, B.E. et al. (2005). Hazardous effects of sewage water on the environment: focus on heavy metals and chemical composition of soil and vegetables, *Management of Environmental Quality: An International Journal*, 16, 338-346.
- ²¹⁸ Wielenga, K. (2010). *Waste Without Frontiers: Global Trends in the Generation of Transboundary Movements of Hazardous Wastes and Other Wastes*. Prepared for the Secretariat of the Basel Convention. Geneva: Secretariat of the Basel Convention.
- ²¹⁹ Wielenga, K. (2010). *Waste Without Frontiers: Global Trends in the Generation of Transboundary Movements of Hazardous Wastes and Other Wastes*. Prepared for the Secretariat of the Basel Convention. Geneva: Secretariat of the Basel Convention.
- ²²⁰ Greenpeace (2009). Where does e-waste end up? Available from <http://www.greenpeace.org/international/en/campaigns/toxics/electronics/the-e-waste-problem/where-does-e-waste-end-up/>. Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.

- ²²¹ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ²²² Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ²²³ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ²²⁴ The Basel Action Network (2005). *The Digital Dump: Exporting Reuse and Abuse to Africa*.
- ²²⁵ Robinson, B.H. (2009). E-waste: an assessment of global production and environmental impacts. *Science of the Total Environment*, 408, 183-191.
- ²²⁶ Robinson, B.H. (2009). E-waste: an assessment of global production and environmental impacts. *Science of the Total Environment*, 408, 183-191.
- ²²⁷ Nimpuno, N., Scruggs, C., Bengtsson, M. et al. (2011). *Information on Chemicals in Electronic Products: A Study of Needs, Gaps, Obstacles and Solutions to Provide and Access Information on Chemicals in Electronic Products*. TemaNord. Available from <http://www.norden.org/da/publikationer/publikationer/2011-524>.
- ²²⁸ Schluep, M., Hagelueken, C., Kuehr, R. et al. (2009). *From E Waste to Resources*. United Nations Environment Programme.
- ²²⁹ Schluep, M., Hagelueken, C., Kuehr, R. et al. (2009). *From E Waste to Resources*. United Nations Environment Programme.
- ²³⁰ Food and Agriculture Organization of the United Nations (FAO). Prevention and Disposal of Obsolete Pesticides. Available from <http://www.fao.org/agriculture/crops/obsolete-pesticides/what-dealing/en/>.
- ²³¹ Food and Agriculture Organization of the United Nations (FAO). Prevention and Disposal of Obsolete Pesticides. Available from <http://www.fao.org/agriculture/crops/obsolete-pesticides/what-dealing/en/>.
- ²³² Food and Agriculture Organization of the United Nations (FAO). Prevention and Disposal of Obsolete Pesticides. Available from <http://www.fao.org/agriculture/crops/obsolete-pesticides/what-dealing/en/>.
- ²³³ Food and Agriculture Organization of the United Nations (FAO). Prevention and Disposal of Obsolete Pesticides. Available from <http://www.fao.org/agriculture/crops/obsolete-pesticides/what-dealing/en/>.
- ²³⁴ World Health Organization. Country Health Profile. Country Health Profile of Mali (updated 2006). Available from <http://www.afro.who.int/en/mali/country-health-profile.html>.
- ²³⁵ Goldman, L. and Tran, N. (2002). *Toxics and Poverty: The Impact of Toxic Substances on the Poor in Developing Countries*. World Bank.
- ²³⁶ Africa Stockpiles Programme. About the ASP. Available from <http://www.africastockpiles.net/index.php?page=about-asp>.
- ²³⁷ Hilson, G. (2002). Small-scale mining in Africa: Tackling pressing environmental problems with improved strategy. *The Journal of Environment and Development*, 11, 149-174.
- ²³⁸ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf.
- ²³⁹ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf.

- ²⁴⁰ Arctic Monitoring and Assessment Programme and United Nations Environment Programme (UNEP) (2008). *Technical Background Report to the Global Atmospheric Mercury Assessment*. UNEP Chemicals Branch. Available from http://www.chem.unep.ch/mercury/Atmospheric_Emissions/Technical_background_report.pdf.
- ²⁴¹ United Nations Environment Programme (UNEP) (2010). Study on Mercury Sources and Emissions, and Analysis of Cost and Effectiveness of Control Measures (UNEP Paragraph 29 Study). UNEP Chemicals Branch, Division of Technology, Industry and Economics.
- ²⁴² Ikingura, J.R, Mutakyahwa, M.K.D., Kahatano, J.M.J. (1999) Mercury and mining in Africa with special reference Tanzania. *Water, Air and Soil Pollution*, 97, 23-232.
- ²⁴³ Haradi, M., Nakachi, S., Cheu, T. et al. (1999). Monitoring of mercury pollution in Tanzania: Relation between head hair mercury and health. *Science of the Total Environment*, 227, 249-256.
- ²⁴⁴ Amonoo-Neizer, E.H., Nyamah, D., Bakiamoh, S.B. (1996). Mercury and arsenic pollution in soil and biological samples around the mining town of Obuasi, Ghana. *Water, Air and Soil Pollution*, 91, 363-373. Hilson, G. (2002). Small-scale mining in Africa: Tackling pressing environmental problems with improved strategy. *The Journal of Environment and Development*, 11, 149-174.
- ²⁴⁵ Lebel, J., Mergler, D., Branches, F. et al. (1998). Neurotoxic effects of low-level methylmercury contamination in the Amazonian Basin. *Environmental Research*, 79, 20-32; Appleton, J.D., Williams, T.M., Breward, N. et al. (1999). Mercury contamination associated with artisanal gold mining on the island of Mindanao, the Philippines. *The Science of the Total Environment*, 228, 95-109.
- ²⁴⁶ World Meteorological Organization, Global Ozone Research and Monitoring Project (2010). *Scientific Assessment of Ozone Depletion: 2010*. Report No. 52. Available from http://ozone.unep.org/new_site/en/scientific_assessment_2010.php.
- ²⁴⁷ United Nations (2010). *The Millennium Development Goals Report 2010*.
- ²⁴⁸ World Meteorological Organization, Global Ozone Research and Monitoring Project (2010). *Scientific Assessment of Ozone Depletion: 2010*. Report No. 52. Available from http://ozone.unep.org/new_site/en/scientific_assessment_2010.php.
- ²⁴⁹ World Meteorological Organization, Global Ozone Research and Monitoring Project (2010). *Scientific Assessment of Ozone Depletion: 2010*. Report No. 52. Available from http://ozone.unep.org/new_site/en/scientific_assessment_2010.php.
- ²⁵⁰ Ozone Secretariat, United Nations Environment Programme (2005). *Production and Consumption of Ozone Depleting Substances under the Montreal Protocol, 1986-2004*. Available from http://ozone.unep.org/Publications/Production_and_consumption2005.pdf.
- ²⁵¹ Ozone Secretariat, United Nations Environment Programme (2005). *Production and Consumption of Ozone Depleting Substances under the Montreal Protocol, 1986-2004*. Available from http://ozone.unep.org/Publications/Production_and_consumption2005.pdf.
- ²⁵² Organisation for Economic Cooperation and Development (2001). *OECD Environmental Outlook for the Chemicals Industry*.
- ²⁵³ United Nations Environment Programme, Global Environment Monitoring System and UNESCO (2008). *Water Quality for Ecosystem and Human Health*. Available from http://www.unwater.org/wwd10/downloads/water_quality_human_health.pdf.
- ²⁵⁴ European Chemical Substance Information System Table 3.1 Available from <http://esis.jrc.ec.europa.eu/index.php?PGM=cla>. Note: this database is routinely updated.

- ²⁵⁵ United Nations Environment Programme, Global Environment Monitoring System and UNESCO (2008). *Water Quality for Ecosystem and Human Health*. Available from http://www.unwater.org/wwd10/downloads/water_quality_human_health.pdf.
- ²⁵⁶ Kloas, W., Urbatzka, R., Opitz, R. et al. (2009). Endocrine disruption in aquatic vertebrates. *Annals of the New York Academy of Sciences*, 1163, 187-200. Guillette, L.J., Pickford, D.B., Crain, D. et al. (1996). Reduction in penis size and plasma testosterone concentrations in juvenile alligators living in a contaminated environment. *General and Comparative Endocrinology*, 101, 32-42; de Solla, S.R., Bishop, S.A., Van Der Kraak, G. et al. (1998). Impact of organochlorine contamination on levels of sex hormones and external morphology of common snapping turtles (*Chelydra serpentina serpentina*) in Ontario, Canada. *Environmental Health Perspectives*, 106, 253-260.
- ²⁵⁷ Mann, R.M., Hyne, R.V., Choung, C.B. et al. (2009). Amphibians and agricultural chemicals: review of the risks in a complex environment. *Environmental Pollution*, 157, 2903-2927.
- ²⁵⁸ United Nations Environment Programme, Global Environment Monitoring System and UNESCO (2008). *Water Quality for Ecosystem and Human Health*. Available from http://www.unwater.org/wwd10/downloads/water_quality_human_health.pdf.
- ²⁵⁹ United Nations Environment Programme, Global Environment Monitoring System and UNESCO (2008). *Water Quality for Ecosystem and Human Health*. Available from http://www.unwater.org/wwd10/downloads/water_quality_human_health.pdf.
- ²⁶⁰ United Nations Environment Programme, Global Environment Monitoring System and UNESCO (2008). *Water Quality for Ecosystem and Human Health*. Available from http://www.unwater.org/wwd10/downloads/water_quality_human_health.pdf.
- ²⁶¹ Khan, S., Cao, Q., Zheng, Y.M. et al. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution*, 152, 686-692.
- ²⁶² International Assessment of Agricultural Knowledge, Science and Technology for Development (2009). *Agriculture at a Crossroads: Global Report*. Washington, DC: Island Press.
- ²⁶³ United Nations Environment Programme (2010). *Global Honey Bee Colony Disorders and Other Threats to Insect Pollinators*.
- ²⁶⁴ Ross, P.S. and Birnbaum, L. (2003). Integrating human and ecological risk assessment: A case study of persistent organic pollutants (POPs) in humans and wildlife. *Journal of Human and Ecological Risk Assessment*, 9, 303-324.
- ²⁶⁵ Woodruff, T.J., Janssen, S.J., Guillette, L.J. et al. (2010). *Environmental Impacts on Reproductive Health and Fertility*. New York: Cambridge University Press. 108-109.
- ²⁶⁶ Schwaiger, J., Mallow, U., Ferling, H. et al. (2002). How estrogenic is nonylphenol? A transgenerational study using rainbow trout (*Oncorhynchus mykiss*) as a test organism. *Aquatic Toxicology*, 59, 177-189. Anway, M.D., Cupp, A.S., Uzumcu, M. et al. (2005). Epigenetic transgenerational actions of endocrine disruptors and male fertility, *Science*, 308, 1466-1469.
- ²⁶⁷ US Environmental Protection Agency. *Persistent Organic Pollutants: A Global Issue, A Global Response*. Available from <http://www.epa.gov/international/toxics/pop.html>.
- ²⁶⁸ Swackhamer, D.L., Needham, L.L., Powel, D.E. et al. (2009). Use of measurement data in evaluating exposure of humans and wildlife to POPs/PBTs. *Integrated Environmental Assessment and Management*, 5, 638-661.
- ²⁶⁹ Hites, R.A. (2004). Polybrominated diphenyl ethers in the environment and in people: A meta-analysis of concentrations. *Environmental Science and Technology*, 38, 945-956. Law, R.J., Allchin, C.R., de Boer, J. et al. (2006). Levels and trends of brominated flame retardants in the European environment. *Chemosphere*, 64, 187-208.

- ²⁷⁰ DiGangi, J. and Petrлік, J. (2005). *The Egg Report: Contamination of Chicken Eggs from 17 Countries by Dioxins, PCBs and Hexachlorobenzene*. International POPs Elimination Network. Available from http://www.ipen.org/ipenweb/documents/egg/global_eggsreport.pdf.
- ²⁷¹ Wang, Y., Fu, J., Wang, T. et al. (2010). Distribution of perfluorooctane sulfonate and other perfluorochemicals in the ambient environment around a manufacturing facility in China. *Environmental Science and Technology*, 44, 8062-8067.
- ²⁷² United Nations Environment Programme, Strategic Approach to International Chemicals Management (2009). *Report of the International Conference on Chemicals Management on the Work of its Second Session*. Available from <http://www.saicm.org/documents/iccm/ICCM2/Meeting%20Report/ICCM2%20report%20advance%20Eng%2023%20Jun%2009.doc>.
- ²⁷³ Allanou, R., Hansen, B.G., van der Bilt, Y. (1999). *Public Availability of Data on EU High Production Volume Chemicals*. European Commission Joint Research Centre, Institute for Health and Consumer Protection, Chemical Bureau. Cited in <http://www.regeringen.se/content/1/c4/26/31/94e4bea7.pdf>, section 2.2.2.
- ²⁷⁴ US Environmental Protection Agency (1998). *Chemical Hazard Data availability Study. What do We Really Know about the Safety of High Production Volume Chemicals?* Office of Pollution Prevention and Toxics. April 1998. Cited in <http://www.regeringen.se/content/1/c4/26/31/94e4bea7.pdf>, section 2.2.2.
- ²⁷⁵ US Environmental Protection Agency (1998). *Chemical Hazard Data availability Study. What do We Really Know about the Safety of High Production Volume Chemicals?* Office of Pollution Prevention and Toxics. April 1998. Cited in <http://www.regeringen.se/content/1/c4/26/31/94e4bea7.pdf>, section 2.2.2.
- ²⁷⁶ For a recent assessment of the successes of the US EPA's HPV Challenge Program, see Environmental Defense (2007). *High Hopes, Low Marks*. Available from http://www.edf.org/documents/6653_HighHopesLowMarks.pdf.
- ²⁷⁷ The European Chemical Industry Council (CEFIC). *Global Product Strategy*. Available from <http://www.cefic.org/Regulatory-Framework/Voluntary-Initiatives1/Global-Product-Strategy/>.
- ²⁷⁸ Alonso-Magdalena, P., Roperо, A.B., Soriano, S. et al. (2010). Bisphenol-A: a new diabetogenic factor? *Hormones*, 9, 118-126. Durando, M., Kass, L., Piva, J. et al. (2007). Prenatal bisphenol-A exposure induces preneoplastic lesions in the mammary gland in wistar rats. *Environmental Health Perspectives*, 115, 80-86; Markey, C.M., Luque, E.H., Munoz de Toro, M.M. et al. (2001). In utero exposure to bisphenol A alters the development and tissue organization of the mouse mammary gland. *Biology of Reproduction*, 65, 1215-1213; Ho, S-M., Tang, W-Y., Belmonte de Frausto, J. et al. (2006). Developmental exposure to estradiol and bisphenol A increases susceptibility to prostate carcinogenesis and epigenetically regulates phosphodiesterase type 4 variant 4. *Cancer Research*, 66, 5624-5632.
- ²⁷⁹ Cohn, B.A., Wolfe, M.S., Cirillo, P.M. et al. (2007). DDT and breast cancer in young women: new data on the significance of age at exposure. *Environmental Health Perspectives*, 115, 1406-1414.
- ²⁸⁰ Goldman, L. and Tran, N. (2002). *Toxics and Poverty: The Impact of Toxic Substances on the Poor in Developing Countries*. World Bank; World Health Organization (2010). *Childhood Lead Poisoning*. Available from <http://www.who.int/ceh/publications/leadguidance.pdf>.
- ²⁸¹ Vahter, M.E. (2007). Interactions between arsenic-induced toxicity and nutrition in early life. *The Journal of Nutrition*, 137, 2798-2804; World Health Organization. (2010). *Childhood Lead Poisoning*. Available from <http://www.who.int/ceh/publications/leadguidance.pdf>.
- ²⁸² Pope III, A.C. and Dockery, D.W. (2006). Health effects of fine particulate air pollutions: lines that connect. *Journal of the Air and Waste Management Association*, 56, 709-742.
- ²⁸³ Agency for Toxic Substances and Disease Registry (March 1999). *Toxicological Profile for Mercury*. Available from <http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=115&tid=24>.

- ²⁸⁴ Khalil-Manesh, F., Gonick, H.C., Weiler, E.W.J. (1993). Lead-induced hypertension: Possible role of endothelial factors. *American Journal of Hypertension*. 6,723-729. Muldoon, S.B., Cauley, J.A., Kuller, L.H. et al. (1996). Effects of blood lead levels on cognitive function of older women. *Neuroepidemiology*. 15, 62-72. Payton, M., Riggs, K.M., Spiro III, A. et al. (1998). Relations of bone and blood lead to cognitive function: the VA normative aging study. *Neurotoxicology and Teratology*. 20, 19-27. Rhodes, D., Spiro, A., Aro, A. et al. (2003). Relationship of bone and blood lead levels to psychiatric symptoms: The normative aging study. *Journal of Occupational and Environmental Medicine*. 45, 1144-1151.
- ²⁸⁵ Brook, R.D. (2008). Air Pollution. What is bad for the arteries might be bad for the veins. *Archives of Internal Medicine*. 168, 909-911. Baccarelli, A., Martinelli, I., Zanobetti, A. et al. (2008). Exposure to particulate air pollution and risk of deep vein thrombosis. *Archives of Internal Medicine*. 168, 920-7.
- ²⁸⁶ International Labour Organization (2011). *ILO Introductory Report: Global Trends and Challenges on Occupational Safety and Health. XIX World Congress on Safety and Health at Work: Istanbul Turkey, 11-15 September 2011*. Available from http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_162662.pdf.
- ²⁸⁷ Shenker M. (2010). A global perspective of migration and occupational health. *American Journal of Industrial Medicine*. 53,329-337.
- ²⁸⁸ World Health Organization (2010). *Persistent Organic Pollutants: Impact on Child Health*. Available from http://whqlibdoc.who.int/publications/2010/9789241501101_eng.pdf/.
- ²⁸⁹ World Health Organization (2010). *Persistent Organic Pollutants: Impact on Child Health*. Available from http://whqlibdoc.who.int/publications/2010/9789241501101_eng.pdf/.
- ²⁹⁰ Goldman, L. and Tran, N. (2002). *Toxics and Poverty: The Impact of Toxic Substances on the Poor in Developing Countries*. World Bank.
- ²⁹¹ Diallo, Y., Hagemann, F., Etienne, A. et al. (2010). *Global Child Labour Developments: Measuring Trends from 2004 to 2008*. International Labour Organization. Available from <http://www.ilo.org/ipecinfo/product/viewProduct.do?productId=13313>.
- ²⁹² Diallo, Y., Hagemann, F., Etienne, A. et al. (2010). *Global Child Labour Developments: Measuring Trends from 2004 to 2008*. International Labour Organization. Available from <http://www.ilo.org/ipecinfo/product/viewProduct.do?productId=13313>.
- ²⁹³ Goldman, L. and Tran, N. (2002). *Toxics and Poverty: The Impact of Toxic Substances on the Poor in Developing Countries*. World Bank.
- ²⁹⁴ International Council of Chemical Associations (2011). International Council of Chemical Associations (ICCA) 1st Update Report for the UN Strategic Approach to International Chemicals Management (SAICM). Available from http://www.icca-chem.org/ICCADocs/111109_ICCA_1st_Update_SAICM_Report_SB.PDF.
- ²⁹⁵ US Center for Disease Control and Prevention (2009). *Fourth National Report on Human Exposure to Environmental Chemicals*. Department of Health and Human Services. Available from <http://www.cdc.gov/exposurereport/pdf/FourthReport.pdf>.
- ²⁹⁶ Organisation for Economic Cooperation and Development (1999). *Phasing lead out of gasoline: an examination of policy approaches in different countries*. Available from <http://www.unep.fr/energy/transport/documents/pdf/phasingLead.pdf>; Mathee, A., Röllin, H., Schirnding, Y. et al. (2006). Reductions in blood lead levels among school children following the introduction of unleaded petrol in South Africa. *Environmental Research*, 100, 319–322; He, K., Wang, S., Zhang, J. (2009). Blood lead levels of children and its trend in China. *Science of the Total Environment*, 407, 3986–3993.
- ²⁹⁷ World Health Organization (2009). *Mortality and Burden of Disease Attributable to Selected Major Risks*. Available from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf.

- ²⁹⁸ Gottesfeld, P. and Pokhrel, A.K. (2011). Review: Lead exposure in battery manufacturing and recycling in developing countries and among children in nearby communities. *Journal of Occupational and Environmental Hygiene*, 8, 520-32.
- ²⁹⁹ Gottesfeld, P. and Pokhrel, A.K. (2011). Review: Lead exposure in battery manufacturing and recycling in developing countries and among children in nearby communities. *Journal of Occupational and Environmental Hygiene*, 8, 520-32.
- ³⁰⁰ Lanphear, B.P., Hornung, R., Khoury, J. et al. (2005). Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. *Environmental Health Perspectives*, 113, 894–899.
- ³⁰¹ Van Leeuwen, F.X.R. and Malisch, R. (2002). Results of the third round of the WHO coordinated exposure study on the level of PCBs, PCDDs, and PCFDs in human milk. *Organohalogen Compounds*, 56, 311–316.
- ³⁰² Van Leeuwen, F.X.R. and Malisch, R. (2002). Results of the third round of the WHO coordinated exposure study on the level of PCBs, PCDDs, and PCFDs in human milk. *Organohalogen Compounds*, 56, 311–316.
- ³⁰³ Tuomisto, J. (December 2009). *Persistent Organic Pollutants in Human Milk*. Fact Sheet 4.3. World Health Organization, European Environment and Health Information System. Available from http://www.euro.who.int/_data/assets/pdf_file/0003/97032/4.3.-Persistant-Organic-Pollutantsm-EDITED_layouted_V2.pdf.
- ³⁰⁴ United Nations Environment Programme (2009). Status report on the human milk survey jointly by the Secretariat of the Stockholm Convention and the World Health Organization. *Conference of the Parties of the Stockholm Convention on Persistent Organic Pollutants Fourth Meeting*. Geneva. Available from <http://chm.pops.int/Portals/0/Repository/COP4/UNEP-POPS-COP.4-INF-31.English.PDF>.
- ³⁰⁵ Concentrations in Nigeria: 857 ng/g lipid weight; Senegal: 464.5 ng/g lipid weight.
- ³⁰⁶ Jaga, K. and Dharmani, C. (2003). Global surveillance of DDT and DDE levels in human tissues. *International Journal of Occupational and Environmental Health*, 16, 7-20. Levels in Zimbabwe in 1991: 2390 ng/g lipid weight; Uganda in 1999: 3510 ng/g lipid weight.
- ³⁰⁷ Chan, J.K.Y., Xing, G.H., Xu, Y. et al. (2007). Body loadings and health risk assessment of polychlorinated dibenzo-p-dioxins and dibenzofurans at an intensive electronic waste recycling site in China. *Environmental Science and Technology*, 41, 7668–7674.
- ³⁰⁸ Kunisue, T., Watanabe, M., Iwata, H. et al. (2004). Dioxins and related compounds in human breast milk collected around open dumping sites in Asian developing countries: bovine milk as a potential source. *Archives of Environmental Contamination and Toxicology*, 47, 414–426.
- ³⁰⁹ Sergeev, O., Shelepchikov, A., Denisova, T. et al. (2008). POPs in human milk in Chapaevsk, Russia, five years following cessation of chemical manufacturing and decade of remediation programme, pilot study. *Organohalogen Compounds*, 70, 1946-1949.
- ³¹⁰ Kannan, K., Corsolini, S., Falandysz, J. et al. (2004). Perfluorooctanesulfonate and related fluorochemicals in human blood from several countries. *Environmental Science and Technology*, 38, 4489-4495.
- ³¹¹ Calafat, A.M., Needham, L.L., Kuklennyik, Z. et al. (2006). Perfluorinated chemicals in selected residents of the American continent. *Chemosphere*, 63, 490- 496.
- ³¹² Olsen, Geary W. et al. (2008). Decline in Perfluorooctanesulfonate and Other Perfluoroalkyl Chemicals in American Red Cross Adult Blood Donors, 2000-2006. *Environmental Science and Technology*, 42, 4989-4995.
- ³¹³ Zhang, W., Lin, Z., Hu, M. et al. (2011). Perfluorinated chemicals in blood of residents in Wenzhou, China. *Ecotoxicology and Environmental Safety*, 74, 1787-1793.
- ³¹⁴ Harada, K.H., Yang, H.R., Moon, C.S. et al. (2010). Levels of perfluorooctane sulfonate and perfluorooctanoic acid in female serum samples from Japan in 2008, Korea in 1994-2008 and Vietnam in 2007-2008. *Chemosphere*, 79, 314-9.

- ³¹⁵ Fujii, Yukiko. (2012) Levels and Profiles of Long-Chain Perfluorinated Carboxylic Acids in Human Breast Milk and Infant Formulas in East Asia. *Chemosphere*, 86:3, 315-21.
- ³¹⁶ US Centers for Disease Control and Prevention (2009). *Fourth National Report on Human Exposure to Environmental Chemicals*. Department of Health and Human Services. Available from <http://www.cdc.gov/exposurereport/pdf/FourthReport.pdf>.
- ³¹⁷ US Centers for Disease Control and Prevention (2009). *Fourth National Report on Human Exposure to Environmental Chemicals*. Department of Health and Human Services. Available from <http://www.cdc.gov/exposurereport/pdf/FourthReport.pdf>.
- ³¹⁸ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9.
- ³¹⁹ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9.
- ³²⁰ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9. The researchers also included secondhand smoke, indoor biomass combustion, and naturally occurring arsenic exposure in drinking water in Bangladesh. These non-industrial chemical sources of disease are excluded in the statistics shown here. Deaths and DALYs attributable to only mobile air pollution sources and other fuel combustion sources cannot be separated from other industrial sources of air pollution in this analysis.
- ³²¹ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9.
- ³²² Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*. 10:9. McCartor, A., and Becker, D. (2010). *Blacksmith's Institute's World's Worst Pollution Problems Report 2010*. Blacksmith Institute,
- ³²³ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9.
- ³²⁴ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9.
- ³²⁵ Thundiyil, J.G., Stober, J., Besbelli, N., Pronczuk, J. (2008). Acute Pesticide Poisoning: A Proposed Classification Tool. *Bulletin of the World Health Organization*. Available from <http://www.who.int/bulletin/volumes/86/3/07-041814/en/>. Goldman, L. (2004). *Childhood Pesticide Poisoning: Information for Advocacy and Action*. United Nations Environment Programme and the World Health Organization. Available from <http://www.who.int/ceh/publications/pestpoisoning.pdf>.
- ³²⁶ Murray, D., Wesseling, C., Keifer, M. et al. (2002). Surveillance of pesticide-related illness in the developing world: putting the data to work. *International Journal of Occupational and Environmental Health*, 8, 243-248.
- ³²⁷ London, L. and Baillie, R. (2001). Challenges for improving surveillance for pesticide poisoning: policy implications for developing countries. *International Journal of Epidemiology*, 30, 564-570.
- ³²⁸ Jeyaratnam, J. (1990). Acute pesticide poisoning: a major global health problem. *World Health Statistics Quarterly*, 43, 3139-44.
- ³²⁹ Jeyaratnam, J. (1990). Acute pesticide poisoning: a major global health problem. *World Health Statistics Quarterly*, 43, 3139-44.
- ³³⁰ Goldman, L. and Tran, N. (2002). *Toxics and Poverty: The Impact of Toxic Substances on the Poor in Developing Countries*. World Bank.

- ³³¹ World Health Organization (2010). Global Alert and Response. Nigeria: mass lead poisoning from mining activities, Zamfara State. Available from http://www.who.int/csr/don/2010_07_07/en/index.html. Lead poisoning: eight Zamfara villages still contaminated. *Daily Times*. Available from <http://dailytimes.com.ng/article/lead-poisoning-eight-zamfara-villages-still-contaminated>.
- ³³² Gutschmidt, K., Haefliger, P., Ziker, T. *Outbreak of Neurological Illness of Unknown Etiology in Cacua Municipality, Angola; 2 November – 27 November, 2007. WHO rapid assessment and cause finding mission*. Available from http://www.who.int/environmental_health_emergencies/events/Angola%20cause%20finding%20mission%20report%20Executive%20Summary%20for%20Web%20V190308.pdf.
- ³³³ Polgreen, L. and Simons, M. (2006). Global sludge ends in tragedy for Ivory Coast. *The New York Times*.
- ³³⁴ Haefliger, P., Mathieu-Nolf, M., Locicero, S. et al. (2009). Mass lead intoxication from informal used lead-acid battery recycling in Dakar, Senegal. *Environmental Health Perspectives*, 117, 1534-1540.
- ³³⁵ Pesticide Action Network Asia Pacific (2010). *Communities in Peril: Global Report on Health Impacts of Pesticide Use in Agriculture*. Available from <http://www.pan-uk.org/publications/communities-in-peril>.
- ³³⁶ *IRIN News*. Bangladesh: Pesticide Poisoning Takes Its Toll. Available from <http://irinnews.org/Report.aspx?ReportId=87773>, 19 January.
- ³³⁷ Huffington Post (2011). China Lead Poisoning: Over 600 Sickened in Latest Incident, Including 103 Children, 12 June.
- ³³⁸ Bi, X., Thomas, G.O., Jones, K.C. et al. (2007). Exposure of electronics dismantling workers to polybrominated diphenyl ethers, polychlorinated biphenyls, and organochlorine pesticides in South China. *Environmental Science and Technology*, 41, 5647-5653.
- ³³⁹ Mancini, F., Van Bruggen, A.H., Jiggins, J.L. et al. (2005). Acute pesticide poisoning among female and male cotton growers in India. *International Journal of Occupational and Environmental Health*, 11, 221-232.
- ³⁴⁰ Dasgupta, S., Meisner, C., Wheeler, D. et al. (2007). Pesticide poisoning of farm workers-implications of blood test results from Vietnam. *International Journal of Hygiene and Environmental Health*, 210, 121-32.
- ³⁴¹ Pesticide Action Network Asia Pacific (2010). *Communities in Peril: Global Report on Health Impacts of Pesticide Use in Agriculture*. Available from <http://www.pan-uk.org/publications/communities-in-peril>.
- ³⁴² Gochfield, M. (2003). Cases of mercury exposure, bioavailability, and absorption. *Ecotoxicology and Environmental Safety*, 56, 174-179.
- ³⁴³ Omran, A.R. (1971). The epidemiologic transition. A theory of the epidemiology of population change. *Milbank Memorial Fund Quarterly*, 49, 509-538.
- ³⁴⁴ World Health Organization (2010). *Global Status Report on Noncommunicable Diseases*. Available from http://www.who.int/nmh/publications/ncd_report_full_en.pdf.
- ³⁴⁵ World Health Organization (2010). *Global Status Report on Noncommunicable Diseases*. Available from http://www.who.int/nmh/publications/ncd_report_full_en.pdf.
- ³⁴⁶ World Health Organization (2010). *Global Status Report on Noncommunicable Diseases*. Available from http://www.who.int/nmh/publications/ncd_report_full_en.pdf.
- ³⁴⁷ International Agency for Research on Cancer (2011). *Agents Classified by the IARC Monographs, Volumes 1 101*. Available from <http://monographs.iarc.fr/ENG/Classification/index.php>.
- ³⁴⁸ Siemiatycki, J., Richardson, L., Straif, K. et al. (2004). Listing occupational carcinogens. *Environmental Health Perspectives*, 112, 1447-59.
- ³⁴⁹ Schettler T. (February 2006). Toward an ecological view: complex systems, health and disease. *San Francisco Medicine: Journal of the San Francisco Medical Society*.

- ³⁵⁰ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9.
- ³⁵¹ Prüss-Ustün, A., Vickers, C., Haefliger, P. et al. (2011). Knowns and unknowns about the burden of disease due to chemicals: a systematic review. *Environmental Health: A Global Access Science Source*, 10:9.
- ³⁵² Doll, R. and Peto, R. (1981). The causes of cancer: quantitative estimates of avoidable risks of cancer in the United States today. *Journal of the National Cancer Institute*, 66, 1191-308.
- ³⁵³ President's Cancer Panel (2010). *Reducing Environmental Cancer Risk: What We Can Do Now*. US Department of Health and Human Services, National Institutes of Health, National Cancer Institute.
- ³⁵⁴ Clapp, R.W., Howe, G.K., Jacobs, M. (2006). Environmental and occupational causes of cancer re-visited, *Journal of Public Health Policy*, 27, 61-76. Landrigan, P.J. and Baker, D.B. (1995). Clinical recognition of occupational and environmental disease. *Mt Sinai Journal of Medicine*, 62, 406-11. Davis, D.L. and Hoel, D. (1990). Trends in cancer mortality in industrial countries. Introduction. *Annals of the New York Academy of Science*, 609, ix-xi.
- ³⁵⁵ Cavali, F. (2006). Cancer in the developing world: can we avoid the disaster? *Nature Clinical Practice Oncology*, 3, 582-583.
- ³⁵⁶ Cavali, F. (2006). Cancer in the developing world: can we avoid the disaster? *Nature Clinical Practice Oncology*, 3, 582-583.
- ³⁵⁷ De Roos, A.J., Gao, D.L., Wernli, K.J. et al. (2005). Colorectal cancer incidence among female textile workers in Shanghai, China: a case-cohort analysis of occupational exposures. *Cancer Causes and Control*, 16, 1177-1188.
- ³⁵⁸ Li, W., Ray, R.M., Gao, D.L. et al. (2006). Occupational risk factors for nasopharyngeal cancer among female textile workers in Shanghai, China. *Occupational and Environmental Medicine*, 63, 39-44.
- ³⁵⁹ San Sebastián, M., Armstrong, B., Córdoba, J.A. et al. (2001). Exposures and cancer incidence near oil fields in the Amazon basin of Ecuador, *Occupational and Environmental Medicine*, 58, 517-522.
- ³⁶⁰ Bhat, A.R., Wani, M.A., Kirmani, A.R. (2010). Brain cancer and pesticide relationship in orchard farmers of Kashmir, Indian. *Journal of Occupational and Environmental Medicine*, 14, 78-86.
- ³⁶¹ Thrupp, L.A. (1991). Sterilization of workers from pesticide exposure: the causes and consequences of DBCP-induced damage in Costa Rica and beyond. *International Journal of Health Services*, 21, 731-57.
- ³⁶² Longnecker, M.P., Klebanoff, M.A., Zhou, H et al. (2001). Association between maternal serum concentration of the DDT metabolite DDE and preterm and small-for-gestational-age babies at birth. *Lancet*, 358, 110-114.
- ³⁶³ Duty, S.M., Silva, M.J., Barr, D.B. et al. (2003). Phthalate exposure and human semen parameters. *Epidemiology*, 14, 269-277.
- ³⁶⁴ Benjamin, J., Apelberg, F.R., Witter, J.B. et al. (2007). Cord serum concentrations of perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA) in relation to weight and size at birth. *Environmental Health Perspectives*, 115, 1670-6.
- ³⁶⁵ Joensen, U.N., Bossi, R., Leffers, H. et al. (2009). Do perfluoroalkyl compounds impair human semen quality? *Environmental Health Perspectives*, 117, 923-927.
- ³⁶⁶ National Research Council (2006). *Assessing the Human Health Risks of Trichloroethylene*. Washington DC: National Academy Press.
- ³⁶⁷ Rodier, P.M. (1995). Developing brain as a target of toxicity. *Environmental Health Perspectives*, 103 (suppl 6), 73-76; Rice, D. and Barone, S. Jr.(2000). Critical periods of vulnerability for the developing nervous system: evidence from humans and animal models. *Environmental Health Perspectives*, 108(suppl 3), 511-533; Woodruff, T.J., Axelrad, D.A., Kyle, A.D. et al. (2003). *America's Children and the Environment: Measures of Contaminants, Body Burdens, and Illnesses*. US Environmental Protection Agency.

- ³⁶⁸ Grandjean, P. and Landrigan, P.J. (2006). Developmental neurotoxicity of industrial chemicals, *Lancet*, 368, 2167-2178.
- ³⁶⁹ Grandjean, P. and Landrigan, P.J. (2006). Developmental neurotoxicity of industrial chemicals, *Lancet*, 368, 2167-2178.
- ³⁷⁰ National Academy of Sciences, Committee on Developmental Toxicology (2000). *Scientific Frontiers in Developmental Toxicology and Risk Assessment*. Washington, DC: National Academies Press.
- ³⁷¹ Lanphear, B.P., Hornung, R., Khoury, J. et al. (2005). Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. *Environmental Health Perspectives*, 113, 894-899.
- ³⁷² Joint FAO/WHO Expert Committee (2010). *Joint FAO/WHO Expert Committee on Food Additives. Seventy-third meeting, 8-17 June, 2010. Summary and Conclusions*. Available from <http://www.who.int/foodsafety/publications/chem/summary73.pdf>.
- ³⁷³ World Health Organization (2010). *Childhood Lead Poisoning*. Available from <http://www.who.int/ceh/publications/leadguidance.pdf>.
- ³⁷⁴ World Health Organization (2009). *Mortality and Burden of Disease Attributable to Selected Major Risks*. Available from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf. World Health Organization. (2010). *Childhood Lead Poisoning*. Available from <http://www.who.int/ceh/publications/leadguidance.pdf>. United Nations Environment Programme (2012). Global Clean Fuels and Vehicles Database. Available from http://www.unep.org/cleanfleet_database/Maps/leadElimination/index.asp.
- ³⁷⁵ World Health Organization (2009). *Mortality and Burden of Disease Attributable to Selected Major Risks*. Available from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf.
- ³⁷⁶ Liu, L., Bao, H., Liu, F. et al. (2011). Phthalates exposure of Chinese reproductive age couples and its effect on male semen quality, a primary study. *Environment International*, Apr 25. [Epub ahead of print].
- ³⁷⁷ Ren, A., Qui, X., Jin, L. et al. (2011). Association of selected persistent organic pollutants in the placenta with the risk of neural tube defects. *Proceedings of the National Academy of Sciences of the United States of America*, 108, 12770-12775.
- ³⁷⁸ Taha T.E. and Gray, R.H. (1993). Agricultural pesticide exposure and perinatal mortality in central Sudan. *Bulletin of the World Health Organization*, 71, 317-21.
- ³⁷⁹ Guillette, E.A., Meza, M.M., Aquilar, M.G. et al. (1998). An anthropological approach to the evaluation of preschool children exposed to pesticides in Mexico. *Environmental Health Perspectives*, 106, 347-353.
- ³⁸⁰ Grandjean, P., Harari, R., Barr, D.B. et al. (2006). Pesticide exposure and stunting as independent predictors of neurobehavioral deficits in Ecuadorian school children. *Pediatrics*, 117, 546-56.
- ³⁸¹ Ide, L.S. and Parker, D.L. (2005). Hazardous child labour : lead and neurocognitive development. *Public Health Reports*, 120, 607-612.
- ³⁸² World Health Organization (2009). *Mortality and Burden of Disease Attributable to Selected Major Risks*. Available from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf.
- ³⁸³ World Health Organization (2009). *Mortality and Burden of Disease Attributable to Selected Major Risks*. Available from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf.
- ³⁸⁴ Association of Environmental and Occupational Clinics. AOEC Exposure Codes. Available from <http://www.aoecdata.org/ExpCodeLookup.aspx>.
- ³⁸⁵ Jeebhay, M.F. and Quirce, S. (2007). Occupational asthma in the developing and industrialised world: a review. *International Journal of Tuberculosis and Lung Disease*, 11, 122-33.
- ³⁸⁶ Jeebhay, M.F. and Quirce, S. (2007). Occupational asthma in the developing and industrialised world: a review. *International Journal of Tuberculosis and Lung Disease*, 11, 122-33

- ³⁸⁷ Braman, S.S. (2006). The global burden of asthma. *Chest*, 130, 4S-12S.
- ³⁸⁸ Braman, S.S. (2006). The global burden of asthma. *Chest*, 130, 4S-12S. World Health Organization. Asthma. Available from <http://www.who.int/respiratory/asthma/en/>. Accessed: October 11, 2011.
- ³⁸⁹ Braman, S.S. (2006). The global burden of asthma. *Chest*, 130, 4S-12S.
- ³⁹⁰ Braman, S.S. (2006). The global burden of asthma. *Chest*, 130, 4S-12S.
- ³⁹¹ Masol,i M., Fabian, D., Holt, S. et al. (2004). *Global Burden of Asthma*. Developed for the Global Initiative for Asthma. Available from www.ginasthma.org/pdf/GINABurdenReport.pdf. Braman, S.S. (2006). The global burden of asthma. *Chest*, 130, 4S-12S.
- ³⁹² World Health Organization (2009). *Mortality and Burden of Disease Attributable to Selected Major Risks*. Available from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf.
- ³⁹³ World Health Organization (2009). *Mortality and Burden of Disease Attributable to Selected Major Risks*. Available from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf.
- ³⁹⁴ Mendonca, E.M., Algranti, E., de Freitas, J.B. et al. (2003). Occupational asthma in the city of Sao Paulo, 1995-2000, with special reference to gender analysis. *American Journal of Industrial Medicine*, 43, 611-7.
- ³⁹⁵ Hnizdo, E., Esterhuizen, T.M., Rees, D. et al. (2001). Occupational asthma as identified by the surveillance of work-related and Occupational Respiratory Diseases programmes in South Africa. *Clinical and Experimental Allergy*, 31, 32-9.
- ³⁹⁶ Yang, C., Peng, X., Huang, W. et al. (2011). A time-stratified case-crossover study of fine particulate matter air pollution and mortality in Guangzhou, China. *International Archives of Occupational and Environmental Health*, Sep 30. [Epub ahead of print]
- ³⁹⁷ Saiyed, H.N., Tiwari, R.R. (2004). Occupational health research in India. *Industrial Health*, 42, 141-148.

Global Chemicals Outlook

Chapter II: Economic Implications of the Trends in Chemicals Production, Trade and Use

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Economic Terms Glossary

Benefits of Action	The full benefits to society of implementing policies. Attention should be paid to both financial and non-market impacts on all stakeholders and how these are shared across society.
Costs of Action	The cost of implementing policies. Attention should be paid to both financial and non-market impacts on all stakeholders and how these are shared across society. Efficiency considerations in the macroeconomy are key. The emphasis from the government perspective tends to be on financial costs of policy administration, training and new technologies.
Costs of Inaction	These are essentially the <i>true</i> costs of not implementing policies, specifically including negative financial and non-market impacts on all stakeholders, and how these are shared across society. Are they the true costs or indicative of the net costs (not considering the costs imposed by removing funding from other priorities in order to implement chemicals)?
Diminishing Marginal Returns	As the amount of any one input is increased, holding all other inputs constant, the amount that output increases for each additional unit of the expanding input will generally decrease.
Economic	The main indicator of economic development is increasing gross domestic product GDP per capita, reflecting an increase in the economic productivity and average material wellbeing of a country's population. Economic development is closely linked with economic growth - changes or expansion in a country's economy. Economic growth is conventionally measured as the percentage increase in GDP during one year.
Externalities	Externalities arise when certain actions of producers or consumers have unintended effects on other actors in society (firms and individuals) for which no compensation is exchanged. Externalities may be positive or negative. Pollution is used as the classic example of a negative externality.
Labour Productivity	The amount of goods and services that a worker produces in a given amount of time.
Market Failure	Market failure occurs when all costs of production do not fall exclusively on producers (i.e. externalities), nor are reflected in the price of the product or service. The natural consequence of artificially cheap production and consumption is overproduction and excess consumption – both of which lead to unsustainable depletion of natural resources and pollution, which imposes further costs on society as a whole.
Net Social Benefit (Cost)	Economic assessment frameworks weigh costs of policy implementation against financial and monetized non-market impacts, positive and negative, of that policy change, in theory reflecting economic values of all stakeholders over distance and time. If the overall benefit of the policy is estimated to be higher than the costs that arise from implementing that policy, then the policy has a net social benefit. If the opposite is true, the planned policy action brings about a net social cost.
Non-market impacts	Since observable market prices do not generally exist for an environmental good or common (in this sense it is a value of the actual common or value of the environmental good such clean air, clean water, clean soil, etc), the marginal social cost of damage to the environmental good or common is not usually readily available in monetary terms.
Opportunity Cost	The cost of any activity measured in terms of the value of the next best alternative foregone (lost benefit).
Policy Action	Policy action is any improvement in how chemicals policies are designed, enacted, implemented and enforced beyond the baseline, or status quo, situation.
Productivity	The ratio of inputs to outputs for a specific production situation.

1. Introduction

Policymaking is a question of trade-offs. When it comes to chemicals, a lack of evidence for the necessity of improved global management has undermined the efforts of even the most persistent policy-makers to argue the case for preventative approaches. The result is an investment in capacity for sound management of chemicals that has widely been acknowledged as lacking.

Industry and government costs of sound management of chemicals policies are better understood than the benefits of such policies. An asymmetrical analysis such as this means that nothing clear is known of the net outcome of investing in chemicals management, making further investment difficult to justify for both industry and governments, particularly in developing countries and countries in transition. This is particularly true when financing sound management of chemicals requires diverting funds from some other worthy policy goal, or where scarce financial resources are strained as in developing countries and economies in transition (DCEITs).

Without a full economic analysis, it can only be hypothesized that investment in improving capacity for chemicals management in developing countries will result in higher net societal benefits. Yet, considering the magnitude of unheeded opportunity costs from poor resourcing of sound management of chemicals, suggests that: 1) financial and external costs may be significant enough to tip the balance if fully priced and internalized in markets and 2) the tradeoffs between chemicals management and other funding priorities might not be quite so stark. In reality, investment in improved management of chemicals production, use and disposal equates to investment in industrial development, health, education and other priority areas. Poor chemicals management detracts from progress on these fronts and more.

Despite the evidence for a healthy environment being a core component of pro-poor economic growth, scientific conservation or moral arguments have rarely proven sufficient to make the case for investment in environmental sustainability. What has been successful, however, is giving economic evidence to economic and development planners proving the environmental contribution to overall societal welfare. To date, weak economic research and communication concerning the foregone benefits of sound chemicals management has ultimately led to failure to integrate chemicals management priorities into national government planning authorities and industry strategies.

Based on secondary analysis of existing data, this analysis examines values of observed trends in chemicals production, consumption and disposal. Global Chemicals Outlook chapter II considers a broad array of economic implications of the trends observed for the synthetic chemicals and toxic metals discussed in Chapter I. Internal and external costs are reflected across two categories – financial implications for industry and monetized values for human health and environmental degradation from mismanagement across chemicals lifecycles. In considering the full range of implications, both ‘hidden’ and ‘visible’ benefits from investment in sound management of chemicals are brought to the fore.

The *Global Chemicals Outlook* does not estimate the total value of financial impacts, human health and ecosystem services¹ benefits from sound management of chemicals. Rather, the valuations presented here are broadly categorized under ‘potential avoided costs and broader benefits under a scenario of investment in sound management of chemicals keeping pace with the needs generated by increasing chemicals intensification in DCEITs. Where data is missing, this gap is highlighted in discussions resulting in a holistic discussion of the likely global benefits from sound management of chemicals.

1.1 Policy Inaction in the Context of Chemicals Production, Consumption and Disposal Intensification Trends

In practical terms, the aim of sound management of chemicals policies is to protect human health and the environment, mitigate costs, enhance benefits and manage preparedness for future risks from problematic chemicals amenable to safer management as envisioned by SAICM and chemical regulatory programmes.

Many countries have the fundamentals of law to manage chemicals, but the implementation is poorly supported; thus, it is fragmented and ineffective. Moreover, all chemicals risks of concern in developing countries exist in developed countries, though most are managed much more effectively. What is lacking is the transfer of ‘know how’ and experience in managing chemicals risks from industrialized to developing countries. As such, the fundamental points of policy inaction in the context of trends in chemicals production, consumption and disposal are:

1. Further investment in chemical policy development (where required) and implementation globally, and
2. Increased transfer of chemicals management experience to DCEITs, in keeping with the pace of economic development.

Action also includes responses from industry, and cooperation between public and private sectors. Core questions concerning the political and economic realities of allocating resources to support action arise in every regulatory process and in every private investment decision; however, because governments and companies rarely have unlimited resources.² Choices have to be made. In making these decisions, typically some ‘weighing up’ of costs versus benefits is conducted either formally or informally, and the net impact of various options compared.

In perfect market conditions, further policy intervention on chemicals management may not be necessary because every actor should share the goal of minimizing risks from chemicals mismanagement. The concerns around safe chemicals management centre on situations of market failure caused by externalities. However where health and environment impacts are borne by individuals and firms across society – or external to chemicals-related economic activities – this gives chemicals producers and users weaker motivations to ensure that chemicals are managed soundly throughout their lifecycles. Externalities are often unpriced (or non-market³) – and are impossible to accurately quantify, though economic valuation and analysis techniques exist to generate reasonable estimates.⁴

Even when ‘priced’, health and environment-related external costs can be overlooked because they are too indirect (e.g. private costs of illness), are not documented or are grossly underestimated. Despite its limitations⁵, economic analysis allows important external values to be monetized and included to help balance decision-making processes. This is a crucial function of this type of analysis because industry and government costs of meeting chemicals policy requirements are typically much better understood than the benefits of such actions. Costs are measured in financial terms,⁶ whereas, on the contrary, investments in sound management of chemicals are made for precautionary, legal, cultural, political and other not easily quantifiable reasons that nevertheless have value for society.

In a public governance context, economic analysis determines the impact of a project or programme on society, not only in terms of direct monetary benefits, but also with wider impacts not included in standard financial analyses. Externalities assessment is also becoming increasingly important to industry both as custodians of shareholder’s investments and fulfilling their broader role in society.⁷

1.2 Defining the Economic Implications of Chemicals Intensification in DCEITs

The baseline scenario for the current analysis reflects the point of departure for many decision-makers in both the public and private spheres: no further investment in chemicals policies or transfer of management ‘know-how’ achieved in poorly-resourced countries currently experiencing the fastest growth in chemicals production, consumption and disposal challenges.

Given that *costs of action* are relatively well understood, this analysis focuses exclusively on the benefits of any improvement beyond the baseline scenario. Using existing data, it assimilates a broad array of economic evidence to analyze:

1. **Avoided costs:** the economic costs of the chemical production, consumption and disposal trends to 2020 noted in Chapter I, assuming a baseline of policy insufficiency (i.e. no further action) in the context of chemicals intensification trends in DCEITs; and
2. **Further benefits:** the development benefits that could accrue from enhanced policy action on sound management of chemicals for DCEITs, and others, to be discussed in Chapter III.

Financial and external costs associated with the documented trends in Chapter I that could be otherwise avoided through sound management of chemicals include: 1) financial costs to the chemicals and related industries, and 2) financial and non-market external health and environment costs (Sections 2 and 3). Knowledge-based, preventive approaches to chemicals risk management can create additional benefits beyond ‘avoided costs’ in the form of improved production and resource efficiencies, trade and investment, innovation and employment impacts (Section 4).

Clearly, this is not a complete economic analysis setting out to prove that investments in chemicals management yield higher net benefits than other potential investments. It is but one side of the equation that in practice needs to be applied in specific corporate, regional or national situations and compared with a judicious cost assessment; in turn, the results would then be weighed up against the net returns of other options for ‘action’. Nevertheless, a useful framework defining the economic benefit of sound management of chemicals in the context of chemicals intensification trends is created in the course of this analysis and supported with the most complete review of existing relevant evidence.

1.3 Why Inaction on Sound Management of Chemicals is Likely to be Costly

If chemicals are crucial to development, safe and effective management of chemicals as envisaged by the WSSD 2020 goal is integral to sustainable development.

Three distinct strands of increasing chemical intensity link the costs and trends documented to country-specific development:

1. **The shift in industrial production and use of chemicals to DCEITs.** The chemical manufacturing and processing industry, once largely located in the highly industrialized countries, is now steadily expanding into developing countries and countries with economies in transition. Some of the fastest growing segments of the bulk and agricultural chemical industries are now located in China, India, Russia and Brazil; however, new chemical manufacture and processing facilities can today be found in countries ranging from Indonesia and Thailand to Nigeria and South Africa.
2. **The ongoing agricultural use of chemicals in a number of developing countries.** Agricultural chemicals and pesticides used in farming were among the first synthetic chemicals to diffuse into developing countries and continue to be among the most important flow of chemicals for these countries.

- 3. The increasing consumption in developing countries of products posing particular chemical use or life-cycle challenges.** Highly formulated chemical personal care products, paints, adhesives, lubricants and chemically complex articles such as cell phones and laptops are being purchased and used in regions of the world recently thought to be underdeveloped and remote. Indeed, the consumption of chemicals in developing countries is growing at a rate such that one third of all chemical consumption may be in developing countries by 2020.⁸

There are several implications from the shift of chemicals production from developed to developing countries: the supply chain is longer, and therefore harder to manage, and products are more likely to fail to meet health and safety standards. Recourse against those parties originally responsible for the failure is more difficult, leaving consumers ‘downstream’ or public bodies in the end-markets to carry the cost. Within developing countries, risk management standards are generally less rigorous than in industrialized economies, so that risks of local accidents are relatively higher in DCEITs. The intensification of the use of chemicals means that the scope for unintended ‘incidents’ is growing rapidly; this is compounded by the introduction of numerous novel compounds, which may by themselves, or in combination with others, generate new (emerging) risks.

As this chemical intensity increases, the prospect for widespread and multifaceted exposures of communities and the environment to chemicals of high and unknown concern also increases. The trans-boundary movement of synthetic chemicals resulting from the transport mechanisms of environmental media such as air and water adds to this chemical intensity. While each of these sources contributes only a fraction of the environmental load in each country, together they form an increasingly significant and complex background mix (the “cocktail effect”) of synthetic chemicals not present 50 years ago.

The private costs for industry associated with these risks have not been reviewed systematically, nor explored much beyond the topic of industrial accidents and disasters. UNEP commissioned a report, *Risks to the Financial Sector from Chemicals* (Dlugolecki and Cochran 2012), as a major endeavor to surmount this crucial gap in the wider understanding of economic benefits of fulfilling the SAICM 2020 goal. This study explores the way in which the financial sector (insurance, banking and asset management) interacts with the chemical sector. Currently, the attention given to chemical sector risks varies within this sector. The insurance industry is cautious about involvement with ill-defined risks with potential for major costs. Banks have tended to ignore ‘soft’ issues generally when providing credit or financial services. A growing number of institutional investors do consider Environmental and Social Governance (ESG)⁹ issues, but this is relatively new. Given the increasingly strict regulation of insurance and banking solvency, which will lead to less risk-taking (i.e. reduction in exposure to the chemicals industry), it seems unlikely that these branches of the finance industry are strong levers for the public sector to create a sustainable chemicals industry through the sector’s financial relationships. However, a significant element of global stock markets is made up shares in chemical companies and companies that depend critically on chemicals, so movements in their value are of major concern to institutional investors. In recent years there have been approaches by Socially Responsible Investments (SRI)¹⁰ investors and policymakers, in alliance with NGO’s, seeking to create a more comprehensive regulatory framework for managing chemicals risks.

Economic data from US and Europe, among others, give some clues as to external costs, their magnitude and the longevity of this legacy in industrialized countries. The UNEP Costs of Inaction (COI) Initiative reviews relevant cost information in the COI Baseline Assessment Report (2011), including information from developing and emerging economies where available. The findings tell of many knowledge gaps, but what information is available gives indications of significant costs. New estimates on occupational health costs from pesticides in sub-Saharan Africa give an indication of just how these costs are. A study conducted in parallel to the *COI Baseline Assessment Report* (2011) estimates total health-related pesticide costs for smallholders in sub-Saharan Africa from 2005-2020 at US\$ 90 billion, assuming a continued scenario of inadequate capacity for pesticides management in this region. This highly conservative estimate has important implications for development assistance – and as a pointed comparison, total 2009 Overseas Development Assistance (ODA) to the Health Sector in sub-Saharan Africa for just basic health services was US\$ 4.8 billion. In the same year, this was probably exceeded by annualized occupational health costs associated with pesticides, estimated at US\$ 6.2 billion.¹¹

The costs of inaction data demonstrates a potentially broad pattern of avoided costs from pollution prevention efforts – but sound management of chemicals will benefit countries and regions beyond just cost savings. UNEP’s Green Economy Report (2011) makes the economic and social case for investing just 2 per cent of global GDP in greening ten central economic sectors. The chemicals sector contributes to economic development mainly through the value of chemicals products and products containing chemicals (technological contribution) and direct employment. Sound management principles and action help to maximize this contribution, paving the way for a green economy to emerge.

The list and quantification of benefits assessed in the following discussion is not complete, but it does show unheeded *opportunity costs* from poor resourcing of sound management of chemicals and suggests that financial and external costs may be significant enough to tip the balance if fully priced and internalized in markets. Although difficult to quantify, risks associated with a disjointed, under-resourced approach to chemicals policy implementation are likely to be considerable. Moreover, potential opportunities for progress on sustainable economic development and poverty alleviation are boundless. In reality, investment in improved management of the chemicals life-cycle (i.e. production, transport, use and disposal) equates to investment in industrial development, health, education and other priority areas. Poor chemicals management detracts from progress on these, fronts and more. As such, the suggested trade-off between chemicals and other funding priorities might not be quite so stark as is believed.

2. Financial Implications of Chapter I Trends

Costs of Inaction for the Chemicals Industry and Related Sectors¹²

Although disastrous chemicals incidents make the headlines, the true costs of chemical mismanagement are dispersed and hidden throughout the population and over time. Such costs are typically carried by a nation’s social welfare system and its’ citizens, because often these are greater than the resources of the corporation that created the problem. Despite all efforts to “make the polluter pay”, much of the cost of pollution clean-up also falls upon the public sector. The polluter does pay somewhat, however, and certain enterprises in chemicals and related industries have been seriously affected by chemicals mismanagement events. Poor management of chemicals across lifecycles contributes to inefficiencies in the chemicals industry, with increased risks of unintended ‘incidents’ leading to higher insurance costs, loss of productivity and adverse reputation impacts, with consequent loss of asset value. Chemicals intensification of DCEITs with inadequate policies and regulations, may increase financial risks even further for laggard companies and countries.

2.1 Public-Private Sharing of Responsibility for Sound Management of Chemicals in the Context of Chemicals Intensification

Governments cannot deliver safe chemicals management alone. The current structure of the global chemicals market – in which private actors generally produce, handle and use chemicals – means that industry must, and does, carry the main responsibility for ensuring safe use of chemicals.¹³ Furthermore, there must be shared responsibility between firms down the value-chain in order to maintain appropriate risk management of any product or service.

Many developed countries have transferred significant portions of the tasks involved by sound management of chemicals to the private sector and away from governmental institutions. This approach requires state capacity for ensuring enforcement and compliance with the law. Private companies have the responsibility of performing the tasks required by chemicals risk management, i.e. identification and assessment of chemicals’ hazardous properties and risks, dissemination of hazard, risk and safety information and making informed choice of chemicals to be placed on

the market and organization of safe use. Public authorities have the responsibility to ensure these tasks are performed correctly, i.e. organization of safe use and compliance monitoring.¹⁴ A key challenge is to continue extending these practices deep into DCEITs.

One mechanism available to governments for use to fulfill its responsibility is legislation pertaining to product, environmental damage and other forms of liability. In recent years, collective redress, born of the “mass tort” approach inspired by asbestos has become an increasingly common approach throughout the world for groups of victims wishing to undertake costly litigation in cases against large international corporations and governments.¹⁵

Insurance is one of the last stages in the process of risk management; well-governed companies understand the need to first avoid risks if possible by taking safer alternatives, and next reduce unavoidable risks by physical and social risk management. Only then should risk transfer through insurance be considered. Over recent decades, companies involved in chemical-related activities have responded to this fact, and the difficulty and cost of obtaining liability insurance, by:

- Forming trade associations with positive risk management approaches, including adopting self-imposed standards;
- Recognising that they have to attract insurers, not vice-versa;
- Seeking out specialist insurance brokers and specialist insurers;
- Self-insuring, using captives where possible;
- Forming mutuals, e.g. Primex (though this is unusual); and
- Seeking government support for the formation of insurance pools.

The global chemical industry has major active programmes in Responsible Care and the Global Product Strategy, as well as long-standing support for UNEP’s APELL programme (See Box 16, Section 4.4), to facilitate progress. Similarly, the global crop protection industry has its own programme (including its involvement with the African Stockpiles Programme), and so do other industries. In terms of broader industry engagement, the International Organization for Standardization (ISO) standard-setting process is a far-reaching quasi-regulatory effort driven by the benefits to industry of responsible, harmonized global standards to enable harmonization. Increasingly, these are being directed at sustainability goals, as industries come to realize that global expectations of responsible corporate citizenship increasingly demand better performance on this front, i.e. ISO 14000s and ISO 16000s.

While some corporations currently pursue such improvements, many more have not made commitments to moving towards improved management of chemicals in the future. These enterprises potentially create new supply risks for themselves, their markets and financiers.

2.2 Global Chemicals Supply Chain Risks for Industry in the Context of Chemicals Intensification

With globalization and other business practices such as ‘just-in-time’ stock control, chemicals supply-chains have altered radically (See Figure 1). Supply-chain risks rank high in the concerns of international chemical companies. An interruption in the supply of a key raw material (even one used in very small quantities) has the potential to disrupt an entire production line, with knock-on effects for other suppliers as well as customers. The most significant ones for international chemical companies are the potential impact of natural catastrophes or political unrest. A recent study has revealed that a natural catastrophe in China on the scale of the 2011 Japan earthquake and tsunami would have a very severe impact on supply chains in many industries, given China’s critical role in global manufacturing¹⁶. Another example is the recent political unrest in Egypt which seriously affected Egyptian chemical manufacturers as well as Saudi Arabian manufacturers wishing to use Egyptian ports.

The “typical” supply chain used by international chemical companies comprises a mixture of owned and outsourced manufacturing, with a large supplier base scattered around the world. Tracking raw material and intermediate product suppliers (for example, knowing where production facilities are - not just the location of sales offices - and ensuring compliant manufacturing standards) is a major but necessary aspect of risk management, particularly in those countries where regulation is weak. Improving the resiliency of supply chains makes good business sense. In addition, end-customers are increasingly requiring such action and demanding enforcement through regulation.

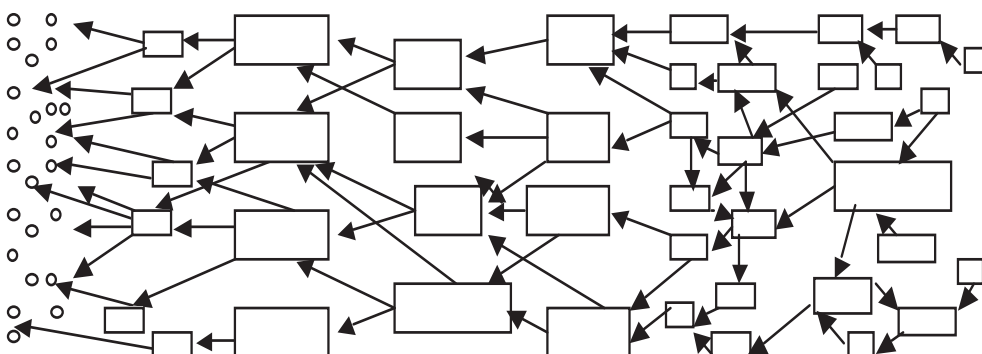
The role of commodity brokers and traders (who produce nothing and often never handle goods) has been specifically highlighted in the recent amendment of an EC Directive (2001/83/EC, as amended by 2011/62/EU) dealing with the counterfeiting of pharmaceuticals. Given the very significant role of such intermediaries (and the sharp rise in the seizure of counterfeit and sub-standard medicines which have penetrated the lawful supply chain), they are all now to be considered “wholesalers”, subject to registration and compliance audits. The directive also introduces important requirements in respect of traceability and product integrity.

In respect to the latter, the requirement that the manufacture of active pharmaceutical ingredients (APIs) conforms to Good Manufacturing Practice, irrespective of where they are produced, would appear to address issues relevant not only to the integrity of the final product and its ingredients, but also to the manner in which pharmaceuticals are produced. It is also important to note the common use of excipients, which can also be a source of problems. An excipient is any intentionally added component of a finished pharmaceutical product other than the claimed therapeutic or diagnostic ingredient(s). Excipients are added to facilitate administration or manufacture, improve product delivery, promote the consistent release and bioavailability of the drug, enhance stability, assist in product identification, or enhance other product characteristics.

The fact is that regulation is weaker in developing countries, where greater expansion of chemicals production and use is taking place, makes it more likely that errors and counterfeiting incidents will increase, with more product recalls and higher risks for industrial disasters.

Figure 1. Increasing Supply Chain Risks

Customers	Depots	Ware-houses	Packaging & Labelling	Making end-product	Brokers & traders	Manufacturers & suppliers of bulk chemicals, API's & excipients
Myriads	Many	Several	Several	Several	Many	Many
Independent	In-house/ indep. ^t	In-house or outsourced			Independent	In-house or outsourced or supplier



The Association for Sustainable & Responsible Investment in Asia (ASRIA 2007) reported that the Asian supply chain to Europe and North America “is brittle and unprepared to address many of the emerging toxic chemical issues.”¹⁷ Their analysis suggests that this is due to more permissive regulation and the fact that safer supply chains are more expensive and therefore can be undercut by lower cost producers. One over-riding problem is the prevalence of mislabelled bulk chemicals in the Chinese market. It is common for suppliers to substitute locally available, often sub-standard chemicals for international standard products in the view that end consumers will not be able to detect the difference. Frequently “compliance” with health and safety or environmental standards, where these exist, has come to mean one compliant manufacturing line in a factory with multiple lines. A further complicating factor for contingency planning is that consumer electronics manufacturers will not often commit to a new safer component which cannot be second-sourced from a competing supplier.

The question of where the burden of risk falls, either physical or financial, depends on how complex the supply chain is, as well as the various regulatory regimes that are involved. It is not possible to give a global estimate of the economic chemicals risk to chemicals industry or indirectly to the finance sector because the data to assess these risks are limited and have not yet been analyzed. Looking to the insurance sector for a substitute risk assessment, as has been done in the case of costs of climate change¹⁸, is not satisfactory, because coverage is so limited and the risks are not well-studied.

The total amount of insurance capacity available to support chemical liability risks (including pharmaceuticals) has been estimated at US\$ 2,500 million (US\$ 2.5 billion) for the world as a whole, in one year. In other words, if all the possible liability policies were purchased and then paid out in full, the total pay-out would be about US\$ 2.5 billion (note this excludes first-party property damage to the chemical plant, and also excludes lost sales) The actual purchase is far below this according to observers, and is tiny compared to the annual sales of the global chemical industry (including pharmaceuticals) of over US\$ 4,000 billion (US\$ 4 trillion) in 2010 (See GCO, Chapter I).

Indeed, the prospect of emerging or novel risks makes the global chemicals risk unknowable. To contribute to filling this gap, this analysis looks at what information exists concerning private costs to industry of chemicals mismanagement within the following framework: 1) Disasters, technical and natural; 2) Occupational hazards, illness and injury; 3) Improper waste management; and 4) Downstream risks in consumer products.

2.2.1 Costs of Technical (Man-made) and Natural Disasters Related to Chemicals Mismanagement

Major incidents can happen during the processing, storage or transport of potentially hazardous chemicals; occasionally, these are though frequent enough that their prevention is a high priority for industry and public authorities. These events put workers and local communities at risk, both in the immediate aftermath and over the longer term where persistent toxics and latent disease are concerned. They also can place a severe financial burden on responsible parties and local economies.

For 2010, Swiss Re’s *Sigma* analysis on natural catastrophes and man-made disasters estimates the costs of man-made disasters at US\$ 3 billion, out of a total of US\$ 218 billion disaster-related economic losses for the year. There are important biases in these reports and impacts or cost for impaired lives of workers or communities are not included, but interestingly, they show that many of the most costly man-made disasters (in monetary terms) involved fires or explosions in industrial plants, damage to pipelines and tanker crashes.¹⁹

The Swiss Re *Sigma* reports do not detail the extent to which the poor handling of chemicals played a causal role in these incidents and/or whether the effects included significant chemical-related damage. Nevertheless, analyzing the reports allows the key observation to be made: not every incident related to a chemical-related enterprise necessarily reflects chemicals mismanagement, but the presence of chemicals may increase the severity of the incident. Secondly, insurance is often not involved in chemical-related incidents and disasters meaning that very large multinational companies rely

to a large degree on their own resources while small to medium sized enterprises (SMEs) sometimes cannot or do not purchase the relevant insurance.

Incidents involving chemicals have many historical examples in industrialized countries (See Box 1); and these still occur quite frequently. The difference now is that, for the most part, government and industry work better together to minimize the impacts of such incidents when they do occur. For example, at Bamberg, Germany on 18 July, 2008 poisonous fumes escaped during the anti-rust treatment of metal parts at an automotive parts supplier, Bosch GmbH injuring 128 people. Yet production resumed several hours after the incident. Apart from the initial report of the incident, there is no further reference to it in the media, presumably because the workers affected received immediate, appropriate health care and their earnings were protected.²⁰

Box 1. The Seveso Disaster: A Wake-up Call on Lack of Industrial Disaster Preparedness

On 10 July 1976, an explosion occurred at the ICMESA chemical company in Meda, Italy, a subsidiary of Swiss multinational Roche. High concentrations of TCDD, a highly toxic form of dioxin were emitted into the air. Downwind from the factory the dioxin cloud polluted a densely populated area, including Seveso village, which later gave its name to the disaster.

Local and regional authorities did not foresee that the plant was a source of risk. “The reason for this particular accident becoming such a symbol is because it exposed the serious flaws in the response to industrial accidents. The disaster brought home the need to combine industrial development with the protection of our citizens and the quality of the environment”: so said Stavros Dimas, EU Commissioner for the Environment in 2006 at the 30th commemoration of the disaster. The European ‘Seveso’ Directive was created to prevent such ignorance in the future and to enhance industrial safety, and was adopted in 1982. It obligates appropriate safety measures, and also public information on major industrial hazards, which is now known as the ‘need to know’ principle.

Seveso is considered an open case on the health impacts of dioxin though epidemiological studies are underway that are confirming long term dioxin health effects. Using data from Seveso, Mocarelli et al. (2011) have recently produced the “first human study to show that dioxin exposure during development may permanently impair sperm production in adulthood”. Victims were compensated directly by the multinational with instruments of private settlement for material losses. The Italian State, the Lombardy region and affected municipalities also received financial compensation. Notably, no public discussion took place concerning the criteria for compensation and the way to invest the compensation given to public actors.

Source: Centemeri (2008) discusses the impact of Seveso in European legislation development; Barrett (2011) discusses Mocarelli et al. (2011).

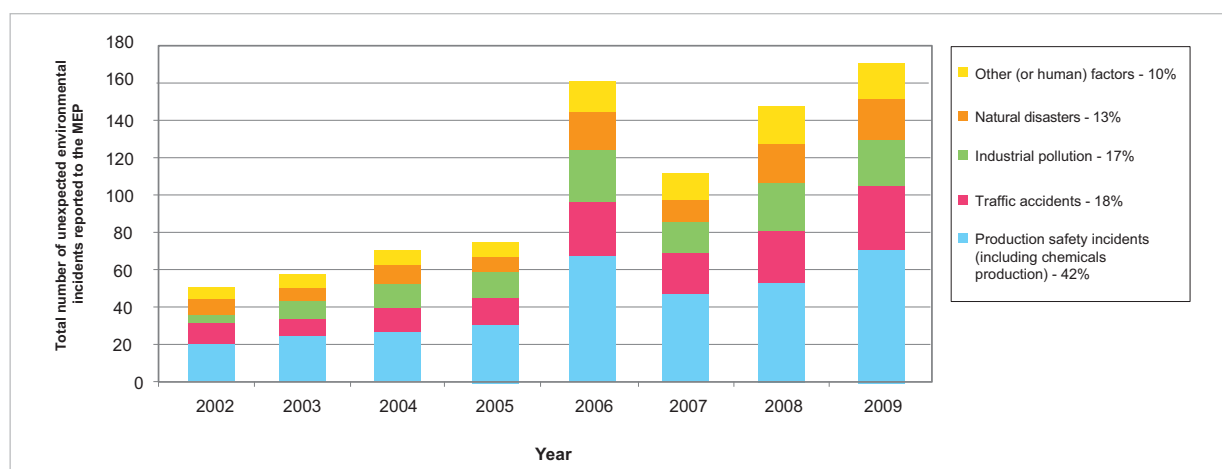
China plays a significant role in industrial incidents reported today, doubtless reflecting the growing level of industrial activity in that country. China is now one of the largest countries in the world for chemical production and consumption. A wide variety of chemical enterprises are represented within the country. While growth in the chemical sector has been a valuable element of China’s social and economic development, the chemical industry also presents the significant risk of accidents that may cause severe impacts on human health as well as environmental and financial losses.²¹

China’s chemical industry has undergone notable rapid growth in recent years, and it is estimated that over 35,000 large petroleum and chemical enterprises in the country produce over 40,000 different types of products. In 2010, it was estimated that the industrial output of these enterprises accounted for 22.1 per cent of China’s gross domestic product.

In spite of the concerted efforts made by the government, enterprises, research institutes, and other stakeholders to prevent chemical accidents, their number is nevertheless increasing annually. According to national statistics, in 2008 the total number of accidents recorded and handled by the Ministry of Environmental Protection of the People’s Republic of China (MEP) was 135, an increase of 22.7 per cent compared to 2007 (See Figure 2). Two high-profile accidents brought increased attention to the issue in particular:

- In November 2005, an explosion at the Jilin Petrochemical Company resulted in eight deaths, over 60 injuries, and the evacuation of 10,000 people. The explosion caused benzene (a toxic, carcinogenic chemical) to flow into the Songhua River, causing widespread water pollution that affected hundreds of kilometres of the waterway in China and Russia. The pollution halted water supply to the city of Harbin, home to approximately 3.4 million people, for days. This was a landmark event for chemicals management in China.
- An explosion at an organic chemical facility in Hechi City resulted in 21 deaths, 60 injuries, and the evacuation of more than 11,000 people in August 2008. According to the Deputy Chief Administrator of the State Administration of Work Safety, this was the deadliest chemical accident to occur in China of the past decade.

Figure 2. Growing Incidence of Unexpected Environmental Accidents as Reported to the Ministry of Environmental Protection (MEP) in the People's Republic of China (2002-2009)



Note: Generated based on data contained in two presentations by Professor Zhao Jinsong, Department of Chemical Engineering, Tsinghua University Research Center of Accident Prevention and Emergency in Chemical Process 1) "Analysis on Hazard and Operability", UNEP SCP APELL Workshop 26-27 April, 2010, Zhangjiagang. The Office of Emergency Command Leading Group at the Ministry of Environmental Protection compiled the underlying data in 2008 and 2009. The percentages relate to data for 2008 that were used as the baseline for all years; and 2) "Process Safety and HAZOP" UNEP's Global APELL 25th Anniversary Forum held in Beijing, China on 14-18 November 2011.

Operation of relatively out dated equipment, inadequate safety management, operational errors, and procedure violations prevail as the most common causes of chemical accidents in China. This is particularly true in smaller operations, including those that use, transport, store or dispose of hazardous chemicals – a problem that plagues all countries.

Risks are further compounded by the relatively vast geographical dispersion of facilities throughout the country and their location in or next to urban areas and along rivers (primarily the Yangtze, Huanghe, Pearl and Songhua rivers) and coasts, thus posing a risk of contaminating drinking water supplies.

Some costs associated with these types of incidents have been documented by Chinese authorities. In 2006, it is estimated that accidents in the petrochemical industry caused losses of approximately US\$ 11 billion (75 billion Yuan). The explosion accident in 2008 at the Guangwei Group in Hechi city is estimated to have direct costs of approximately US\$ 11 million (more than 75 million Yuan RMB). These figures do not reflect the injuries, loss of human life or environmental damage. Estimates from industrial incidents in industrialized countries show the potential scope for future costs in China and other emerging economies (See Box 2).

Box 2. Three Examples of the Cost of Industrial Accidents in the EU and US

- Pasadena, Texas, October 1989. A series of explosions at the Phillips Houston Chemical Complex (HCC) killed 23 and injured 314 others. It cost an estimated US\$ 1,456 million (US\$ 1.45 billion) in 1996 US dollar terms. A large portion of these costs are attributed to additional business disruption. Source: Fewtrell and Hirst (1998)
- Toulouse, France, 21 September 2001. An explosion of ammonium nitrate causing 30 fatalities and an estimated 10,000 injuries. Estimated damage costs of approximately €1.5 billion (US\$ 1.8 billion in 2011 terms). Available from <http://www.grida.no/publications/et/ep3/page/2607.aspx>
- Buncefield, United Kingdom, December 2005. The Buncefield oil storage depot incident was the biggest explosion and fire in peace-time Europe. 200 people required immediate medical attention and 3,408 litigants subsequently sought damages. The total cost of the incident was estimated at £1 billion (US\$ 1.5 billion in 2011 dollar terms). A four month trial concluded in July 2010, with five companies being found guilty and ordered to pay a total of £9.5 million (US\$ 14.6 million) in fines and costs.

Source: British Government website on the Buncefield disaster.
Available from <http://www.buncefieldinvestigation.gov.uk/index.htm>; Hiles (2010)

According to the China Petroleum and Chemical Industry Federation (CPCIF), there are 189 main provincial chemical parks and industrial parks across 25 provinces, municipalities and autonomous regions in China (except Guangdong, Guangxi, Qinghai, Xizang, Anhui and Guizhou). In total, there may be more than 1,000 chemical parks and chemical clusters existing or under construction within the country. In and of themselves, these parks are a good innovation for sharing chemicals risk management knowledge, technology and experience. They concentrate awareness and response facilities and potentially reduce risks of transportation-related accidents for feedstocks. However, less than 100 of these new parks have been planned or constructed integrating the necessary management capabilities on safety and environmental protection²². This increases the probability of “domino-effect” accidents due to the large quantity and variety of chemicals and hazardous installations in close proximity to one another, where the consequences of an accident can trigger further accidents in other facilities.

Similar reasoning has led to concerns over natural disasters and direct/indirect releases of hazardous materials. Young et al. (2004) review a long list of natural–technologic events in the United States for flood, earthquake and volcanic events. Of greatest concern, are large-scale unintentional releases from industrial, waste and agricultural sites located near water sources, streams, rivers or coastlines during flooding; earthquake instigated releases and fires²³; accidents in the transport of hazardous cargo on ash-covered roads after volcanic eruptions. It is not clear what preventative action can be taken, if any, to mitigate such releases. However, some hazardous materials may be intentionally discharged after floods and hurricanes for pest control or to counteract contamination, and these are amenable to safe management practices. Moreover, US GAO (2011) discusses how landfills used for the disposal of debris created by disasters may also contain hazardous waste that could have long-term, negative environmental impacts if not well managed. For example, a Louisiana emergency order authorized some potentially hazardous materials to be disposed of in landfills not equipped for such waste in the aftermath of Hurricane Katrina.

2.2.2 Costs of Occupational Hazards

Assessing the economic value of occupational illness and injury involves estimation of tangible costs of death, disability and medical treatment for workers, as well as the costs of treatment, transport and number of work days lost.

The costs from this type of exposure cannot be underrated. Leigh (2008) and others demonstrate that costs of occupational injury and illness are as large as total costs of cancer in the US indicating that this category must be taken seriously. In 2004, preventable diseases resulting from workplace chemical exposures cost California insurers, employers, workers, and their families a total of US\$ 1.4 billion in both direct medical costs and indirect costs, including

lost wages and benefits and lost years of productive life. According to the UK Health and Safety Executive (2011), an estimated 8,000 cancer deaths in Britain each year are attributable to past exposure to occupational carcinogens. Around half of these are asbestos related (including mesothelioma). Fifteen per cent of Chronic Obstructive Pulmonary Disease (COPD - including bronchitis and emphysema - may be work related. This suggests there could be some 4,000 COPD deaths each year due to past occupational exposures to fumes, chemicals and dusts.

In theory, those in riskier employment are compensated for the probability of harm through salary and other benefits, including health insurance. Judicial processes in many (but not all) countries are also an avenue for seeking additional compensation in the case of injury or death. Though an extreme example of the harm (and cost) generated by the mishandling of chemical substances, the ongoing asbestos story has fundamentally shaped attitudes towards risk within the chemical industry, and insurance industry, as reported by *Munich Re Group* (2009 2010).

The asbestos industry grew rapidly in the late nineteenthth century. The use of asbestos as a fire-retardant was thought to be a revolutionary and extremely effective new safety technology. It was adopted rapidly but the health effects were ignored, denied and hidden (although there were admitted difficulties in isolating the effects of asbestos from those of other diseases and other substances and from the effects of smoking and diffuse pollution) (See Box 8, Section 3.1.1).

With a latency period of 10 to 50 years, deaths from asbestos-related diseases have still to peak in the industrialized countries where asbestos was used in vast quantities throughout the Twentiethth century.²⁴ Even where the use of asbestos is now prohibited, it remains a significant risk for construction and demolition workers, in particular, as the substance is prevalent in existing buildings. According to the WHO (2004), there are currently 125 million people exposed to asbestos risk, most presumed to be in the informal construction sector of developing countries (where health insurance protection is largely lacking).²⁵

Compensation of asbestos-related diseases is the prototype for how industry and legal systems tackle emerging risks with global dimensions. It is the most complex of all complex damages: a global risk, taking different forms in different countries, a long-term risk which extends beyond the individual time horizons.²⁶ The compensation mechanisms involved include: “non-causal” insurances (health, life); workers’ compensation; employers’ liability; general liability; special compensation funds (employers/government); and, most notably, the tort system²⁷ in the US (and UK), and the birth of “mass tort” litigation, particularly in the US due to the immense potential costs for individuals of taking major corporations to court. Some of these mechanisms focus solely on workers, but many victims are not workers. It should be noted that contracts of insurance based on legal liability are not designed to provide immediate relief to the victims of such incidents, nor do they guarantee longer-term compensation funds.

RAND (2005) estimated that by 2002 compensation claims for asbestos-related injuries cost businesses and insurance companies in the US more than US\$ 70 billion. Future claims could cost businesses in the US in the range of US\$ 130 to 195 billion. In the US alone insurance claims related to asbestos have been estimated at between US\$ 100bn to US\$ 200bn, but many thousands more claims are filed each year.²⁸ Most of American manufacturers (80+ corporations) targeted by litigation have sought the protection of bankruptcy courts. More than 50 “trust funds” have been established, each with their own settlement rules. The current typical compensation for a mesothelioma victim is said to be US\$ 880,000, with as much as a third paid to the claimant’s lawyer. There remains significant issues regarding securing future claims.

In recent decades unilateral asbestos bans in developed countries have seen the manufacture of asbestos textiles and brake linings, for example, shift to countries with weaker regulatory environments, notably in Southeast Asia. However, throughout the developing world many more workers are exposed in the unregulated informal construction and demolition industries, including over 100,000 workers employed in shipbreaking sites in India and Bangladesh. With the consumption of asbestos expanding in eastern Europe and Asia, the adverse health effects of asbestos use will inevitably follow. In 2007, global consumption was 2.1m tonnes: 30 per cent in China, 15 per cent in India and 13 per cent in Russia.²⁹

2.2.3 Costs of Improper Waste Management

Most hazardous waste comes from industrial sources and requires special handling and treatment, even in small quantities, to avoid supply chain risks. Disposal options for hazardous waste include injection wells, incineration, and bioremediation, among others, but landfill is most commonly used in most countries, as hazardous waste cannot often be incinerated safely.³⁰

Failure to develop and implement waste policies enforcing better management practices leads to incidents that range from sudden disasters or long-term, insidious contamination where the hazardous by-products of chemicals production and use are concerned. The greatest concern with the disposal of hazardous waste in landfills or injection wells is that toxic substances will leak into surrounding groundwater aquifers, a major source of drinking water worldwide; and once contaminated it is extremely difficult and costly to remediate.

Poor liability laws and the relatively low-cost of landfilling and incineration lead to deficient investment in preventative or safer hazardous waste management systems by many firms and countries. The historical mishandling of toxic waste from industry in developed countries, most notably the US, has been credited in part for the birth of environmental management and the move towards making industry responsible for its waste worldwide.

In the US, first-of-its-kind legislation – the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) – was enacted in response to a need for remedial action on numerous pre-existing toxic waste dump sites and to ensure that the industry parties responsible for the mismanaged waste carried the cost burden for this work.³¹ Incidents such as these, and the policy responses to them, brought to the fore the principle of “polluter pays” – that industry had to accept stewardship of their pollution and waste from “cradle to grave”. Potentially Responsible Parties (PRPs) finance or conduct clean-up and remediation work, or contribute to the Superfund (as CERCLA is more commonly known) that finances such work at EPA-identified hazardous waste sites, including those most seriously contaminated sites on the National Priority List. The Superfund also received contributions from environmental fines and penalties, and until 1995, from excise taxes on petroleum and chemical feedstocks, as well as an environmental tax on industry. This fund covers the public cost for cleanups when the responsible parties are not identified or non-compliant (See Box 3).³²

Box 3. The Cost of administering the Superfund Program

The US EPA's Office of Solid Waste and Emergency Response (OSWER) is accountable for achieving Superfund's cleanup goals. US EPA receives annual appropriations from the Superfund trust fund for programme activities.

Since 1981, Superfund appropriations have amounted to US\$ 1.2 billion annually; portions of the US EPA's Superfund appropriation have also been transferred to other agencies or programmes that support site cleanup.

In fiscal years 1999 through 2007, US EPA spent 77 per cent of its Superfund monies on remedial and removal activities and almost all of the rest on enforcement and administration activities. US EPA's annual enforcement expenditures fell from US\$ 243 million to US\$ 187 million over this period, but they consistently accounted for 13-15 per cent of total Superfund expenditures. Superfund programme administration costs also declined from fiscal year 1999 through fiscal year 2007, from US\$ 143 million to US\$ 132 million. Although declining in constant dollars, these costs increased from 8-10 per cent of total Superfund expenditures during this period.

Note: Adapted from US GAO (2008) Superfund: Funding and Reported Costs of Enforcement and Administration Activities GAO-08-841R, 18 August 2008. Available from <http://www.gao.gov/products/GAO-08-841R>

On the date of its 30th Anniversary, Superfund had appropriated a total of US\$ 33.4 billion to the US EPA for its Superfund programme. The US Government Accountability Office (GAO) estimated in 2009 that additional private responsible party work at national priority listing (NPL) sites was worth US\$ 22.5 billion, but exactly how has been spent by industry is unknown as expenditure reporting is not required.

Are we beginning to see a repeat of history in emerging economies? On 4 October 2010, more than one million cubic metres of highly caustic waste escaped from a broken reservoir at an aluminium plant in Kolontar, western Hungary.³³ The highly alkaline and toxic deluge flowed through villages, streams and rivers into the Danube. This disaster left 10 dead, 150 injured and 7,120 homeless people; it poisoned Danube tributaries and has left in its wake widespread dust containing high content of heavy metals: arsenic, mercury and chrome. Total damage has been estimated at between US\$ 191 to US\$ 255 (€150 - €200) million, although effects expected to be long-lasting and costs may mount further over time.

The insured loss (held by a Hungarian insurer) was estimated at US\$ 4.7 (€3.7) million – totally inadequate cover for the extent of damage from the incident with no specialist cover for environmental liabilities. The Hungarian Aluminium Production and Trade Company (MAL Zrt), the aluminium manufacturer, claims it did nothing wrong and provided just US\$ 150,000 to help with clean-up (amounting to US\$ 504 for each family affected by the sludge). In September 2011, the Hungarian Government levied a US\$ 600 (€470) million fine on MAL Zrt. for environmental damage committed in the course of operating a waste facility for the storage of red sludge. The government has also promised that MAL Zrt. will not become bankrupt due to its economic importance in the local region.³⁴ The National Bureau of Investigation of Hungary is conducting an inquiry and has arranged for the assets of the former directors to be frozen. Currently, more than 30 legal actions have been taken by those affected, with the plaintiffs claiming a total of more than US\$ 24 million (HUF 6 billion) in damages.

Poor waste management in the context of increasing chemicals intensification in developing countries is a daunting prospect. A particularly worrying trend is the flow of hazardous waste transported to many developing world for treatment and final disposal. Much of this trade is in contravention of the Basel Convention on Transboundary Movements of Hazardous Waste, but the Liability and Compensation Protocol of the Basel Convention has so far been ratified by just 10 countries; it needs 20 ratifications to enter into force and therefore international mechanisms for implementing the “polluters pay principle” are lacking. Nevertheless, national tort processes and a global media have upped the stakes for multinational private operators found to be responsible for improper waste management.

As an example, in 2006 a ship leased (the ‘Probo Kola’) by Trafigura, a London-based oil trader, crossed the Atlantic with a shipment of coker gasoline.³⁵ Caustic washing of the coker gasoline at sea produced naphtha, sold upon arrival in the UK by Trafigura at a profit of approximately US\$ 19 million. The ship continued on the Port of Rotterdam in July 2006. In cleaning out the bilges, as is standard in the changeover of cargo, the Dutch waste management contractors noticed irregularities. After sampling and testing the bilge waste, the disposal company offered to continue the removal and treatment for what turned out to be hazardous by-product of the caustic washing process, but this was at a much higher cost. This offer of disposal for approximately US\$ 1.8 million was rejected by Trafigura, as was a second tender of US\$ 637,055 from a competing waste contractor. Instead, the Probo Kola took to sea again with its bilges full of hazardous ‘slops’.

In August 2006, the ship docked at Abidjan and paid “Compagnie Tommy” US\$ 23,436 to remove and dispose of the waste. This company had just received a waste management licence a number of days before the Probo Kola’s arrival in Cote d’Ivoire. The waste was disposed of at various open dumpsites around the Ivorian capital. Following this, 100,000 people sought medical attention; 30,000 people received medical treatment and 17 people died. The public health care system and the victims of the poisoning paid medical costs. Moreover, the national government had to use public funds to pay a private company for the retrieval, shipment and processing of the toxic waste in France.

In February 2007, Trafigura agreed to pay US\$ 198 (£100) million for clean-up and remediation, but would admit no liability (the jailed executives were released and the company exempted from legal proceedings in Cote d’Ivoire). Compensation payments of US\$ 50 (£30) million were made to 30,000 victims in September 2009 for medical treatment and “not an admission of liability” after Trafigura was pursued in the British courts. Trafigura was also fined US\$ 1.3 (€1) million in the Netherlands in 2010 for illegally exporting toxic waste to Africa. Costs paid out by Trafigura to date, on the basis of these figures, are approximately US\$ 250 million. Trafigura continues to deny responsibility, attributing the mismanagement to the third party it contracted in Abidjan. It obtained a super-injunction in the English courts to suppress press commentary and it continues to claim “...it is simply not possible that this material could have led to the deaths and widespread injuries alleged”.³⁶

2.2.4 Costs of Downstream Risks in Consumer Products

The relative visibility of sudden incidents means such incidents are registered more strongly in public appreciation and memory compared to those risks involving insidious damage over the long-term. Disasters are not typical incidents. However, smaller incidents can lead to significant damage and injury, the bankruptcy of individual businesses and the withdrawal of insurers from certain lines of business or particular types of risk. The final strand of this discussion on supply chain risks focuses on a crucial shift happening in how chemicals risks manifest.

Classic cases are those of chemically contaminated packaged food, household products, consumer electronics and children's plastic toys; relatively few people are injured, but products have to be recalled, the manufacturer or distributor loses market share to competitors, and the value of the company falls. This was the experience for the toy companies Mattel and RC2.

In 2007 RC2 had to issue three major product recalls due to toys from China that were coated with lead paint. The firm reported a cost of US\$ 18 million for product recall (ignoring the value of lost sales). However, the shares slumped by over 50 per cent in value, with a total loss of US\$ 458 million for investors in the company.

In the same year Mattel, a much larger toy firm with annual sales of US\$ 5.6 billion, had three major product recalls, involving over 20 million items, mainly due to lead paint on Chinese imports. On 2 August 2007, Mattel announced that it had taken a charge of US\$ 29 million to cover the cost of these product recalls. One of the Chinese suppliers ceased trading and the co-owner committed suicide. By October, 17 lawsuits had been filed in the United States relating to the recalls. Although the effects on the company's sales and share price were relatively muted, a further blow to the company's reputation came when on 5 June 2009, the Consumer Product Safety Commission fined Mattel and its Fisher-Price division US\$ 2.3 million dollars for violation of Code 16 of Federal Regulations CFR 1303, the Federal lead paint ban.

Low-or no-cost accessories, commonly distributed with consumer products, have become a particular focus of concern. These promotional items are typically manufactured at the distant end of developing country supply chains and have sparked controversies due to the use of banned chemicals.³⁷

Many significant incidents are beginning to emerge of this type, more often than not involving imports from China to developed countries, the UK and US and elsewhere. According to Munich Re (2010b), for example, 69 per cent of recalls carried out by US companies in 2007 involved goods (at least partially) made in China.

- Liaoning, China, 24 April 2007 – *Poisoning due to benzene*.³⁸ 400 school children were poisoned due to benzene-laden paint used for school furniture in Liaoning, China. The furniture manufacturer attempted to cut costs by using paint for outdoor use.
- Panama, 1 July to 16 November 2006 – *Poisoning due to contaminated cough syrup*. A toxic chemical, diethylene glycol, labelled as "substitute glycerin", was obtained from China along with a batch of standard glycerin. The chemicals progressed along the supply chain, passing through various intermediaries to the Panamanian Social Security medicine laboratory for the manufacture of inexpensive medicines: the labels were switched at least twice along the chain and no-one tested the raw materials or medicines. There are various estimates of the resulting casualties. 42 dead/ 47 injured; 250 affected; 1,600 killed or made sick. There is a on-going court case in which claimants seek to prosecute civil servants but, sick survivors claim they are getting no care or compensation (as of June 2011) and there have been accusations of political corruption. Panama has no diplomatic relations with China; therefore, the government is reported to be unlikely to attempt to seek redress.
- United Kingdom, 2009-2010 – *Toxic sofas*. In 2010, some 1,650 people, who had been injured through exposure to the chemical dimethyl fumarate in leather sofas manufactured by two Chinese companies won the right to compensation from a number of UK retailers. Under British law, the UK retailers were held

strictly liable and there has been no suggestion of subrogation against Chinese manufacturers. It took nine months to identify the chemical causing the skin burns and breathing difficulties. Total compensation for the claimants is expected to reach £20 million (US\$ 30 million).

- United States, 2004-2007 – *Chinese drywall*. It is estimated that some 75,000 lawsuits could be filed in relation to Chinese drywall (See Box 4) throughout the US and that total economic losses could reach US\$ 25bn. Estimates suggest that it could cost US\$ 100,000 to US\$ 150,000 per home to remove and replace the drywall and the attached electrical equipment. In the settlement of an early case, seven plaintiffs were awarded compensation totalling US\$ 2.6 million for the damage caused to their homes.

Box 4. The Case of Chinese Drywall Imported to the US from China Between 2004-2007

Drywall (or wallboard) comprises a layer of gypsum pressed between two sheets of paper and is used to construct interior walls and ceilings. It is increasingly made from synthetic gypsum by using gas from coal-fired power plants. The US imported drywall from China between 2004 and 2007 (approx. 5.5 million sheets) to support the construction boom after Hurricanes Katrina and Rita. By late 2009, a study confirmed the strong association between the chemicals emitted by Chinese drywall and metal corrosion (affecting wiring and electronic equipment in homes), while the health effects (headaches and nosebleeds) were still being investigated at that time.

By early 2010 the first cases went to trial and construction companies also filed lawsuits against insurers, who were denying coverage. While attempting to sue the Chinese manufacturers in the US is regarded as a largely fruitless exercise, claimants may pursue a range of defendants involved at various points in the supply chain.

Serious questions have yet to be addressed regarding the extent of cover under standard third-party liability policies (for example, the effect of the pollution exclusion). Could the US demand compensation (subrogation rights) from the Government of China in the current economic climate? During Congressional hearings relating to Chinese drywall, H.R. 4678 Foreign Manufacturers Legal Accountability Act of 2010 failed to become law in the US.

Source: Swiss Re (2009); Munich Re. (2010). *Schadenspiegel* 1/2010.

2.3 Financial Risks for Industry in the Context of Growing Chemicals Intensification in DCEITs

Supply chain risks from increasing chemicals production, use and disposal is a challenging prospect to chemicals, IT, consumer goods and other manufacturing industries, as well as the financial corporates that service and invest in these sectors. Continuing chemical intensification in developing countries has the potential to make this situation even worse. The supply chain is now longer and therefore harder to manage; products are more likely to fail to meet standards, and recourse from those parties responsible for failure is more difficult. As Section 2.2 shows, producers, importers/exporters or retailers may be held legally liable for harm caused by poor quality products and services. In many cases it is their reputational value among consumers and investors that is most at stake.

Currently, the attention given to Environment, Social, Governance (ESG) risks from the chemicals sector varies within the finance sector. The insurance industry is cautious about involvement with ill-defined risks with potential for major costs. Banks have tended to ignore 'soft' issues generally when providing credit or financial services. A growing number of institutional investors do consider ESG issues, but this is relatively new. The costs incurred by the finance sector in a few specific cases of chemicals risk mismanagement demonstrate how great the potential costs for this sector are: for asbestos: over US\$ 100 billion and rising fast; Bhopal: US\$ 3.5 billion; Chinese drywall: US\$ 25 billion; and RC2 toys US\$ 500 million.³⁹

For this reason, the finance sector is a crucial stakeholder to include in considering the implications of chemicals supply chain risks, alongside market access/share and reputational risks to the chemicals industry itself.

2.3.1 Insurance

Insurers have often been seen as ‘deep pockets’ which can compensate injured parties when the chemical enterprise involved has exhausted its own resources in the case of chemicals incidents. The insurance sector has undoubtedly played an important role in how remediation, clean-up and compensation is delivered in the wake of chemicals incidents. There will always be uninsured or underinsured individuals and businesses and, although their immediate health and emergency needs may be catered for by state provision, they will have to pursue the negligent party (and their liability insurers) for recompense along with the property insurers who will seek to recover their claims costs. Clearly, without state provision and first-party insurances,⁴⁰ thousands of individuals and businesses and the economy of the area surrounding Buncefield, for example, would have been severely disadvantaged had they all been required to wait for four or five years to receive compensation for the damage and injury incurred.

There is a considerable distinction between the liability covers available to international corporations in the context of their major, multi-million insurance programmes and what might be available to the typical SME business. In the UK, SME businesses can experience difficulty in obtaining products liability cover when they import from non-EU countries and/ or export to North America (other than for entirely innocuous goods e.g. men’s shirts). While relative buying-power is self-evidently influential in this distinction, the ability of the larger international companies to enforce contractual terms with developing-world suppliers will enable them to pursue compensation for faulty goods (and thus reduce their need to rely upon insurance cover). For developed-world SME businesses, they bear a significant risk of failure or bankruptcy due to supplier mismanagement.

In the context of little to no liability insurance penetration in developing economies⁴¹ with poor capacity for chemicals management, looking to the insurance sector to provide the financial safety net for companies and victims alike is particularly problematic. As matters stand, the product liability insurances of North American and European importers (held strictly liable for damage or injury caused by their products) effectively provide cover for the mismanagement of manufacturers and middlemen in the developing world. The extent to which this is “accepted” is debatable. In some sectors, the food sector for example, it may be unavoidable.

Some would argue that the inability to subrogate effectively against developing world manufacturers and suppliers has been accepted as part of the economic equation of the shift of chemicals and other production: increased claims costs and, in theory, increased product liability premiums have not outweighed the benefits of lower manufacturing costs in developing countries. Moreover, international companies who shift production to developing countries may purchase lower limits for their operations in developing countries, but they are well accustomed to evidencing and agreeing risk control issues with their international insurers and reinsurers. Insurers appear to be aware of the problem but have failed to charge increased premiums to reflect the increased risk due to present market conditions. The clean-up costs for environmental damage from historical and current waste disposal have been a significant burden for the insurance industry, however, (the ratio of insurance coverage to premium collected or capital allocated to the risk can be a factor of hundreds, or even thousands). Another “Chinese drywall” incident could change that perspective.

There have been some moves towards compulsory insurance in some regimes, i.e. EU. The main issue, which a compulsory financial security addresses is the assurance that the operator/polluter (or responsible authority) will have sufficient remediation funds immediately available, in the event of a qualifying incident, and that the polluter’s insolvency should not shift the financial burden of remediation to the responsible authority. Apart from the fact that the insurance industry has no desire to become the “environmental policeman”, the industry does not have the risk appetite or capacity (financial or administrative) to insure all businesses in an appropriately discriminating manner, to the level required to meet current environmental standards and remediation costs.

One of the great fears that insurers have is emerging risks. This concerns the phenomenon where a substance that appeared to be relatively harmless, or even benign, turns out to have serious disbenefits. Current examples of potential problem areas include nanotechnology, endocrine disruptors, and also ‘cocktails’, when a combination of

‘safe’ substances becomes harmful in combination. With the historical examples of tobacco and asbestos, insurers are naturally wary of extending their cover too far in any one area, lest they become exposed to such a phenomenon. The “lesson learned” by the insurance industry with regard to chemicals risks is to monitor emerging risks carefully and to limit exposures (even exclude them) until more knowledge of the substances and their impacts is available. Then they may gradually become more insurable, through the use of limited extensions, specialist policies.

In all, insurers have severely limited their exposure to financial loss from future incidents in the chemicals sector. There are many different risk appetites and underwriting strategies in an industry as diverse and competitive as insurance and re-insurance. At any point in time there may – or may not – be a number of insurers willing to commit capacity to unusual or high-hazard activities, under specific conditions. While there have been some cases where proof of better environmental management has led to lower insurance premiums (See Box 5), but for the most part, the insurance industry’s influence on the environmental and health performance of the chemicals sector is limited, precisely because they sell them limited forms of coverage for ‘good’ risks that are relatively well understood.

Considering recent parallel catastrophic incidents in the energy industry, i.e. Fukushima (nuclear) and Deepwater Horizon (oil), both of which involved pollution by hazardous substances, gives support to identifying the chemicals sector as one that is significantly under-insured. Analysts at Bank of America Merrill Lynch have estimated nuclear liability claims falling to Tepco (operator of the Fukushima plants) could reach US\$ 133 billion if the crisis continues for two years. Meanwhile, JLT Insurance Brokers have estimated global nuclear capacity at US\$ 2.4 to 3.8 billion (€2-3billion).⁴² In the US, proposals have been made to increase the Oil Pollution Act of 1990’s US\$ 75 million cap on liability following the Deepwater Horizon disaster, the actual costs of which have amounted to US\$ 20.4 billion (to 30 June 2011) and are anticipated to double.

Being comprised of many individual companies – which must operate profitably and answer to shareholders in a highly competitive market – the insurance industry struggles to adopt coherent approaches to ESG risks. When they do agree, they can be accused of cartel-like behaviour. Even when the issue is directly relevant, the industry rarely speaks unanimously. The UNEP Finance Initiative hopes to change this through its Insurance working Group (IWG) by means of the *Principles of Sustainable Insurance*, which are being developed following a survey of practices and opinions on ESG issues in 2009.

Box 5. Insurance and Environmental Liability Benefits of Improved Environmental Management

The steadily rising cost and impact of environmental risk liability are related to several factors, including past operational activities, current operational activities, business transactions, and financial and reporting obligations. Many private companies and public agencies have found a sound environmental/chemical management system, such as ISO 14000, to be an effective tool for managing their environmental liabilities. Although the primary purpose for the adoption of environmental/chemical management systems is improving environmental performance, insurance companies such as Swiss Re note that such practices can result in substantial economic benefits in terms of insurance. These insurance benefits include the securing of insurability (ability to acquire insurance coverage), lower deductibles, higher limits insured, broader coverage, and more favorable premium rates. For example, following the development and implementation of a pilot environmental management system programme, the Port of Houston Authority benefited from a 20 per cent reduction in insurance cost.

Source: Swiss Re. (1998). Environmental management systems and environmental impairment liability insurance. http://www.swissre.com/resources/c63dd180455c7cfcb76cbf80a45d76a0-environmental_eng.Paras.0006.File.pdf; Kruse, C.J. (2005). Environmental management systems at ports – a new initiative. In Proceedings of the 14th Biennial Coastal Zone Conference. New Orleans, Louisiana, USA, Jul 17-21, 2005.

2.3.2 Banking, Asset Management and Risks for Investors

There has been a limited acceptance of ESG factors in banking. ESG factors have been admitted into project finance for some time, under the voluntary Equator Principles, based on the International Finance Corporation (IFC) guidelines. These are very detailed, and provide a good basis for risk analysis of projects. However, they are limited to large projects, and do not apply to other banking activities like wealth management and commodities trading, although they could.⁴³

Access to capital – a key determinant of industry competitiveness – is typically dependent on inherent risks being well-understood, transparently communicated and managed. Chemicals risks have touched the banking industry in circumstances where industrial debtors have become bankrupt, leaving the ownership of the corporate assets, including polluted land, to the lending bank. Current credit market anomalies aside⁴⁴, this has led banks to require their clients to purchase environmental impairment insurance (EIL) policies before providing credit in some cases. Nevertheless, the size of many chemicals companies means that they can finance many activities from retained profits, or out of ‘generic’ overdraft or bond facilities. This means that they are not dependent on project-specific banking finance, with its greater degree of risk scrutiny. Moreover given increasingly strict regulation of banking solvency, the way chemicals industry projects are financed is unlikely to be a strong lever for the public sector to influence industry on chemicals risk management.

A significant element of global stock markets is made up shares in chemical companies and companies that depend critically on chemicals, so movements in their value are of major concern to institutional investors. Thus investment or asset management sector, may be implicated in shareholder losses from chemicals mismanagement in developing countries (e.g. Union Carbide after Bhopal). Yet this branch of the finance sector has not previously accorded much weight to product risks when allocating resources to chemical sector propositions or assets.

According to ASrIA, as many as 70 per cent of quoted companies in Asia (with the exception of Japan and the Republic of South Korea) are potentially exposed to toxic chemicals risk ranging from product liability to credit risks. Clearly the risks are bigger with smaller firms. Global companies relying on Asian supply chains need to consider investment in supplier training and technical support if they want to be assured of responsible procurement with vendors. Otherwise, investors in those global firms could easily see their investments depreciate, as happened in 2007 with Mattel and RC2.

Further, it is becoming clear that chemical risks affect a much broader range of companies than simply the chemicals sector. Though national level import testing is not typically proactive in most markets, any food safety advisories or fears of recall can have knock on effects for individual companies or commodity trading, as was seen in the case of fears over fungicide contamination in US imports of Brazilian orange juice in January 2012 (See Box 6).

Box 6. Orange Juice Commodities Futures Impacted Upon by Brazilian Use of Fungicide

Fears that the US might ban imports of orange juice from Brazil drove orange juice commodities futures prices up by 11 per cent to an all-time high on Tuesday, 10 January 2012. A warning issued by the US Food and Drug Administration (FDA) to the Juice Products Association on Monday 9 January, 2012 regarding concerns over traces of fungicide called carbendazim that is illegal in the US prompted the jump.

According to the FDA, a US juice producer had detected low levels of carbendazim in orange juice concentrate imported from Brazil. The pesticide is banned in production of US citrus fruit, but not in Brazil.

The World Health Organization has said risks are high only if large doses are ingested, though carbendazim is a possible carcinogen and can disrupt human hormone systems. Levels found by FDA orange juice testing were either low or nondetectable, but this fact did not stop the food safety concern from impacting markets.

Ray Royce, Executive Director of the Highlands County Citrus Growers Association in central Florida was quoted by Reuters as saying: “Obviously food safety issues are probably going to play a bigger and bigger role in driving food or commodity prices in the future”. Potential benefits of higher prices for growers will likely be wiped out

Source: Reuters (2012). ‘FDA Tests Threaten Brazil Orange Juice Imports’ <http://planetark.org/wen/64392>; *The Guardian*, 11 January 2012 ‘Orange juice prices hit record high after fungicide found in Brazil imports’ <http://www.guardian.co.uk/business/2012/jan/11/orange-juice-prices-fungicide-brazil-us?newsfeed=true>

In recent years, there have been approaches by SRI actors in alliance with NGO's to policymakers seeking to create a more comprehensive regulatory framework for chemicals of high concern. SRI has been in existence for some 20 years, but it is only recently that it has been accepted that SRI is not contrary to the fiduciary duty of making the best returns for clients and beneficiaries; it is a persistent feature of the investment scene though the concept has still to be mainstreamed. The investment community is growing to understand that sound environmental and social reporting is an important element of good corporate governance and not simply incidental to business activities.⁴⁵

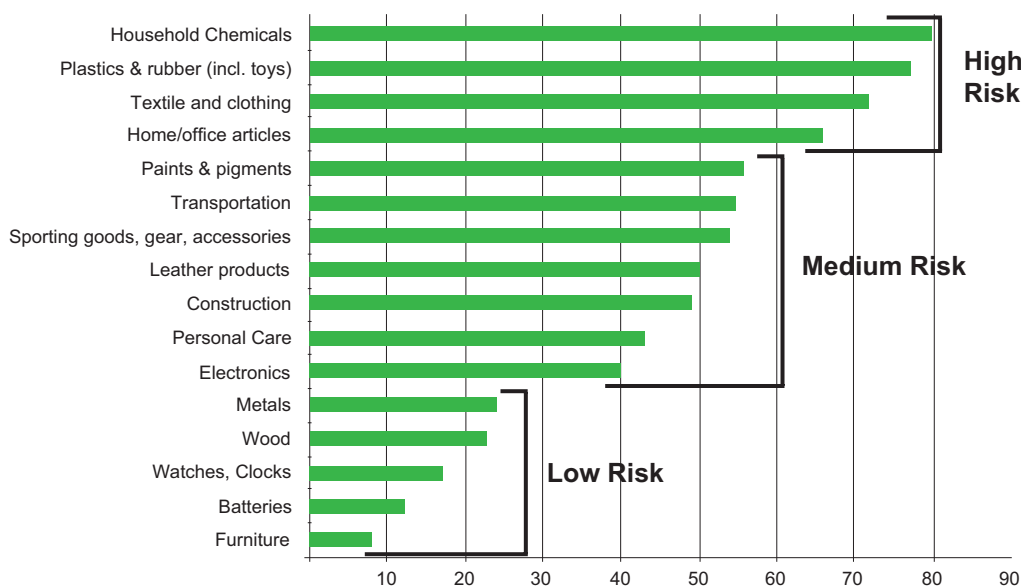
Under the aegis of the United Nations, the Principles for Responsible Investment were drawn up in 2006 to help guide the further development of SRI in conventional asset management operations. These have now been signed up to by 915 organizations with assets under management of approximately US\$ 30 trillion.

MSCI ESG Research, a consultancy firm providing ratings and analysis of ESG-related business practices of companies worldwide⁴⁶, investigated the potential risks for investors that might accrue due to the presence of likely substances of very high concern (SVHCs) in consumer goods being sold by stock companies.⁴⁷ This was based on a two-stage analysis of risk exposure (country risks, product profile) and risk management (phase-out strategy, R&D, product liability suits). The results of this analysis identify three types of companies that should be of particular interest to investors, socially responsible or otherwise (See Figure 3):

1. Retailers. These usually have weaker, longer phase out plans, and poor oversight and knowledge of product content (particularly private or 'own brand' labels).
2. Regulation Resisters. These show no evidence of a phase out strategy, the largest players focus on lobbying instead.
3. Proactive Innovators. These have proactive phase out plans, and are best positioned to benefit from regulatory change and new consumer trends by developing competitive advantages thanks to their strong focus on R&D and Green Chemistry.

Figure 3. Substances of Very High Concern (SVHC) Risk Profiles for Quoted Companies

of potential SVHCs in each product category



Source: MSCI ESG Research, ChemSec's SIN List 2.0 (May 2011)

2.3.3 Market Access and Corporate Reputation

Using the proportion of total liability premium to GDP as an indicator of relative societal litigiousness (US 0.54 per cent, UK 0.44 per cent, Australia 0.40 per cent) appears to confirm the suggestion that businesses in less litigious societies see less need to purchase liability insurance (Italy 0.21 per cent, Japan 0.10 per cent).⁴⁸ Yet, the demand for liability insurance is said to be growing in countries such as China and India – not for production for domestic consumption – but in respect of exports. Developed-world importers are requiring evidence of products liability insurance with limits of up to US\$ 10 million, though manufacturers are said to be very reluctant to pay the requisite premium for these limits. Exporters in Latin America are likely to find that cover for product liability is a prerequisite for exports to North America and Europe in response to legislative requirements like Restriction of Hazardous Substances (RoHS) and Registration, Evaluation, Authorisation and Restrictions of Chemicals (REACH). For example, in the US, many food import refusals by the Food and Drug Administration (FDA) originated in the Dominican Republic, Mexico or other Latin American and Caribbean nations; a frequently cited reason was pesticides.⁴⁹ Even North American companies are finding new demands being placed on them to access the European market (See Box 7).

Box 7. EU REACH Regulation Impacts for US Companies

The Environmental Defense League (EDL) assessed the effect which the EU REACH Directive would have on American companies (and by implication their investors). EDL used the SIN List, which anticipates which substances will be REACH-listed, to determine which chemicals and companies in the US are likely to be affected by REACH. It found that many, and likely most, SIN List chemicals are in active commerce in the US.

At least 77 SIN List chemicals are produced annually in amounts of one million or more pounds, and at least 14 exceed one billion pounds annually. At least 235 companies are producing or importing SIN List chemicals in the US. Many SIN List chemicals are produced or imported by multiple companies at numerous sites, with as many as 41 companies at 62 separate sites.

Nearly all of the SIN List chemicals have already been formally designated by EU officials as meeting the criteria used to define substances of very high concern under REACH. In marked contrast, the US Environmental Protection Agency (EPA) had undertaken only very limited activity to address these chemicals. Hundreds of companies in the United States produce or import hundreds of chemicals designated as dangerous by the EU, and hence will be directly impacted by controls imposed on such chemicals under the EU's new chemicals regulation.

Source: Environmental Defense League (2009). *Across the Pond-Assessing REACH'S First Big Impact on US Companies and Chemicals (Update)*.

Through its negotiated and ratified agreements the WTO strives to expand international market access, improve global competitiveness and discourage unfair practices, and increase transparency and predictability. There has been a long time ongoing discussion about the legality of REACH under WTO legislation, as part of the discussions on environmental standards and Production and Process Methods (PPMs) as technical barriers to trade. Article XIV of the WTO General Agreement on Tariffs and Trade (GATT) contains the environmental exceptions⁵⁰ enforceable under international trade law which allows for REACH and similar regulations. These exceptions allow nations to adopt trade measures necessary to protect “human, animal or plant life or health” subject to certain conditions⁵¹ if such measures do not result in arbitrary or unjustifiable discrimination between countries or disguised restrictions on trade, i.e. the same demands must be placed on domestic/regional as those on imports.⁵²

Within markets, intangibles like reputation are thought to be a strong influence on how companies perform.⁵³ A 2005 Economist Intelligence Unit survey of 269 senior executives responsible for managing risk, revealed reputational risk as the most significant threat to business out of a choice of 13 categories. This report suggests “preoccupation with reputational risk stems primarily from the fact that executives now see reputation as a major source of competitive advantage”.⁵⁴ Rosenzweig (2007) notes how the biggest driver of a company's reputation is financial performance, but a company's reputation among investors, customers and the general public suddenly becomes crucial in the face of

environmental, product quality or employee health scandals. The Conference Board Reputation Risk Working Group conducted an online survey of 148 executives in 2008 in different countries and industries to gather opinions on reputation risk management. Respondents rated product and service quality and safety as the highest concern (50 per cent) for their reputation management efforts.

ASRIA has highlighted the growing importance of reputation in the “tiger” economies, as a further example.⁵⁵ The global media has publicized toxics issues linked to pre-packaged food, household products, consumer electronics and children’s plastic toys manufactured in China. Chinese manufacturers are said to be reluctant to purchase product recall insurance, despite the growing number of product recalls and the potentially serious implications of such incidents, including: government investigations; severe fines; adverse media attention and, in some instances, company collapse. The Chinese Government, however, appears to be growing wary of the reputation of Chinese manufacturers for producing shoddy and unsafe products. China has introduced a tort law, effective from July 2010, featuring unlimited punitive damages for serious bodily injury arising from the production or sale of defective products.⁵⁶ Chinese consumers too are becoming progressively sceptical and discerning following incidents such as the Melamine contamination of baby milk case in 2008.⁵⁷ Internet bulletin boards in China have become a fast-paced source of consumer views on products. Even rumours can create a viral response which can dismantle a negligent company’s reputation in days.⁵⁸

3. External Implications of Chapter I Trends: Costs of Inaction for Human Health and Environment

Chemicals production, consumption and disposal can have ‘spillover’ or external negative impacts for individuals and firms outside these activities when not well managed. Furthermore, informal and/or illegal behaviours are often the source of chemicals pollution, but by their very nature it is unlikely that entities involved in these undertakings take steps to internalize costs. Many of these externalities can be reduced through responsible chemicals management.

The social risk of health impairment due to exposure to chemicals is an insurable risk under certain conditions⁵⁹; members of the public can be compensated under public liability policies, and consumers and distributors under product liability policies (i.e. some costs can be internalized). Employees are generally covered under workers’ compensation or employer’s liability policies. However, it frequently happens that the quantity of liability cover purchased is insufficient to meet the burden of deaths and impaired lives, in which case the costs fall on to the public purse, through social security or the health system, or the victims are left to fend for themselves.

External impacts have market and non-market aspects – or costs that are monetized and costs that are not. Most monetized effects reported for health impacts are based on actual incurred expenses, such as medical expenses, lost wages and lost productivity. Public clean up and remediation costs and lost earnings in other economic sectors impacted upon by chemical pollution are examples of monetized external environmental costs. There is value in using this data to assess potential benefits from sound management of chemicals policies that, if put in place early and effectively, may prevent these damages from occurring. Direct and indirect price data is tangible and therefore compelling. Yet, this type of data does not reflect the full story of human pain and suffering or damage to ecosystems and their capacity for service delivery.

Health and environment economists have developed non-market valuation techniques for giving monetary values to goods that are not traded in markets.⁶⁰ These methods are challenging technically and subject to criticism.⁶¹ Done correctly however, estimates of non-market impacts for society as a whole add greatly to our understanding of the true impacts of policy action – or inaction.

Drawing on the *Costs of Inaction Initiative Baseline Assessment Report*, Section 3, sets out what it means to attribute economic values to chemicals-related health and environment impacts and gives some sense of how this has been done (or not) in developing country contexts. There are some limitations to this study which must be acknowledged upfront. First, in the COI Baseline Assessment Report, more economic data was uncovered on the human health effects of harmful chemicals, compared to environmental or ecosystem services effects. Second, very little data were found to highlight the beneficial ecosystem services effects to national development planning of cost-effective domestic investments in sound chemicals management across key economic development sectors. Third, the chemicals identified in the literature are a tiny fraction of the full spectrum of chemicals that require sound management. Fourth, available information is fragmented in terms of substances included, type of effects assessed, geographical distribution and units of measure. Finally, the various scopes and methodologies, as well as the different levels at which costs are estimated make the data very difficult to compare and aggregate.

3.1 *Attributing Economic Values to Health Impacts*

The vast majority of human health costs linked to chemicals production, consumption and disposal are not borne by chemicals producers, or shared down the value-chain. Uncompensated harms to human health and the environment are market failures that need correction. Chapter I details the health impacts attributable to chemicals for workers, local communities and wider global populations. As discussed in Chapter I, DALYs are a common currency by which deaths at different ages and disability resulting from chemicals can be measured. The WHO (2011) defines DALYs as the “sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability”. Combining DALYs with health economic valuation data⁶² gives the value of a DALY to society in resource allocation decisions.

To better understand the magnitude of chemicals-related external health impacts, it is worthwhile looking briefly at how societal health impacts have been calculated in the US, Europe and other countries, including rare studies for developing countries.

3.1.1 Costs of Illness

Health economic studies commonly rely on some variant of the ‘cost-of-illness’ method. This combines the ‘direct’ costs such as medical care and travel costs with the ‘indirect’ cost of lost production because of reduced working time for people affected by dangerous exposures. Although computationally straightforward, difficulties in assessing the level of health consumption or expenditure and ‘lost productivity’ for children and the elderly mean that this is an inadequate technique for capturing economic impacts of disease or injury on society by itself.⁶³

a) Costs of Adult Occupational Illness and Injury

‘Cost of illness’ goes right to the heart of a crucial stakeholder group in chemicals management – workers who are exposed to toxins in chemicals production, consumption, transport or waste disposal beyond what they have been compensated for through salary and other benefits.

Occupational health impacts are not considered as an externality in many analyses because workers are compensated through salary and other benefits, and judicial processes. Yet, given the forms occupational illnesses can manifest, in many circumstances the externality is not fully ‘priced in’ to standard employment compensation packages.

A ETUI-REHS⁶⁴ report (Pickvance et al. (2005) estimates occupational health impact reductions within the EU-15 arising from REACH are estimated to be worth between €18-27 billion over a 30 year period, with more than 99 per cent of the reductions coming from the avoidance of future cancer deaths. The cost savings of reduced occupational skin and respiratory diseases due to REACH were estimated at around €3.5 billion over a 10-year period, and an aggregate cost savings of €90 billion over a 30-year time period.

Box 8. The Costs of Acute Versus Chronic Illness

Any estimates of health costs associated with chemicals exposure will necessarily be underestimates because of the difference in how acute and chronic illnesses present themselves over different time horizons (among other issues, such as under-reporting, confounding exposures and lifestyle factors).

There are many unknowns in determining causal linkages between exposures and latent disease. Moreover, occupational or environmental-related diseases can first appear as routine disorders.

Asbestos is a prime example. When first brought into commercial use around 1890, there was no indication that these six naturally occurring fibrous crystals would have pathological impacts on human health. All that could be seen were benefits.

Early evidence of harmful effects from this “magic mineral” was confounded with poor working conditions and tuberculosis in the early 1900s, and somewhat with smoking-related lung cancer later. Some evidence was ignored, denied and intentionally suppressed. Until the publication of a paper on mesothelioma by Wagner et al. (1960), the link had not been firmly made. Now, the health impacts are beyond dispute: asbestosis (describing fibrosis of the lung), asbestos-related plural disease and mesothelioma have all been linked with exposure to asbestos materials.

The features of mesothelioma are particularly relevant to illustrating how ‘correct’ pricing of health impacts of chemicals exposures is nearly impossible. Up to 40 years can pass before the disease is diagnosed.

Source: Murray (1990); Osinubi and Colleagues (2000); Munich Re (2009).

Certain occupational injury and illness categories are of paramount importance for developing countries, in particular agricultural exposures. Even in an industrialized country like the United Kingdom: “Agriculture is an industry with high cancer registrations. There are also about 90 deaths per year that are attributed to occupational carcinogens (e.g. substance or occupational circumstance). The most significant carcinogen is TCDD (2,3,7,8-Tetrachlorodibenzodioxin). Non-arsenical insecticides and solar radiation are also significant carcinogens” (HSE 2011).

Improper and harmful pesticide use frequently occurs under weak regulation and enforcement and workers often lack information about the substances they are using. This results in serious consequences for those who work with pesticides, their families and communities, and final consumers. In a 1990 report, the WHO estimates that there are possibly one million cases of serious unintentional pesticide poisonings each year, and that there could be as many as 25 million agricultural workers in the developing world suffering some form of occupational pesticide poisoning each year, though most incidents are not recorded and most patients do not seek medical attention.

WHO (2010) shows that, since in poorer countries most health-care costs must be paid by patients themselves, this creates significant strain on household budgets. Treatment for diabetes, cancer, cardiovascular diseases and chronic respiratory diseases can be protracted and therefore extremely expensive. Such costs can force families into catastrophic spending and impoverishment. Each year, an estimated 100 million people are pushed into poverty because they have to pay directly for health services.

Focusing on occupational pesticide exposures, some ‘cost of illness’ studies in developing countries translate these types of exposures into monetary equivalents. OAS (2005) analyses the economic benefits of environmental health interventions in the Americas. Cited in this study, Cole and Mera-Orces (2003) combine the average costs of care with loss in income to give average private costs of approximately US\$ 17 per case in Ecuador. This is 11 times greater than the average daily wage of an agricultural worker. In Nepal, Atreya (2005) estimate annual costs of illness due to pesticide use to be US\$ 16.8 per household and farmers’ willingness to pay for safer pesticides to be US\$ 132.8 per household. Bwalya (2010) estimates the cost of illness of exposure to chemicals used on cotton fields in the Zambian Kafue River basin at US\$ 2.3 million. Lost labour income (51.1 per cent), medical costs (40.7 per cent) and transport and other costs (8.1 per cent) account for the largest costs. One Zimbabwean study, Maumbe and Swinton (2003), estimates that cotton smallholders lost US\$ 3-6 per year in acute health effects, equivalent to 45-83 per cent of annual pesticide expenditure. Time spent

recuperating from illnesses attributed to pesticides averaged 2- 4 days. As a final example, projections for annualized costs in Uganda suggest that costs of lost farm labour from occupational pesticide poisonings will amount to US\$ 78.54 million by 2024/2025, according to a recent study, Kateregga (2010).

Other occupational illnesses attributable to chemicals mismanagement are likely to increase given the shift in production, rise in consumption and current poor practices in waste management in many countries. Agriculture will remain important however given the necessary rise in food production to feed a world of over 7.5 billion in 2020, as forecast by UNSD (2010). As such, the negative impacts associated with pesticide use are also expected to rise. *Resosudarmo (2001)* estimates that health problems associated with the use of pesticides are more than six times greater in 2020 compared to 1993. In Mali, Ajayi et al. (2002) estimate the human health cost from pesticide use equals 40 per cent of the total pesticide market value.

The Costs of Inaction (COI) Initiative of UNEP Chemicals aims to raise political awareness of the benefits stated in economic terms of providing resources to sound management of chemicals, including through:

- Building capacity for ongoing assessment of the costs of inadequate chemicals management at all levels of government;
- Strengthening the rationale for inclusion of sound chemicals management priorities into national development plans; and
- Demonstrating practical economic analysis techniques for development of sound chemicals management policies, practices and infrastructure.

An International Steering Committee for the COI Initiative has been established and has met three times thus far, the latest meeting having been held in June 2011. The *Baseline Assessment Report* was produced to identify the readily available economic information on the health, environment and development planning effects of harmful chemicals and to assess how useable this information is in policy-making processes. This study also identified the most significant gaps or weaknesses in the existing economic information.

A significant portion of the health cost data uncovered in the Baseline Assessment Report represented health costs of pesticides, and a relatively significant portion of this data came from certain countries in sub-Saharan Africa, including those countries that undertook mainstreaming projects under the UNDP/UNEP Partnership Initiative on Integration of Sound Management of Chemicals into Development Planning.

New evidence on health costs from pesticides in sub-Saharan Africa gives an indication of just how large. UNEP's Costs of Inaction Initiative Baseline Assessment Report used available data to make a conservative estimate for pesticide users on smallholdings in sub-Saharan Africa. It reveals that the costs of injury (lost work days, outpatient medical treatment, and inpatient hospitalization) from pesticide poisonings in this region alone amounted to US\$ 4.4 billion in 2005. This is an underestimate because it does not include the costs of lost livelihoods and lives, environmental health effects, and effects of other chemicals. In 2009, Overseas Development Assistance (ODA) to Health in sub-Saharan Africa amounted to US\$ 10.3 billion. Excluding HIV/AIDS, total assistance to basic health services approximated US\$ 4.8 billion. A conservative projection of the 2005 estimate to 2009 shows costs of injury due to pesticide poisoning in sub-Saharan Africa to be US\$ 6.2 billion. This suggests that the total ODA to general healthcare is exceeded by costs of inaction related to current pesticide use alone.

Informal waste processing in developing countries also poses severe occupational risks (that also have implications for local communities). Regular exposure to persistent organic chemical pollutants, heavy metals and toxic particulates as described above, may lead to numerous diseases and disorders for workers.

b) Costs of Children's Environmentally Attributable Illnesses

Children are a special case in estimating the economic cost of chemicals-related health impacts.

Valuing the economic burden of environmental exposures for children using cost of illness involves quantifying the direct and indirect costs of childhood disease and premature death and lost school days. As children have higher exposures than adults, all things being equal, their developing organ systems are more vulnerable to exposures that can result in lifelong impairment.⁶⁵ For these reasons, it is generally accepted that (i) health benefits to children should be considered separately from the general population and (ii) the willingness to protect children from environmental threats is higher than protecting adults facing similar risks.

In 2004, an estimated 240,000 cases of preventable childhood disease in California were thought to be attributable to chemical substances in food, water, air, soil, the home and community. These cases resulted in approximately US\$ 1.2 billion in both direct medical costs and indirect costs as cited in Wilson et al. (2008).⁶⁶

Philip Landrigan and others (2002) have examined the economic costs of four broad categories of children's illnesses and disabilities associated with exposure to toxic chemicals in the US: asthma, cancer, neurobehavioral disorders and lead poisoning.⁶⁷ Given the limited economic data available, it is worthwhile considering the result of this study even if we can not assume that all of the following disorders are amenable to reduction through increased chemicals safety. It reports annual costs of environmentally mediated diseases in US children of US\$ 54.9 (range US\$ 48.8–64.8 billion). This amounts to 2.8 per cent of total US health care costs. The Landrigan et al. 2002 findings were updated and expanded by Trasande and Liu in 2011. According to this research, the costs of lead poisoning, prenatal methylmercury exposure, childhood cancer, asthma, intellectual disability, autism, and attention deficit hyperactivity disorder were US\$ 76.6 billion in 2008. The above studies acknowledge that their results are likely to be underestimates, given the difficulty of correctly ascertaining the economic value of childhood morbidity and mortality, and other effects.

Applying economic analysis to valuing children's environmental disease attributable to chemicals exposure in developing country situations has yet to be conducted. As such, Costs of illness estimates for children are missing for developing countries (See Box 9). One unknown is how many children are suffering acute or chronic health impacts from chemicals in these countries because, often, this data is not being tracked. Furthermore, many children do not receive medical treatment. Children in developing countries and countries with emerging economies can also have occupational exposures that should be considered. An important methodological concern in such an estimation is to avoid, in so far as is possible, double counting occupational exposures, i.e. where children have been accounted for in existing occupational exposure data.

It will no doubt be a challenging task, but even with limitations, an estimate of children's cost of illness in these regions is needed as an indicator of the scale of costs of inaction for this particular vulnerable population in countries which are set to experience massive increases in chemicals production, consumption and disposal.

Box 9. Estimating Costs of Illness and IQ Loss from Lead for Children in Developing Countries

Some preliminary estimations have been produced as part of the research for the Global Chemicals Outlook, based on available data for Lost DALYs and lost IQ/productivity associated with childhood lead toxicity, applied to three regions experiencing the greatest increases in chemicals intensification globally.

The WHO has estimated Disability Adjusted Life Years (DALYs) lost among children less than five years of age in 2004 at the region level within low- and middle-income countries, and separately for high-income countries. As a proxy for economic valuation, we utilize literature that has conventionally valued DALYs or their Quality Adjusted Life Year counterparts at US\$ 50,000 each in the US context. Correcting for global differences in mean GDP (PPP) in the corresponding year is used. Multiplying US\$ 50,000 by the ratio of the corresponding region's mean GDP to the US GDP in that year gives an economic estimate of DALYs lost associated with childhood lead toxicity in 2004 for Africa, Latin America and Southeast Asia:

Regions (MMIC within)	Lead Attributable DALYs ('000) in children under 5 (2004)	Mean GDP estimate (US\$, PPP)	Value of DALY used (US\$)	Total DALY loss/cohort
Africa	917	1,025.00	1,226.31	225 million
Latin America	478	4,810.00	5,754.69	550 million
SE Asia	3,158	1,729.00	2,068.58	1.3 billion

Using lost economic productivity, using census data combined with WHO data to give estimates for the number children below the age of 5 with lead blood levels greater than 5 micrograms (BPb>5) and the associated loss in IQ to project lost lifetime economic productivity in the same three regions:

Regions (MMIC within)	Children age <5	Children age <5 estimated with BPb>5	Lifetime economic prod. per IQ point (US\$)	Total lost economic productivity (US\$)
Africa	119,869,281	8,151,111.11 (2.565 IQ loss)	576.72	12 billion
Latin America	55,196,305	3,974,133.95 (2.565 IQ loss)	2,707.35	28 billion
SE Asia	183,284,968	27,126,175.28 (2.565 IQ loss)	972.82	68 billion

These preliminary estimates point to some significant costs of childhood chemicals exposures that currently are not well understood or included in economic analyses involving chemicals risks at global, regional or national scales. This issue is the subject of ongoing research at New York University's School of Medicine to generate more robust estimates of the costs of children's environmental health in developing countries for lead, and extend this analysis to mercury and indoor air pollution.

Note: UNEP would like to extend its thanks to Dr. Leo Trasande for his work in generating these preliminary results as part of his contribution. Data sources: <http://www.who.int/gho/database/en/>; <http://www.ers.usda.gov/Data/Macroeconomics/> Source for presumed IQ loss: Gould, E. (2009). Childhood Lead Poisoning: Conservative Estimates of the Social and Economic Benefits of Lead Hazard Control. *Environ Health Perspect* 117:1162-1167. ; Source for economic productivity lost per IQ point: Trasande, L., Landrigan, P.J., Schechter, C. (2005). Public Health and Economic Consequences of Methyl Mercury Toxicity to the Developing Brain. *Environ Health Perspect* 113:590-596, and Unpublished tables, Institute for Health and Aging, University of California, San Francisco.

3.1.2 Costs of IQ Loss from Lead and Mercury Exposures

A second group of economic costs of health impacts are captured in intelligence quotient (IQ) loss resulting from impaired neurological development linked to lead or mercury exposures. Estimating and aggregating future earnings foregone, or lost lifetime productivity, teases out an estimated value of IQ losses to society as a whole.

Trasande and others (2005) look at IQ and productivity losses from mercury in the US. Between 316,588 and 637,233 infants born each year in the US had cord blood mercury levels over levels associated with loss of IQ. The cost of the loss of intelligence in terms of diminished economic productivity over the lifetime of children affected was estimated to amount to US\$ 8.7 billion annually (range US\$ 2.2 to 43.8 billion in 2000). Landrigan et al. (2002) perform this calculation for lead in the US arriving at an estimate of US\$ 43.4 billion.

To illustrate, a World Bank study (2006b) in Pakistan estimates the annual cost of lead exposure to a quarter of the population living in cities at 0.7 per cent of GDP in 2004. IQ losses represent 78 per cent of total cost, and mild mental retardation 15 per cent.

Spadaro and Rabl (2008) document sources of lead and mercury contaminants including: ferrous and non-ferrous metals manufacturing facilities, caustic soda production, incinerators for urban, medical and industrial wastes, cement plants and vinyl chloride monomer production, cement production and chlor-alkali production are shifting from the EU and US to China, India, among other Asian countries. With mercury, a key exposure pathway is fish consumption.⁶⁸ Significantly, “fish contributes an important source of animal proteins to the diet of the world’s poorest” people, according to the FAO (2009).

As discussed in Chapter I, lead and mercury contamination has been documented in the developing world, albeit in a haphazard fashion. For example, informal lead acid battery e-waste recycling (i.e., printed circuit boards)– which are increasingly important waste streams as well as livelihood activities in developing countries and emerging economies – have been shown to be sources of lead poisoning by Haefliger et al. (2009), Huo et al. (2007) and Brigden et al. (2008). The estimated economic costs of this contamination for developing countries is wanting, but the mounting proof of health impacts combined with the US cost information gives some idea of the enormity of actual and future lead and mercury IQ costs in these countries that are potentially avoidable through better chemicals and waste management processes.

Furthermore, external cost information from industrialized countries may already be including impacts from chemicals misuse, poor management and pollution in developing countries transferred through long-range transport and international food and products trade. The work of Pacyna and others (2008) on the socio-economic costs of continuing the status-quo of mercury pollution acknowledges that fish consumption is the most potent pathway for health effects caused by mercury. Fish and fish products are also among the highest globally traded commodities. In 2006, around 37 per cent of all fish caught or farmed was traded internationally, meaning that fish are caught and reared often far from where they are consumed. According to the FAO (2008), global consumption per capita is 17.4 kg on average, with 7kgs of this coming from aquaculture production in which China and Southeast Asia are the global leaders. UNEP GLOMER project (UNEP 2008) suggests that the most damaged regions due to mercury pollution in the year 2020 are likely to be located in the south and Southeast Asia, east and west Africa, and east and west South America. The US National Oceanic and Atmospheric Administration (NOAA) documents that in 2010, imports made up 86 per cent of the seafood eaten in the United States, mainly from China, Thailand, Canada, Indonesia, Vietnam and Ecuador.⁶⁹ The cost estimation work conducted by Trasande and others (2005) in the US states that the mercury exposure captured in their study results principally from consumption by pregnant women of seafood contaminated by mercury from anthropogenic (70 per cent) and natural (30 per cent) sources.

3.1.3 Other Dimensions of Health Economic Valuations

Two other aspects of health economic valuations worth mentioning with respect to chemicals exposures are costs of birth defects and valuation of statistical life (VSL).

Little research has been carried out on the economic impacts of birth defects, particularly those attributable to environmental factors linked to chemicals pollution. Waitzman et al. (1996) have calculated the costs of a variety of specific birth defects. Other recent research has also calculated costs of individual birth defects. For example, Weiss and others (2006) have assessed the costs of treating children with orofacial cleft, one of the most common birth defects. While neither study calculates the cost of the subset of birth defects attributable to environmental/chemical exposures, they highlight the significant costs from these health impacts known to result from chemicals exposure in some cases.

VSL estimates the value of reducing the probability of death that goes beyond market-based losses. It is an important perspective on economic impacts of death that captures complex but crucial issues. As the WHO (2009) discusses, VSL is a highly contested method due to concerns over the disparity in values for preventing assigned to developed and developing nations; designating a value to avoiding or reducing probability of death is also considered unethical in some quarters.⁷⁰ There are also intergenerational and intertemporal considerations which many feel to be poorly integrated in the VSL method. It can also be a way to reflect the threat of death of the main provider in impoverished families. Research into what causes poverty in rural communities also shows that illness of a family member or death of the primary earner is an important factor that pushes households into poverty.⁷¹

The OECD (2007) working group on costs of environmental policy inaction has proposed weighting measures to take distributional, age or income inequality impacts into account when assessing VSL costs of inaction. By attaching a greater weight to impacts which affect developing countries, children or the poor, for example, equity concerns can be included in cost estimates.⁷² This approach can have a significant impact on the aggregate estimates of the costs of inaction.

There still remains considerable inconsistency in estimations of VSL however – even in industrialized countries. For example, from Pearce et al (2006) report that in 2004 the US EPA established VSL at US\$ 6.1 million during an analysis of how far to go in removing arsenic from drinking water. Other studies have suggested that a value of US\$ 3 to 5 million is more suitable for the US, compared to just US\$ 2 million in the UK and considerably less for Japan.

In the chemicals field, the best known use of VoSL is the calculation of health benefits of REACH enactment in the European Union. The Commission of the European Communities' (2003) Extended Impact Assessment estimated that the total health benefits from REACH would be some €50 billion over the next 30 years, assuming 4,500 lives saved every year due to REACH and using the value of €1 million per statistical life. When using willingness-to-pay approaches, Pedersen and others (2005) estimated benefits arising from avoided health costs to be €200-2,500 million in year 2017, which aggregated over 25 years corresponds to €4-50 billion.

These estimates are regarded as purely indicative. Nonetheless, they represent an important attempt to capture health economic impacts that include crucial unpriced quality of life losses.

3.2 *Attributing Economic Values to Environmental Impacts from Chemicals Mismanagement*

The environment can be considered as an asset – a source of resources, an investment with positive returns, a flow of vital goods and services. This 'natural capital' provides economically valuable goods and services. An environmental asset base is constructed of healthy, productive ecosystems which generate economically important 'goods' such as timber and fisheries, and 'services' defined by the UN Millennium Assessment (2005) as "the benefits people obtain from ecosystems"⁷³.

It is in considering environmental impacts that an important category of economic values comes to the fore. Non-use values are related to the knowledge (as opposed to exploitation or ‘use’) that resources available now, i.e. water, animal and plant species, threatened by chemicals mismanagement will continue to exist and will remain an option for ‘use’ later on. Similarly, knowing that future generations will inherit similar resource availabilities as us has been shown to be ‘valuable’ to many. These non-use values are likely to be extremely large; though, as with health, ‘fair’ valuation poses challenges.⁷⁴

Environmental damage from chemicals with quantifiable economic implications and specific relevance to the regions in which chemicals production, consumption and disposal are on the increase include: environmental ‘hotspot’ clean-up and remediation; loss of biodiversity, i.e. loss of species, endangered and otherwise; loss of specific ecosystem services such as ozone depletion, agricultural and marine food production, water resources.⁷⁵

No comprehensive study has been conducted exclusively on the economic implications from environmental impacts from chemicals mismanagement to date. This work is breaking new ground by laying out the state of knowledge for just three aspects – biodiversity, water and food production – with examples of direct and indirect market cost and nonmarket valuation data, as available.

3.2.1 Publicly Funded Environmental Clean Up and Remediation

Increasing chemicals production and consumption and resultant waste in a scenario of poor chemicals management means increased risks of incidents and pollution hotspots. The available data on public expenditures on clean-up and remediation indicates a high-cost efficiency of prevention rather than remediation.

The legacy of such a period in Europe means that annual expenditures on remediation of contaminated sites were 0.05 to 0.1 per cent of GDP in 2007 as estimated by the OECD (2007). There are a small number of European countries for which these costs are much higher, according to the European Environment Agency (2005). In the US, costs of remediation per event site is over US\$ 25 million, based on a sample of 257 sites on the US EPA Superfund National Priorities List.⁷⁶ As of 2000, approximately US\$ 30 billion had been spent on cleaning-up Superfund sites.⁷⁷ In an example from Asia, the Japanese Environment Agency (1991) estimated that soil pollution from cadmium in the Jinzu River Basin cost 882 million Yen FY1989 in lost agricultural productivity; and a further one-year soil restoration costs of 893 million Yen FY1989.

While industrialized countries may spend billions in annual hazardous waste clean up, less developed countries cannot accommodate such costs. Poor design and implementation of liability laws often means that the cost of clean-up and remediation resulting from private economic activities in developing countries often falls largely on public agencies at national and international levels. For example, the Africa Stockpiles Programme calculates that to clear up the 50,000 tonnes of obsolete pesticides in Africa will cost around US\$ 150-175 million.⁷⁸ This is partially assisted by CropLife International, but also requires financial and technical support of GEF, FAO and World Bank, among others. According to Ajayi et al. (2002), the Malian Government spends US\$ 193,000 *per year* on getting rid of obsolete pesticides and empty containers.

Since its inception in 1999, the Blacksmith Institute has completed more than 50 cleanup projects in 21 countries.⁷⁹ A selection of their ‘success stories’ in Table 1 give a sense of the scale of these potential costs in developing countries as chemicals production, use and disposal activities migrate.⁸⁰ Important to note is that Blacksmith Institute’s assistance is also technical and is delivered *pro bono*. Moreover, the costs relate to initial interventions for the most immediate problems and/or to initiate a larger longer term effort.

For instance, emergency remediation of lead pollution resulting from the informal processing of lead rich gold ore in Zamfara, Nigeria over a 1 year period cost US\$ 2.3 million to date (See Box 10). Over time, a complete remediation will cost more.

Table 1. Environmental Clean-up, Remediation and Other Costs in Developing Countries			
Where	Pollutant	Action	Project Duration/ Cost
<i>Emergency Clean-Up</i>			
Africa, Nigeria, Zamfara	Lead	Seven villages were initially identified for immediate remediation. Seven more villages were later identified.	1 year; 2010-2011
<i>Longer term Clean-up and Remediation (listed by region)</i>			
Africa, Zambia, Kabwe	Lead	Clean up conducted of the highest threat level contaminated soils, a canal, and a great number of toxic hotspots. The Zambian government conducted this work. Blacksmith established a local NGO to deliver educational and healthcare services. US\$ 45,000 from Blacksmith leveraged a US\$ 15 million grant from World Bank and US\$ 5 million from the Nordic Development Fund.	8 years; 2000-2008 and ongoing Total Cost: US\$ 20 million to date.
Asia, India, Gujarat	Nitrogen Potassium, Phosphorous Cadmium Chromium	Blacksmith funded the implementation of a three phase clean up of industrial effluents and sludge, the last phase of which was the treatment of the site with vermiculture. 80 per cent reduction was achieved in all harmful materials in soil, water and plants in the area.	3 years; 2006-2008 Total Cost: US\$ 25,000. Plus in kind support from local industry
Asia, India, Kanpur	Hexavalent Chromium	Highly toxic Cr VI can be converted to a much more innocent form, Cr III (trivalent chromium). In addition to being safer for human exposure, Cr III binds more easily with subsurface rocks keeping it out of the water supply altogether. Though proven in laboratories and at other work sites, this technique had never before been used in India. Levels following project completion were non detectable.	3 years; 2004-2007 Total Cost: US\$ 80,000.
Asia, Philippines, Bulacan (Marilao-Meycauayan-Obando River system)	Arsenic Lead Cadmium Chromium	1. Organizing and mobilizing a stakeholder's group; 2. River quality monitoring; 3. Pilot projects for mitigation and remediation; 4. Contaminated soil mapping and removal. Area now included in broad Metro Manila water quality programme funded by Philippines Government and World Bank.	4 years; 2005-2009 Total Cost: US\$ 300,000.
LAC, Dominican Republic, Haina	Lead	Excavation, removal and treatment of contaminated soil from 1. the site of the abandoned lead smelter, and 2. contaminated houses and streets surrounding the main site. Community education days were held and ongoing blood testing conducted.	3 years; 2007-2010 Total Cost: US\$ 404,000.
<i>Establishing stakeholder mechanisms</i>			
Asia, India, Jharkhand	Asbestos	A stakeholder group, working with all key agencies, was initiated to design a solution to this extensively contaminated area. Efforts have continued to galvanize action by government and industry.	3 months; 2006. Total Cost: US\$ 6,600.
<i>Health and Environmental Assessment and Monitoring</i>			
Africa, Mozambique, Manica	Mercury Elemental Mercury	1. Health and technological needs assessment. 2. Training protocol developed for use of retorts and other alternatives.	1 year; 2005 Total Cost: US\$ 30,000.
Africa, Zambia, Lusaka (Kafue River Basin)	Mining and industrial pollution	Extensive surveys of current pollution levels, strategic monitoring of Konkola Copper Mines (KCM) and other industrial waste disposal, and the development of novel weed control technologies.	1 year; 2005-2006 Total Cost: US\$ 10,000.

Source: Blacksmith Institute

Similarly, establishing stakeholder mechanisms or conducting monitoring are crucial in engaging local people, businesses and politicians, but this is just the beginning. The example of the abandoned asbestos mine in Jharkhand is an illustrative one. The Blacksmith Institute has spent a small amount supporting a local workers group to push the agenda, but a serious remediation would cost tens of millions.

As such, the cases highlighted are examples of minimum ‘starter’ costs for projects where remediation and clean-up are actually feasible. Important to note also, that these costs do not include ‘worst case’ scenarios as for Bhopal or Seveso for example, nor compensation payments. The Minamata disaster shows how extensive these compensation payments can become, even if many still consider the redress that was obtained in this case, the biggest mercury poisoning disaster, inadequate.⁸¹

Minamata, a fishing village in the south of Japan, is the site of one of the most well-known industrial pollution incidents involving mercury. In the 1940s and 1950s, symptoms of methylmercury poisoning – or what later came to be known as Minamata disease – were observed in fish, animal, bird and human populations in the area. In 1959, Chisso, a chemical company (acetaldehyde and vinyl chloride), was scientifically proven as the source of the organic mercury causing Minamata disease. Despite this, Chisso, supported by the Japanese government, continued to emit mercury-polluted effluents into the sea until 1968. The human tragedy of Minamata is of an unbelievable scale – 101 direct deaths caused, 800 contributed to and tens of thousands diagnosed with brain and other nervous system damage.

Box 10. Net Benefits of Action on Preventing Environmental Contamination from Informal Processing of Lead-rich Gold Ore in Zamfara State, Nigeria

Medecins sans Frontieres (MSF) were already working in this area of Nigeria when children started to die from lead poisoning in 2010. The region was suffering a food crisis and local women and children were recruited by cartels to extract gold (which occurs in conjunction with lead deposits). When the grinding of the gold ore took place at home, very young children were exposed to lead dust.

MSF estimated that 10,000 individuals, of whom 2,000 were children under five years of age, were at acute risk of death or severe illness. Some 400 children are thought to have died as a direct result of lead poisoning.

While MSF treated the hospitalised children using chelation therapy to reduce the levels of lead in their bodies, Blacksmith Institute and national and local government bodies worked to decontaminate the affected villages and to inform local people how to avoid recontamination.

Blacksmith Institutes’ summary of the project, which lasted from June 2010 until March 2011, lists the total cost at US\$ 2.3 million to date, including the costs of all partners involved: UN; local government; Blacksmith Institute, Terragraphics and MSF.

A study of the area by the Artisanal Gold Council in July 2011 reports that although remediation activities have been conducted in seven villages and more than 1,000 children have begun chelation treatment, processing of ores still continues.

Recognising the economic importance to local livelihoods, a proposal is currently being developed by the Artisanal Gold Council for training interventions to initiate safer mining practices in the region to avoid precisely a repeat of 2010’s tragic events. This provides an interesting comparison of costs versus benefits of action on improved mining practices (including the ultimate elimination of mercury).

The preliminary budget to allow for personnel and training over three years is US\$ 400,000 to US\$ 1,000,000. At the time of writing, this project has yet to find funding. The potential return on investment however is the avoidance of clean-up costs running to the order of millions, the tragic loss of young life and longer term medical care, health and productivity impairments that can be expected from lead-associated IQ loss (See Box 9).

Source: Blacksmith Institute project summaries

Since 1943, community groups, fishermen's cooperatives and Minamata victims made tremendous efforts to get recognition of and compensation for damage to human health and the environment resulting from mercury contamination. After a difficult series of processes, some compensation has been granted, though application processes are still ongoing.

After several decades, the mercury-containing sludge remained in the bay. In order to remove the sludge safely and quickly, and to protect the health of the residents, the prefectural government implemented a clean-up project in 1977. As much as 1.51 million m³ of highly contaminated sludge (more than 25ppm mercury) was dredged from Minamata bay over 14 years and placed on 58Ha of land for a cost of JPY 48.5 billion or approximately US\$ 600 million at 2010 rate.

There is no clear and official data about the number of victims. From various sources it was noted that there are still large numbers of unknown victims and their status needs to be further certified, acknowledged and compensated. The best available estimate suggest that more than 47,600 victims have been compensated.⁸²

In addition, commercial fishing, an important local economic activity, was severely affected through death of fish stocks and collapse of trade. Ultimately, the compensation paid to commercial fishers was a moderate US\$ 100 million at 2010 rate and US\$ 430kg. This value reflects how authorities delayed banning fishing in local fisheries, and the fact that no ban on fishing was enacted in more distant areas, despite fish caught there being found to contain unsafe mercury levels. Ironically, reducing monetary losses for commercial fishing meant health costs in the region were drastically increased.

In the context of the Bhopal disaster (See Section 2.2.1), it is also worth noting that compensation figures are decided largely by the strength of negotiation abilities on both sides and are often not reflective of true damage costs. These decisions can only consider the number of victims at a particular point in time, and do nothing more than estimate likely numbers in the future. This is an important point given exposure incidents involving persistent contaminants and situations where remediation is either not feasible or has not been carried out.

3.2.2 Biodiversity

Valuing biodiversity involves looking at economic values supported by diversity of ecosystems, species and genes, i.e. ecosystem goods and services like water regulation or carbon storage, pollinator services and disease resistance in crops.⁸³ The Economics of Ecosystems and Biodiversity (TEEB) is a UNEP-led project to value ecosystems and biodiversity, supported by the European Commission, German Federal Ministry for the Environment, and the UK Department for Environment, Food and Rural Affairs. In 2008 TEEB reported that the loss of ecosystems and biodiversity has been calculated to cost between US\$ 2 to 4.5 trillion *per year*.

The market values of losses represent the more easily quantifiable economic impact of biodiversity loss from chemicals mismanagement, but there are many other valuable considerations that need to be captured by non-market valuation approaches, i.e. non-use values. One example is that of honey bee populations and pesticide use. The UK National Ecosystem Assessment⁸⁴ estimates that 20 per cent of the UK cropped area is given over to pollinator-dependent crops and note that a high proportion of wild flowering plants depend on insect pollination for reproduction. On that basis, it is conservatively estimated that the value of pollinators to UK agriculture amounts to £430 million *per year*. Honeybees and pollinators have been identified as being under threat from pesticides by Pimentel and others (1992), Pimentel (2005), Chauzat et al. (2006), among others.

Some of the costs associated with these broad trends are captured in a UNEP FI and PRI (2010) study on annualized global environmental external costs from greenhouse gas emissions, overuse of water, pollution and unsustainable natural resource use that uses TEEB data. Volatile organic compounds (VOCs) alone accounted for US\$ 236.3 billion. Mercury emissions were estimated to account for US\$ 22 billion.⁸⁵ It is suggested that at least 27 per cent of total ecosystem losses are due to chemicals pollution. There is a total lack of information/modeling on attributable fraction

of biodiversity loss to chemicals pollution which should be rectified. Moreover, given the limited number of chemicals included in this study – and the fact that some of these fall outside the scope of the Global Chemicals Outlook, i.e. sulphur – this figure is best interpreted as an indication that the biodiversity costs of inaction on chemicals are high. More work, including under UNEP’s Cost of Inaction Initiative, is needed to substantiate these estimates however. Work is required to look at precisely what proportion of this could be reduced by improved chemicals management.

3.2.3 Water

Water availability and quality underpins drinking water provision and food security in our environmental systems. It is key to our economic systems through the livelihoods that water provision services support, and energy generation in some countries. Human well being, beyond basic needs into amenity, recreational, spiritual and cultural domains, has water at its core. These dimensions are all considered in the valuation of this crucial resource.⁸⁶

The costs of chemicals pollution of water resources are reasonably well explored in industrialized countries. Water treatment/remediation is one example. This practice is more costly where preventative measures have not been put in place to avoid or reduce pollution loads in water resources. The recent UK National Ecosystem Assessment⁸⁷ highlights a report summarizing costs incurred by the UK water supply industry in response to a range of groundwater quality problems (arising from nitrates, pesticides and other chemicals, salinity, metals, bacteria) during the years 1975–2004. Total capital and operating expenditure associated with these problems in this period is estimated at £754 million (2003 prices). This figure would necessarily have to be ‘unpacked’ to identify precisely the cost attributable to the chemicals-based pollution fraction given that the treatment intervention also covers salinity and bacterial contamination.

While microbial contaminants are a higher priority, chemical contamination of drinking water supplies is recognized as a serious problem for health by the WHO.⁸⁸ Poor agricultural chemicals management means that the annual cost of treating UK drinking water to meet EU nitrate standards is estimated by Lovett et al. (2006) to be at least £13 million and expected to rise. The same study estimates that £300–£400 million in capital expenditure was made by UK water companies to reduce nitrate levels in ground and surface water from 2004–2009. The US EPA (1997) estimates investment in drinking water treatment facilities to meet Safe Drinking Water Act regulations for pesticides and other chemicals at US\$ 400 million in 1995.⁸⁹ The marginal cost per cubic meter of water treated varies considerably according to the treatment process employed and is highest where high water quality is required, i.e. for the chemicals industry, food and beverage manufacturing. In Scotland, the range is £0.50/m³ to £1.20/m³ water treated for various end uses.⁹⁰

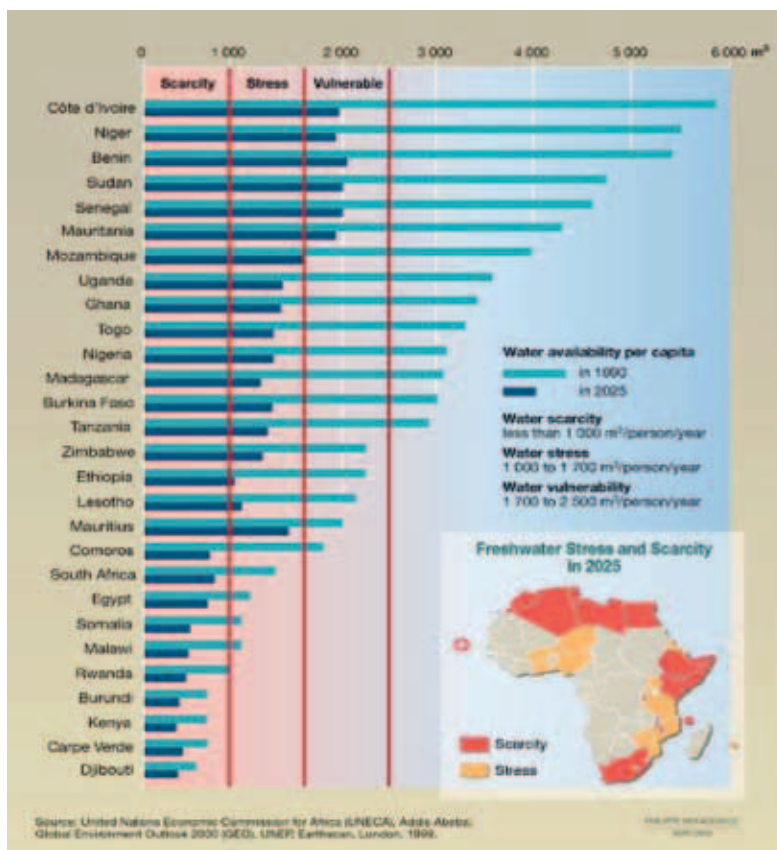
Pimentel (2005) finds that the major economic and environmental losses due to the application of pesticides in the US amounted to US\$ 2 billion in groundwater contamination. Crutchfield et al. (1995) calculate an aggregate willingness to pay for protection of groundwater from chemical contamination at US\$ 197 to 730 million *per year* by rural households in the US.

In industrialized countries, the cost of investment in safe water provision is often shared between the private and public sectors, and at least partially paid for by households and firms (‘users’). In developing and emerging economies, the financial cost of provision and treatment is more likely to be borne by public authorities however. The general population bears other types of costs in the form of poor water availability or quality, with the associated opportunity costs of water sourcing, i.e. education for girls, disease burdens of water contamination.

Water scarcity and stress is already present in many regions with growing chemicals intensity (See Figure 4).⁹¹ Poor chemicals management in production, consumption and disposal phases may in turn heighten water shortage concerns. According to UNEP, a growing number of large groundwater aquifers are facing pollution from organic chemicals, pesticides, nitrates and heavy metals. These aquifers supply an estimated 20 per cent of the global population living in arid and semi-arid regions and meet the growing water demands of several major developing world cities today – for example, Merida, Madras, Bangkok, Hat Yai, Santa Cruz and Dakar.⁹²

Water quality in agricultural use is a key concern as water is a major receiving environment for pesticide. As just one example, Butt et al. (2005) demonstrate the impact of contaminated irrigation water on the heavy metal content of agricultural produce. The economic data is sparse but some estimates do exist for developing countries. Ajayi and others (2002) assert that drinking water contaminated by pesticide residue in surface and well water in could cost the Malian Government at least US\$ 64,200 (not accounting for harm to fish or livestock) per year.

Official development assistance to the water sector in sub-Saharan Africa amounted to US\$ 2.8 billion in 2009 for aid on access and sanitation.⁹³ How cost effective can this expenditure be considered when preventable chemicals pollution undermines water quality in the same region?



3.2.4 Agricultural, Marine and Freshwater Food Production

Increasing chemicals production, consumption and improper disposal in countries that are major agricultural and fisheries food producers has implications for health and well being of local populations, food security and loss of export value. Food production ecosystem services are underpinned by the factors discussed previously – biodiversity, water, UV-B regulation, not to mention climate regulation services (not in the scope of this discussion).

Food security is currently one of the most pressing issues globally. Decreases in agricultural productivity potentially due to increased UV radiation⁹⁴, acid rain, water contamination and soil pollution⁹⁵ attributable to chemicals mismanagement are alarming in this context.

Petty and Waibel (2005) document that in China for every US\$ 1.0 worth of pesticide applied, costs to society in the form of health and environmental damage averaged US\$ 1.86. The Pimentel (2005) study suggests that the major economic and environmental losses due to the application of pesticides in the US amounted to US\$ 1.5 billion in pesticide resistance and US\$ 1.4 billion in crop losses; and US\$ 2.2 billion in bird losses, among other costs. The total estimated US\$ 10 billion in environmental and societal damages estimated in this study are an increase over the US\$ 8 billion reported in and earlier (1992) study by the same researchers. In an African context, Ajayi et al. (2002) estimate that the costs to agriculture from ineffective pest management resulting from pesticide resistance and destruction of natural pest regulators were estimated at over US\$ 8.5 million annually for cotton crops alone.

Fisheries are one of the most economically important ecosystem services globally (See Box 11). Fish products are the single most valuable agricultural export from developing countries. From FAO (2009), 79 per cent of 2006 world fishery production took place in developing countries. Fish production constitutes a third of GDP in some small island developing states, and is as high as 10 per cent in Cambodia (capture fisheries only) and 5.77 per cent in Laos (aquaculture only). Shrimp production accounts for 7 per cent of GDP in Madagascar.

Box 11. Some Dimensions of the Global Fisheries Industry

- Global capture fisheries production in 2006 was about 92 million tonnes, with an estimated first-sale value of US\$ 91.2 billion. Fish aquaculture production in 2006 had a value of US\$78.8 billion.
- In 2006, an estimated 43.5 million people were directly engaged in primary production of fish. This represents both part-time and full-time work. In addition, a further 4 million people were engaged on an occasional basis (2.5 million of these in India). It is further estimated that about 95 per cent of that employment is located in the developing world.
- Substantial earnings derived from compensatory fees paid under access agreements that many developing countries have concluded with Distant Water Fishing Nations. The aggregate value of such agreements concluded by the EU alone is estimated around €170 million for a single year.

Source: Vannuccini (2004); UNEP (2005); FAO (2008)

Marine and inland water chemicals pollution –including eutrophication from agricultural run off, pollution from mining and forestry activities, marine dumping of untreated wastewater post industrial-use, and pollution from sea transport of chemicals – undermine ecosystems supporting fisheries. In China, the World Bank and PRC (2007) cite the effect of acute water pollution incidents on commercial fisheries has been estimated at approximately 4 billion Yuan for one year (2003). Again, unpicking the fraction attributable specifically amenable to improvements through better chemicals management practices is not possible.

In one example from the United States by Hoagland and Scatasta (2006), development planning effects of harmful algal blooms caused by excess nutrients, particularly phosphorus, agricultural fertilizers and household detergents, are at least US\$ 82 million per year. These costs include US\$ 38 million per year in commercial fisheries impacts and US\$ 3 million per year in coastal monitoring and management.⁹⁶ Crucially, there is a significant overlap between top fish/fish product producers and countries experiencing rapid increases in chemicals intensity (See Figure 5).

4. Benefits of Action on Sound Management of Chemicals Policies for National Development

Productivity, international trade and investment, innovation and employment impacts are important in determining the pace of economic growth, which in turn is crucial for absolute poverty reduction. Mostly, economic analysis of regulation and competitiveness assumes that environmental regulations increase production costs and slow economic growth. However, as experience with environmental regulation grows, so too does the understanding that health and environment-related policies do not undermine national industrial competitiveness.⁹⁹ Indeed, the UNEP Green Economy Report (UNEP 2011) shows that there is evidence that regulation can play a role in stimulating economic growth, while also obtaining improvements in environment and quality of life.¹⁰⁰

Development capitalizes on the value that chemicals yield. Yet those properties of chemicals that enable value are often the very properties that also present hazard – the linkage is inescapable. In that context, safe management of chemicals will always be necessary if economies are to develop effectively; it is a necessity, not a luxury. This final section sets out categories and examples for the development benefits that could accrue from enhanced policy action on sound management of chemicals in DCEITs – or could be forgone if no further improvements in chemicals management is made by 2020 in these countries.

Policy-makers need to see concretely how sound management of chemicals will contribute to economic performance relative to other investment opportunities, if they are to channel resources towards such policies. In a complete economic analysis, the benefits explored here would complement costs of inaction data to provide the ‘benefits’ - side of equations to calculate the potential return on investment in further improving global and national capacities for chemicals management.

4.1 The Contribution of Sound Management of Chemicals to the Development of a Green Economy

After global meltdown in the financial services sector in 2008 the call for a profound systemic change to how we ‘do business’ in order to sustain and progress gains in quality of life for all was loud and clear.¹⁰¹ Leading this, UNEP launched their Green Economy Initiative in 2008, and released the Green Economy Report in 2011. This report makes the case for investing just 2 per cent of global GDP, or around US\$ 1.3 trillion, in *greening* 10 central economic sectors to achieve progress on each of the key vectors of sustainable development: “improved human well-being and social equity, [...] significantly reducing environmental risks and ecological scarcities”.

The chemicals sector contributes to economic development through the value of chemicals products and products containing chemicals (technological contribution) and direct employment. In addition, sound chemicals management principles and action helps to maximize this contribution, paving the way for a green economy to emerge. UNDP (2009) shows how sound management of chemicals can contribute to the achievement of the Millennium Development Goals, which set targets for reducing poverty, hunger, disease, illiteracy and environmental degradation, and promoting universal primary education and women’s empowerment. Sound chemical management is also a vital element that underpins the sector’s role in a green economy, as UNEP defines it. For example:

- *Agriculture:* With increasing global demand for food, a new approach to food security must include green technologies that reduce hazardous chemical inputs including pesticides and fertilizers.¹⁰²
- *Water:* Water scarcity is determined by many factors, including the polluting of water supplies by toxic chemicals. Nearly 1 billion people do not have access to clean water. In a green economy, water will need to be used more efficiently, available to all at a reasonable cost and free from chemical pollutants.¹⁰³

- *Manufacturing:* In a green economy, eco-design of products and closed loop manufacturing will become the norm rather than the exception. This involves investing in cleaner technologies, greening of supply chains, and reducing the use of hazardous chemicals.
- *Waste management:* In situations where waste cannot be avoided, materials and energy in a green economy will be recovered for recycling and remanufacturing. Sound chemical management is critical to the safe recycling of waste products as the chemical hazards in these products must be reduced or carefully controlled through the redesign of products and packaging.
- *Building:* The development of green buildings including improvements in energy and water efficiency and reductions in toxic chemical use is an essential component of a green economy. These design parameters have proven to result in improvements in health and safety and increased worker productivity.
- *Transportation:* In a green economy, vehicles and transportation systems will be designed to be more efficient and use cleaner fuels such that carbon emissions will be greatly reduced as will air emissions of hazardous chemicals that threaten public health.
- *Tourism:* In a green economy, green-oriented tourism will flourish, including improved systems for energy and water efficiency and responsible chemicals and waste management in this industry.

4.2 Productivity Increases Enabled by Sound Management of Chemicals

Rapid increases in demand for raw materials have given rise to concerns over resource availability and security of supply worldwide.¹⁰⁴ In a world of unprecedented growth in new economies, a more productive use of finite resources may well be the technological ‘rescue’ of the twenty-first century.

Productivity is the ratio of outputs to inputs, including capital investment, labour, energy and raw materials, for specific production situations. Increased productivity – more production per unit of inputs used or same production with lower inputs – is important for meeting domestic demand for goods and services, and creating surplus for export¹⁰⁵. Productivity is closely linked with the concept of efficiency, whereby rising efficiency implies productivity growth which, at a national level, determines the sustainable level of prosperity that can be achieved by a country.

Sound management of chemicals includes a number of strategies and approaches with potential to enable greater productivity in some key sectors for developing countries, such as agriculture and mining and greater efficiency through energy use reductions, wise industrial use of chemicals and recovery of valuable materials from waste streams.

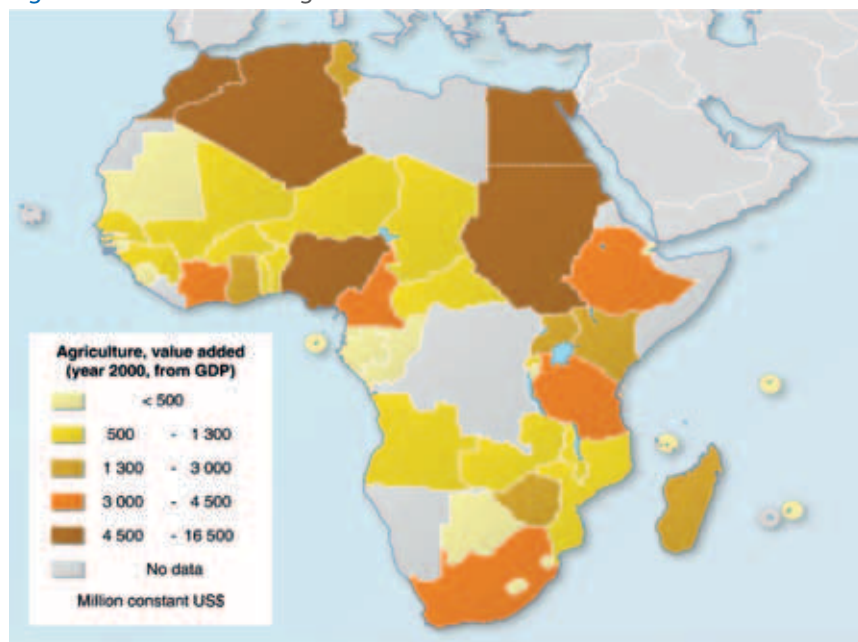
4.2.1 Agricultural Production

In 2008, 58 governments¹⁰⁶ approved the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), co-sponsored by FAO, GEF, UNDP, UNEP, UNESCO, World Bank and WHO.

IAASTD (2009) assessed how to meet the sustainability goals of reducing hunger and poverty; improving nutrition, health and rural livelihoods; and facilitating social and environmental sustainability. The report concluded that the world’s interconnected crises in climate, energy, water, and food demand immediate change in agricultural policies, institutions and practices. A recent briefing by International Institute for Environment and Development (IIED) supports this finding. IIED (2011) suggests that blending modern science with traditional agriculture methods could help protect food supplies and make agriculture more resilient to the effects of climate change.

Investment opportunities relevant to chemicals management include, among others, techniques for organic and low-input agriculture, economic and non-economic valuation of ecosystem services, reducing water pollution and bio-controls of pests as substitutes for agrochemicals. In many developing and transition countries, agriculture represents a significant economic sector (See Figure 6).

Figure 6. Contribution of agriculture to GDP in Africa



Source: World Bank, World Development Indicators, through UNEP DEWA/Geneva Data Portal <http://geodata.grid.unep.ch/> Accessed January 2006

According to ILO (2009), although agriculture continues to shed workers in nearly all countries, it remains one of the top-10 employers in developing countries. From IAASTD (2009), globally, 40 per cent of the population works in agriculture and 70 per cent of the world's poor depends on agriculture for their livelihood. This activity represents up to 50-60 per cent of the total economy in some countries (Guinea-Bissau, Central Africa, Ethiopia) and representing 20-40 per cent in sub-Saharan Africa.¹⁰⁷

Sustainable agriculture is characterized by shifting both industrial and subsistence farming towards efficient use of water, extensive use of

organic and natural soil nutrients, optimal tillage and integrated pest management (IPM). IPM encompasses a series of practices and methods that include crop rotation, crop distance, nutrient management, providing conditions for natural enemies of pests, pest monitoring, and use of pheromones or mechanical control of pests. A gradient of measures is employed with targeted pesticide use as a last resort with priority given to non-synthetic pesticides and preventive substances. These approaches to agriculture reduce reliance on pesticides, improve farmer health and environmental quality, increase profitability, and move cultivation to more sustainable methods (See Box 12).

Box 12. Increased Potato Yields from Integrated Pest Management in Ecuador

Pesticides were introduced to in the northern highlands of Ecuador in the 1940s, boosting yields and incomes. However, subsequently the region suffers from one of the highest pesticide poisoning rates in the world.

Farmers use highly hazardous pesticides such as carbofuran and methamidophos. Implementation of IPM techniques reduced pesticide applications in plots from 12 to 7 and lowered the overall amount of pesticides needed. The IPM fields yielded as many or more potatoes but production costs decreased from US\$ 104 to US\$ 80.

Researchers attribute the success of the project to capacity building of an expanded repertoire of farming techniques as well as a decrease in neurological effects among farmers which illustrated the link between health and agricultural productivity.

Source: Full version of this case study is available from http://web.idrc.ca/en/ev-29128-201-1-DO_TOPIC.html.

A study from Kasetsart University's Faculty of Economics, cited in UNEP/WHO (2008), found that after eight to nine years, integrated farming is more cost-beneficial; households practicing integrated farming methods could save up to 40 per cent of their expenses, primarily in purchases of food and agrochemicals. At the national level, an IRDC¹⁰⁸ study by Resosudarmo (2001) estimates that Indonesia's IPM programme prevents the occurrence of approximately 3,500 acute poisoning cases, 12 million chronic poisoning cases, and 12 million restricted activity days related to the use of pesticides over the next 20 years among rice farmers alone. This could reduce rice farmers' health costs by as

much as Rp 12 billion (US\$ 1.2 million) in 10 years. On this basis, the total GDP gain from implementing the national IPM programme in 2001-20 is equivalent to 3.65 per cent of Indonesia's GDP in 2000, while the increase in household incomes is 1.5 to 4.8 per cent. (This and five other country studies are summarized in Table 2).

Table 2. Some Studies Showing the Economic Benefits of Good Agricultural Practices (GAP) and Integrated Pest Management (IPM)

Bangladesh	In assessing Integrated Pest Management in Bangladesh, it was found that on average, farmers can increase rice output, and thus increase profits, by approximately 17 per cent by improving technical, allocative and scale efficiency in production (Dasgupta et al. 2004).
Belize	In Belize, implementing Good Agricultural Practices (GAP) over a five year period would allow for the net benefit of Belize Dollars (BZ\$) 324.5 (US\$ 166) per acre per year and BZ\$ 119,071,604.37 (US\$ 61 million) net present value over a five year period. The benefit/cost ratio of 3.15 shows that GAP is economically beneficial as well as being able to foster environmental and social development objectives (Parades 2010).
Indonesia	In Indonesia from 1991 to 1999, an integrated pest management programme was able to help farmers reduce the use of pesticides by approximately 56 per cent and increase yields by approximately 10 per cent (Oka, 1995). The total GDP gain from implementing the national IPM programme in 2001-20 is equivalent to 3.65 per cent of Indonesia's GDP in 2000, while the increase in household incomes is 1.5-4.8 per cent. The revenue from only a 5 per cent increase in the tax on pesticides is enough to train more than 80 per cent of rice farmers in the IPM technique over the next 20 years. The effects/benefits of this are: 1) the avoidance of 23,000 and 79 million cases of acute and chronic pesticide poisoning, respectively, among rice farmers; 2) a total GDP gain equivalent to 22 per cent of Indonesia's GDP in 2000; 3) household income gains of 8-28 per cent (Resosudarmo 2001).
Philippines	In the Philippines, the aggregate value of environmental benefits for the five villages in the Central Luzon where the IPM research programme was centered was estimated at US\$ 150,000 for the 4600 local residents (Cuyno et al. 2001).
Uganda	In Uganda, the total discounted [using a 4 per cent discount rate] monetized benefits of the proposed actions for strengthening the governance of chemicals management for the agriculture sector are estimated to be US\$ 1.98 billion over the entire analysis period 2011 to 2025. Crop yield gains are estimated at 20 per cent of the projected value added from cultivated areas expected to be effected upon by the proposed actions (Kateregga 2010).
Vietnam	In Vietnam, when a health tax of 10 per cent is put on current pesticide prices, farmers' health costs would be reduced by 4,597 VND (US\$ 0). Additionally, farmers would gain 46,826 VND (US\$ 3) because of savings from pesticide, labour, and fertilizer expenditures. As such, total benefit and net benefit to farmers would be 51,423 VND (US\$3) and 12,292 VND (US\$ 1), respectively. Thus, at the farm level, net benefit continues to increase as pesticide health tax increases. It is also noted that government would receive an amount of 36,022 VND (US\$ 2) with this tax level (Nguyen and Tran 2003).

Organic agriculture uses many of the techniques of IPM but places greater emphasis on disease and pest prevention through improved soil health, expanded biodiversity and cultivation practices. It excludes the use of plant growth regulators, genetically-modified organisms, and synthetic pesticides, although it permits the use of some natural products for insect control. Badgley and others (2007) studied organic farms in developing countries finding that their yields outperformed conventional practices by 57 per cent. Research by Stockdale and others (2001) shows 60 to 80 per cent increased yields in arable crops achieved in European context compared to conventional farming methods.

4.2.2 Gold Production

Mining and chemicals issues is a rich area for exploration in economic analysis that has not yet been tapped. Within this sector, one of the most crucial chemicals issues in mining is the use of mercury in gold extraction. UNEP (2010) conservatively estimates that artisanal and small-scale gold mining (ASGM)¹¹⁰ sub-sector supplies 13 per cent of global gold production per year valued at approximately US\$ 10 billion.¹¹¹ Swain et al. (2007) show how mercury amalgamation is the most commonly used method in ASGM to extract gold in due to its ease of use, low cost and abundant (legal and illegal) supply. According to Veiga et al. (2006), this sector is the largest source of global mercury demand, with most mercury used by artisanal miners illegally diverted from other end uses. Most of this mercury is released into the environment, making ASGM the single largest source of intentional-release mercury in the world.

The Mercury Watch database estimates that releases from small-scale gold mining have increased roughly 30 per cent to 1,320 tonnes per year in 2011.

Telmer and Veiga (2009) estimate that approximately 5 per cent of mercury used in whole ore amalgamation is released into the air – in the case of open burning this often inhaled by the miner/processor. The remaining 95 per cent largely makes its way from mining tailings into waterways and onto land with further serious consequences for human health.¹¹² Evidence of mercury pollution emissions from ASGM has been gathered in many countries including the Philippines, Thailand, Tanzania and Mongolia, and surveyed globally.¹¹³ In all, ASGM activities are accompanied by severe social and environmental consequences¹¹⁴ and the environmental and health problems caused by mercury to the miners, child and women laborers are well documented¹¹⁵.

Rapid growth is predicted for informal gold production in developing countries and countries with economies in transition. Combined output in mature mining operations fell in 2009¹¹⁶ and as gold prices continued to rise, mining operations are seen to be shifting to Africa and Asia where artisanal and small-scale practices are most prevalent.

In that context, prevention of mercury pollution can produce vast health and economic benefits at the local, national and global level. The financial benefits of mercury reduction or avoidance include: 1) significantly less use of mercury leading to lower health and environment costs; 2) cost reduction in basic production inputs; 3) ensuring that environmental services can be accessed by people safely; and 4) more sustainable livelihoods especially in impoverished communities.

UNIDO GMP (2006), among others, assert that the financial gains for miners are crucial in removing obstacles to the adoption of ‘low or no’ mercury technologies in these practices. In cases where the whole ore is amalgamated, losses of mercury can be very large¹¹⁷ and could cost the miner as much as 13-30 per cent of earnings.¹¹⁸ Rising mercury prices in 2010 have already encouraged miners to use their mercury more efficiently through a number of techniques.

Mercury capturing systems reduce the volumes lost when the amalgam is burned.¹¹⁹ This mercury can be recycled and reactivated, allowing miners to use their mercury numerous times. However, this practice encourages continued mercury use, maintains mercury exposures, and postpones its eventual release into the environment. Other processes can achieve high gold recovery rates while avoiding mercury, and some use no synthetic chemicals. Pilot projects have been implemented in several countries such as Colombia, Ecuador and the Philippines.

The Swiss-funded “Support to Artisanal Mining in Mongolia” (SAM) project in Mongolia has been hailed as a particular success. A pilot plant was established at Bornuur to carry out experimental work in mercury-free technology for gold extraction at the cost of approximately US\$ 120,000. The project set out to investigate various techniques for gold recovery without the use of mercury and cyanide. The plant provides milling services for around 200 miners from the surrounding areas, producing 250g of gold on a daily basis worth US\$ 14,070 at December 2011 prices. Working on the basis that the miner receives 50 per cent of market spot prices, this potentially means earnings of US\$ 35 per miner per day.¹²⁰

Non-chemical techniques appear to be well-accepted by the miners but suffer from a lack of mainstreaming mechanisms. As long as mercury still circulates in the market, the alternative methods will not be effectively implemented.

4.2.3 Industrial Chemical and Energy Resource Use

Reducing the use of toxic substances by substituting safer chemicals (where substitutes can be found that are effective and not prohibitively costly) or processes results in cleaner production and reduced manufacturing costs. This may take the form of eliminating fugitive emissions, reducing solvent use, implementing chemical recovery, or substituting safer reactants. It can also help reduce overall operating costs by lowering or eliminating purchases of costly raw materials and energy, monitoring costs, needs for protective equipment, and end of pipe treatment.

Switching from mercury-based to membrane technology based chlor-alkali production is one example. Chlor-alkali production relies on energy intensive electrochemical technology, representing up to 40 per cent of operating costs

depending on energy prices. Historically, the chlor-alkali industry has been dominated by mercury-based production technology. A study by Prochemics (2008) documents how membrane technology can replace mercury-based production techniques however, and it requires less energy and has been shown to lower operating cash costs by 25 per cent on average. Though there is a lack of certainty for the economics of conversion, the case for switching to mercury-free technology in chlor-alkali production may speak more directly to conditions in the developing world where energy prices are higher. A report prepared by the Government of India (2006) estimates an internal rate of return (IRR) for an initial investment of Rs 600 million (US\$ 10,7 million) is 23.1 per cent.¹²¹

Especially when coupled with audits of the production process, pollution prevention can increase efficiency. UNEP/UNIDO (2010) show how production audits can identify use of toxic substances or polluting processes that need updating in SMEs in emerging economies.

UNIDO also takes the global lead on Chemical Leasing, an innovative approach within the scope of chemicals recycling that closes material supply chains between suppliers and users of chemicals and reduces unnecessary chemicals usage.¹²² While in traditional models the responsibility of the producer ends with the selling of the chemical, in chemicals leasing business models the producer remains responsible for the chemical during its whole life cycle, including its use and disposal. Consequently, chemical consumption becomes a cost rather than a revenue factor for the chemicals supplier. To reduce costs and waste, the supplier will try to reduce the amount of chemical used. It is applicable to small, medium and large enterprises in a wide range of different sectors. UNIDO project experiences show that applying these new models reduces ineffective use and over-consumption of chemicals and helps companies to enhance their economic performance (See Box 13).¹²³

Box 13. UNIDO Chemicals Leasing and Solvents in Egypt

The Egypt National Cleaner Production Centre (ENCPC), coordinates chemical Leasing activities in Egypt under the Technology Transfer and Innovation Council (TTICs) of the Ministry of Industry and Foreign Trade. The ENCPC aims to enhance competitiveness and productivity of Egypt's industry through Cleaner Production. Egypt's industrial sector accounts for 35 per cent of national GDP and employs approximately 25 per cent of the national workforce. There are eight main industrial sectors: food, chemical, textile, metal, engineering, wood, pharmaceutical and non-metallic minerals. About 270,000 companies (95 per cent) are classified as small and medium enterprises.

The hydrocarbon solvent supplier supervises the application of the solvent in the process of cleaning equipment at GM Egypt. When this process is completed, the supplier takes back the solvent waste for recycling at its plant. This model has achieved cost reductions of 15 per cent related to reduction of solvent consumption from 1.5 L per vehicle to 0.85 L per vehicle. Part of this reduction was achieved from preventing the use of the hydrocarbon solvent for purposes other than that of cleaning of equipment (e.g. washing worker hands, cloths, etc.). Other aspects of cost savings include avoided costs for solvent waste disposal. Other economic benefits cited by partners include sharing liability and benefits and the creation of a long term business relationship due to the length of contract necessary.

Source: UNIDO case studies available from <http://www.chemicalleasing.com/index.htm>.

4.2.4 Recovery of Valuable Materials from Waste Streams

Good end-of life chemicals management practices means better recovery of valuable resources from waste streams. E-waste is a particularly relevant example. Chapter I discusses how this waste stream is increasingly important in developing and emerging economies with inadequate waste management systems for safely managing the toxics contained in e-waste products. Liu and others (2010) show that currently the majority of global e-waste (90 per cent) is shipped to China while Liu et al. (2006) give some indication of the growing domestic production. The Basel Convention suggests that serious challenges are also arising from the smaller proportions making its way to the African region because of limited capacity for controlling e-waste reprocessing and recycling.¹²⁴

E-waste contains some valuable resources, i.e. copper, aluminum gold and other rare earth metals, much in demand as metals commodities prices increase. Typically, e-waste is processed in the informal sector to obtain these valuable elements. Crude recycling techniques are used and residues disposed of informally, generating a host of chemicals and heavy metals-related health and environmental concerns. From IGES (2010)¹²⁵, components and hazardous substances in e-waste include: mercury-containing components; batteries; printed circuit boards (PCBs); cathode ray tubes (CRTs); liquid crystal displays (LCDs); and, plastics containing brominated flame retardants (BFRs, in various plastic parts) and plastics made of polyvinylchloride (PVC, in wire insulation). The following are a list of these unsafe practices and the types of risks they perpetuate through the mishandling of these substances¹²⁶:

- Metals such as aluminum, copper and iron/steel are recovered using simple hammers, chisels or stones which can result in the inhalation of hazardous cadmium dust and other pollutants by workers
- Uncontrolled incineration of cables and wires is often used to recover copper, resulting in the emissions of dioxins and furans;
- Insulating foam, primarily polyurethane (PUR), from obsolete refrigerators is burned as a co-fuel when burning cooling grills of air conditioners leading to the release of ozone depleting CFCs into the atmosphere;
- CRT-monitors are broken using basic tools to recover copper and steel, resulting in the inhalation of hazardous cadmium dust and other pollutants;
- E-waste plastics which is permeated with halogenated flame retardants, such as PBDEs, and plasticizers, such as phthalates are often subjected to open burning;
- Wet chemical leaching processes using cyanide are sometimes used to recover precious metals, i.e. gold from printed wiring boards (PWB), though this practice has not been observed in all countries.¹²⁷

With the best applicable recycling technologies up to 95 per cent of steel and 88 per cent of aluminum can be recovered from desktop computers while avoiding the toxic emissions discussed above.¹²⁸ According to the Oko Institut (2009), poor practices lead to approximately 10 per cent aluminum-losses in refining stages for computer components. Manual pre-treatment, as opposed to burning, can recover 100 per cent of the copper contained in cables. Printed wiring boards and contacts treated in high-tech refineries can return 100 per cent of the input copper.

USGS (2001) suggests that one metric tonne of electronic scrap from personal computers (PCs) contains more gold than that recovered from 17t of gold ore and 40 times more copper than copper ore. A study by Keller (2006) discusses how much palladium, gold and silver are contained in printed wiring boards and contacts. The efficiency of standard hydrometallurgical recovery of gold operations in Asia has been estimated to be between 6 per cent and 30 per cent. Alternative treatment in high-tech metallurgical refineries lead to recovery rates of 92 per cent to 96 per cent, by comparison.

Sound recycling of refrigerators and freezers results not only in the recovery of bulk metals, i.e. copper, steel and aluminum.¹²⁹ An Oko Institut (2009) study in Ghana demonstrates that even a partial deployment of manual dismantling and sorting processes lead to above average metals recovery rates while also enabling up to 90 per cent recovery of ozone-depleting chemical refrigerants and foaming agents. One key outcome from this study shows that revenue from recycling of one desktop computer could be increased from US\$ 7.22 to US\$ 13.19 per unit - a 45 per cent increase - with better waste and chemicals management practices.

Sound recovery and destruction of these appliances, carried out with the best applicable technologies, can generate significant greenhouse gas emission reductions. Under certain conditions, materials recovery operations resulting in carbon emission reductions can potentially be further monetized at the company and national level through carbon markets, i.e. Clean Development Mechanism (CDM) and other mechanisms. The Oko Institut (2009) pilot implementation of best recycling practices for the large household appliance category of e-waste suggests that with proper management savings of of 2–7 t CO₂-equ per device can be achieved, depending on the size and type of refrigerator.

It is important to note that the current lack of information about chemicals in products (such as e-products) is an obstacle in achieved improved recycling of resources more generally.

4.2.5 Health Related Productivity Increases

From Section 3.1, the links between health and labour productivity are clearly established. Estimating and aggregating future earnings foregone, or lost lifetime productivity, teases out an estimated value of costs-of-illness and IQ losses to society as a whole. In addition, there are positive implications for productivity over in securing reduced health impacts for populations as a whole.

Using lead exposure and IQ-loss as the example: Grosse et al. (2002) goes further to calculate that the removal of lead from gasoline in the US could have economic benefits through increased lifetime productivity of US\$ 110-319 billion annually due to greater cognitive potential in each successive birth cohort. Tsai and Hatfield (2010) have estimated that the benefits from the removal of lead from gasoline on a global scale range from US\$ 1 to 6 trillion per year with a best estimate of US\$ 2.4 trillion per year, or 4 per cent of global Gross Domestic Product (GDP). According to the World Bank (1998) the technical solutions for removing lead from gasoline can be implemented at moderate costs. With such large social benefits, the removal of lead from gasoline is a highly cost-effective measure. In the United States alone, the benefits of phasing out lead were estimated to outweigh the costs more than 10 times.

For mercury, Sundseth and others (2010) have estimated that if airborne emissions could be reduced by 50 to 60 per cent before 2020, the resulting prevention of water and fish contamination, and exposures to pregnant women and children, could have global economic benefits of US\$ 1.8 to US\$2.2 billion in 2020.

4.3 Technological Innovation Gains Enabled by Sound Management of Chemicals

Technological innovation is a key driving factor in growing economies and building prosperity.¹³⁰ Economic models are not well enough developed to explain exactly the impact of science and technology developments on economies but the linkage exists. Investments in infrastructure, labour and resource productivity have diminishing marginal returns that would remain limited without technological innovations that push out production frontiers.

Innovation in the chemicals sector opens up new ways to use existing resources at lower cost or more productively through chemistry, development of safer alternatives to hazardous synthetic chemicals currently used in industry, and potentially supply of new chemical resources.

Effective adaptation to both harness and manage chemicals can benefit from the reality that much of that adaptation has already been accomplished in developed nations. Adopting existing technologies and approaches and learning from that experience is an easily obtainable 'innovation' that will influence the pace at which developing countries adapt to safely managing chemicals.

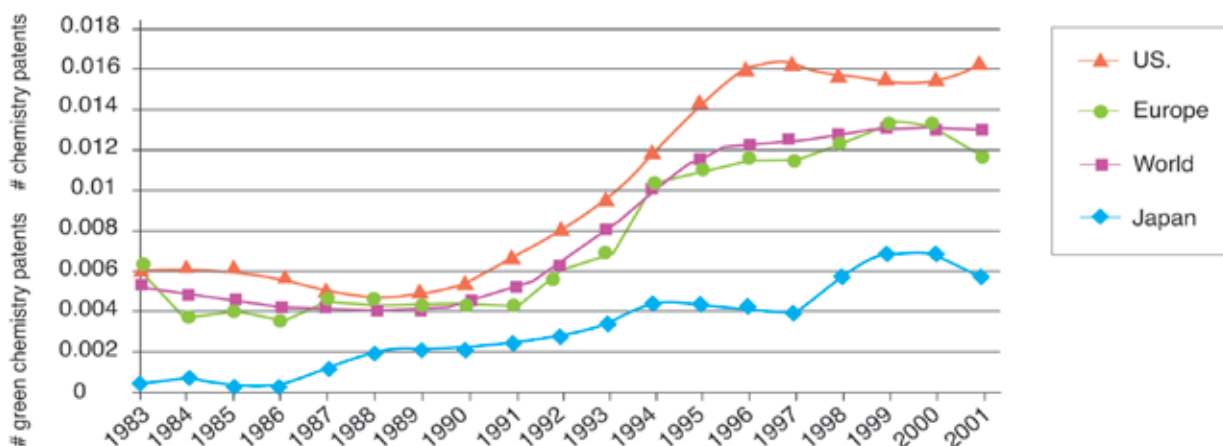
Innovative safety measures have also been developed from industry experience with chemicals incidents in industrialized countries. The 1986 Basel chemical spill following a fire at Sandoz agrochemical warehouse spurred the company to create the doCOUNT 2.0 Sustainability Management Suite for lifecycle analysis to help them extend their health and safety and environmental risk management procedures. This led to the creation of a new company dedicated to commercializing this approach.¹³¹

Green Chemistry is recognized as an important innovation in achieving sustainability, and encapsulates or enables the principle of substitution in sound management of chemicals that can be transferred from developed to emerging and developing economies.¹³²

In his seminal publication, Lancaster (2002) stated that: “Green chemistry is not a new branch of science, but more a new philosophical approach that underpins all of chemistry and has technological, environmental and societal goals”. As such, it is not a new technology specifically, but a new process by which we think about the whole lifecycle of a product or service, with a view to substituting or designing-out harmful components and supporting more sustainable consumption and production. Furthermore, it is not necessarily capital-intensive innovation, and by no means exclusive to developed economies. Constraint-based innovation,¹³³ nanotechnology and byproduct synergies; the examples are as diverse as the possibilities are endless.

The strengthening of environmental regulations has been shown to stimulate innovation of new technologies, more efficient resource use and new production processes in firms. Oltra et al. (2010) demonstrate how patents have a close to perfect link to technical invention, as a measure of innovation.¹³⁴ As an example, UNEP (2010b) review of 400,000 patents selected from a pool of 60 million found a boom in green technological activity resulting from international efforts on climate change. Nameroff and others (2004) document how, worldwide, the emphasis on *green chemistry* technology relative to chemical, plastic, rubber, and polymer technologies has increased since 1988, though the relative share of green chemistry patents remains low. The US appears to have a competitive advantage in green chemistry (See Figure 7).¹³⁵ This advantage has been attributed largely to revisions of major US environmental laws in the late 1980s and early 1990s that catalyzed the move towards new and better ways of designing, producing and using synthetic chemicals.

Figure 7. A Regional Analysis of Green Chemistry Patents Showing US Leading Innovation in this Area



Source: From Nameroff et al. (2004) cited in Oltra et al. (2008).

Technological innovation in industry is a risky business that can yield high dividends or place companies at a loss.¹³⁶ Relative performance, not absolute, is what matters in the market, and some companies will lose out. Creating a culture of innovation in national contexts however is a win-win prospect. *Creative destruction* refers to the process by which new, more productive industries displace older industries in cycles of industrial development defined by our current development paradigm. Environmental regulations catalyze creative destruction by incentivizing industries to innovate. In our example of *green chemistry*, this manifests in two distinct ways: 1) ‘upgrading’ the chemicals sector as a whole to the best practices currently being used by early-innovators and adopters and 2) integration of new technologies or products across economic sectors, displacing older or more hazardous methods and materials. The use of *green chemistry* in a range of industrial activities is expected to generate significant direct cost savings, as well as indirect savings from avoided liability for environmental and social impacts.¹³⁷ Pike Research, a clean technologies market intelligence firm, forecasts that total savings across industry from *green chemistry* developments will reach US\$ 65.5 billion, and that it represents a market opportunity worth approximately US\$ 100 billion in 2020.¹³⁸

Against a backdrop of investment in education, R&D infrastructure, intellectual property rights and fixing credit markets, the further investment in policy development (where required) and implementation; and transfer of chemicals management experience to developing countries contributes to capacity for innovation.

4.4 International Trade and Investment Supported by Sound Management of Chemicals

Some countries experiencing the fastest growth in chemicals intensity are among the poorest countries that look to international trade and attracting foreign direct investment to fuel economic growth.

Typically, economies in many developing countries are inward looking, but many emerging economies have strongly developing export-oriented domestic sectors including agriculture, mining and industrial manufacturing. Even where firms are purely focused on domestic markets, they may supply other domestic producers participating in global value chains.

The net effect of more stringent environment and safety-related product standards in the EU and US has been to restrict market access to some substandard products and services. Since domestic producers are subject to the same

The Principles of Green Chemistry

1. Prevent waste: Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.
2. Design safer chemicals and products: Design chemical products to be fully effective, yet have little or no toxicity.
3. Design less hazardous chemical syntheses: Design syntheses to use and generate substances with little or no toxicity to humans and the environment.
4. Use renewable feedstocks: Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are the wastes of other processes; depleting feedstocks are made from fossil fuels (petroleum, natural gas or coal) or are mined.
5. Use catalysts, not stoichiometric reagents: Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.
6. Avoid chemical derivatives: Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
7. Maximize atom economy: Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
8. Use safer solvents and reaction conditions: Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.
9. Increase energy efficiency: Run chemical reactions at ambient temperature and pressure whenever possible.
10. Design chemicals and products to degrade after use: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. Analyze in real time to prevent pollution: Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. Minimize the potential for accidents: Design chemicals and their forms (solid, liquid or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

requirements, this restriction is not discriminatory under WTO law. Nor is it arbitrary as such restrictions are typically supported by scientific evidence. As discussed in Section 2, supply chain risks become all the more pointed in light of these types of regulatory innovations.

An opportunity exists in helping domestic industry to take on basic chemicals management tasks (i.e. identification and assessment of chemicals' hazardous properties and risks, dissemination of hazard, risk and safety information, making informed choice of chemicals inputs and organization of safe use) in order to gain access to markets with more stringent health and environmental standards. UNEP and UNCTAD conduct a joint project on organic agriculture and food security in Africa under the Capacity Building Task Force on Trade and Environment.¹³⁹ They reported in 2008 on the positive impact of organic agriculture on poverty, noting that farmers save the costs of pesticides, gain extra income from selling surplus produce, and often obtain premium prices for certified organic produce in markets that they would have otherwise been unable to access.

As domestic suppliers to internationally-focused producers, laggard companies can also affect sustainable supply chains of companies who are seeking to export to markets with stringent product standards. ICCA GPS (2009) assert that (SME) in industry are a weak link in domestic and global supply chains. Both the ICCA and the UNIDO Cleaner Production programme suggest these businesses lack the financial and technical resources to implement adequate risk assessments, product audits and training. Working with informal entities is a challenge in this context, alongside monitoring of illegal activities.

Foreign direct investment by the global chemicals sector is an opportunity to 'raise the bar' on domestic chemicals management. Global chemicals production firms enter low regulation economies for a variety of factors. *Jaffe and colleagues (1995)* find that patterns of migration for the chemicals industry are consistent with general processes of development, investment in manufacturing capability and availability of raw materials. Brunnermeier and Levinson (2004) support this finding. Pollution regulation costs form only a small proportion of total costs even within pollution intensive firms. Access to suppliers and markets, the existence of a developed industrial base and tax incentives are also likely to be key factors. Cost of labour may be important for some individual firms, but generally the chemicals sector is not considered a labour intensive-industry.

As discussed in Section 2, sound management across chemicals lifecycles is central not only to managing chemicals risks themselves, but also to reputation and other financial risks in this sector. With a number of high profile industrial accidents and disasters in its history, the need for risk management is well understood within the global chemicals industry. In emerging markets, investment is increasingly attractive where perceived sovereign risk is reduced and some regulation operates, or at least the basis for improvement exists, among other factors.

The global chemicals industry supports some types of regulation and voluntary measures across chemicals lifecycles and the sector. Where global chemicals companies invest, they do so on the understanding that health and environmental regulation is likely to be strengthened over time.¹⁴⁰ At times, these companies lead the way in introducing voluntary health and safety and environmental best practices.

Among other initiatives, the ICCA promotes and co-ordinates Responsible Care[®], a voluntary programme that commits the chemical industry to continuous improvement in all aspects of health, safety and environmental performance.¹⁴¹ The ICCA Global Product Strategy (GPS) (2011) is a particular capacity-sharing exercise. It commits global companies to promote the safe use of chemical products and enhance product stewardship throughout the value chain – and is particularly aimed at supporting SMEs in developing countries.

A partnership between UNEP and Dow Chemicals has a similar objective in aiming to enhance industrial health and safety measures in China. With five business centres, 20 manufacturing sites and approximately 3,900 employees, Dow has a substantial presence in China. Learning from its own history, Dow Chemical Company approached UNEP-DTIE in 2006 to explore the possibility of developing a partnership to build chemical safety capacities in China by championing community awareness and emergency preparedness systems, using UNEP's APELL Programme as a blueprint (See Box 14). The APELL Programme focuses on identifying possible industrial hazards at the local level, raising safety awareness, and establishing local capacity for immediate and multi-party responses in the event an emergency should occur. The ultimate goal of the pilot project is to develop the tools and national capacity for the replication of the APELL process to promote safer operations and emergency preparedness in other industrial areas and sectors within China.¹⁴²

Box 14. UNEP's Programme on Awareness and Preparedness for Emergencies at Local Level (APELL) in China

In 2005, after the chemical accident along the Songhua River, China's government increased its efforts to improve prevention and emergency preparedness for chemical accidents. Around the same time, UNEP Sustainable Consumption and Production Branch and Dow Chemical Company developed a partnership to champion community awareness and emergency preparedness systems in China, using UNEP's programme on Awareness and Preparedness for Emergencies at Local Level (APELL) as the blueprint. Such responses demonstrate commitment within industry to secure more effective safety and quality performance from company operations and suppliers, even in emerging and developing economies.

The ultimate goal of the pilot project was to develop the tools and national capacity for the replication of the APELL process to promote safer operations and emergency preparedness in other industrial areas and sectors within China.

The pilot project started in October 2008 and was completed in December 2010. The following project outputs will be used to up-scale pilot results and replicate similar projects in other regions of China in the future:

- A needs assessment study identifying China's existing policies and needs on chemical emergency preparedness and safer production, including recommendations of hotspot areas/zones for the project's pilot demonstration activities;
- Expert recommendations for improving the Emergency Plan of the Jiangsu Yangtze International Chemical Industry Park in Zhangjiagang City (where pilot demonstration activities took place);
- A Training Handbook on Emergency Prevention and Preparedness for Chemical Industrial Accidents in China building upon the APELL approach; and
- A Guideline for Environmental Emergency Management in Chemical Industrial Parks in China.

Currently, UNEP is discussing with MEP and other partners in China such as the Association of International Chemical Manufacturers (AICM) and the China Petroleum and Chemical Industry Federation (CPCIF) on how to extend the experience of pilot activities in Zhangjiagang to other chemical parks in China. This initiative shows how industry and government interests can be mutually reinforcing, and that industry often penetrates more deeply and with greater leverage than governments can muster; in addition, it underscores the need for these stakeholders to work together.

Source: UNEP (2011a).

Other sectors for which reputation for environmental quality is important in many developing countries include trade in goods and services derived from native biodiversity (biotrade).¹⁴³ Some of the sectors that fall under this heading are directly linked to chemicals usage e.g. agricultural exports, garment industries, cosmetics and herbal medicines. Others are more indirectly affected e.g. ecotourism. When thinking about economic benefits from sound management of chemicals, it is about expansion in these sectors, not just avoided losses. Selecting biotrade value chains to develop in a national context depends on the biodiversity products and services native to individual countries.¹⁴⁴ Cultivating a positive image and being associated with ‘high quality’ biodiversity-based products benefits national economies. The UN World Tourism Organization (2002) claims that ecotourism constitutes 2-4 per cent of the global tourism market and is a vital growth prospect in developing countries. Based on 2010 data, this means ecotourism potentially generates US\$ 18-36 billion in revenue worldwide. Documented linkages between sound chemicals management practices and the value of biotrade benefits are required, however, to estimate the contribution to this opportunity for trade.

Advancing sound management of chemicals in developing and emerging economies is a question of leveling the playing field for all participants in global markets. A multitude of initiatives exist within the international community to assist countries to close the gaps in their national legislative frameworks and to work with industry to improve chemicals risk performance. For example, the International Chemicals Secretariat (2006) illustrates how developing countries can gain from using openly available information on substances generated by REACH to assist domestic industry. These and more options for policy are discussed in Chapter III.

While national policymakers need to be mindful of unnecessarily high compliance costs, environmental regulations have demonstrable benefits for industry— according to industry leaders themselves. In a UNGC/Accenture (2010) survey, 90 per cent of corporate leaders see sustainability as important to their company’s future success, largely motivated by the need to strengthen brand, trust and reputation¹⁴⁵ in recognition of decreasing brand loyalty among consumers and increasing distrust of ‘big business’. No doubt many of these CEOs are also concerned about resource security, and at least some are interested in simply “doing the right thing”.

4.5 Employment Impacts in the Transition to Sound Management of Chemicals

For many, jobs are at the heart of industrial competitiveness concerns. Sound management of chemicals improves the *quality* of many livelihoods within the chemicals sector and other activities, and creates employment in the agricultural and environmental services sectors. Moreover, as the discussion below and in 4.4. illustrate, the risk of jobs being lost due to increased chemicals regulations is very low.

There are more than 3.6 million jobs in the global chemicals industry¹⁴⁶, but with some exceptions, it is not a labour-intensive industry. The introduction of pollution control technology can displace workers in some instances, as has been observed by CEFIC (2011) in Europe. Employment in the EU chemicals industry has decreased on average by 2.2 per cent per year during the past 10 years, but this is a question of fostering decent work¹⁴⁷ and making livelihoods safer and more productive.

The UNEP Green Economy Report (2011) acknowledges the short-term job losses in some sectors but suggests that ultimately these will be offset by ‘green’ jobs. Managing chemicals appropriately requires international traceability, monitoring and surveillance and trained labour force in pollution control and environmental service industries. It is expected that more jobs will be created in new supporting industries than those that are lost in the industries subject to health and environment regulation. Luken and Van Rompaey (2007) show how industries located in developing countries have already begun to invest in environmental management improvements. In effect, an industry will thrive because of enabling sound chemicals and wastes management policies.

A move to organic farming is suggested as increasing employment opportunities.¹⁴⁸ In developed nations, the additional cost of the required additional labour can prove challenging to business. In developing countries, with low opportunity costs of labour, this may enable desirable rural livelihood development.

Finally, in appraising employment benefits from policy investments, the key issue for economists concerns the trade-offs between current employment opportunities and other potential alternative livelihoods. In terms of the employment dependent on ecosystem services in rural areas of developing and emerging economies, improved chemicals management is crucial to the economy. Otherwise, productivity in these sectors, i.e. agriculture, fishing and tourism, is negatively impacted on by poor chemicals management (See Section 3). Sound management of chemicals, including their disposal, can reduce vulnerability from destruction of environmental services and human health impacts.

Conclusions

Debates about resource allocation have frequently posited a trade-off between the economic gains associated with industrial development, on the one hand, and the costs imposed by regulation on the other. What is lost in this formulation is recognition that the failure to adopt sound chemicals management can impose large economic costs and conversely, sound chemicals management can yield significant economic benefits in terms of economic development, poverty reduction and, crucially, reduced human health and environmental risks.

The economic benefits from sound management of chemicals will vary – potentially quite significantly – from country to country depending upon production volumes, the level of economic development, the character of chemical use and exposure, and to a significant extent, and how well chemicals policies are implemented and enforced. The list of benefits assessed in this discussion is not complete; nor does the analysis correspond to the marginal benefits attributable to the intricacies of policy action on sound management of chemicals precisely. The pros and cons of individual policy instruments will also vary depending on national situations. At the global level, the data and model is not yet available to make a comprehensive estimate of the total benefits from sound chemicals management. Further work to generate and amass this evidence is needed.

Undeniably, however, there is not a country in the world that is not becoming more chemically intensive; and there are many that would profit from improved chemicals management. The question is: do we need total certainty to know we have to act? Chemicals intensification brings economic costs at the expense of development gains where there is poor capacity for preventing related accidents and exposures. It follows that investment in sound chemicals management policy frameworks, technology and knowledge generate benefits from avoiding these costs, as well as laying the foundation for enhanced productivity, new opportunities for trade, investment and business creation through innovation.

This analysis has elected to present the benefits of investment in improvement in chemicals policies in global terms rather than focusing on more economy-specific examinations of chemical-management challenges. Bridging to the latter will be important in enabling countries, donors of country development and the private sector to deliver both development and chemicals management. It is not a case of new resources suddenly being uncovered. Limited resources will have to be re-allocated either by countries or funding agents to accomplish this. It will be important for governments to anticipate the strategies required to manage chemicals more effectively in the face of increasing chemicals intensity, and the costs associated with these. Any estimates of costs of implementation must be weighed against the overall benefits of enhanced management of chemicals in the face of increasing chemicals intensity.

An important starting point is to realize that very few countries are starting from a point of absolutely zero legal infrastructure or institutional capacity for chemicals management. Most have some level of chemical regulatory apparatus in place, and industrial development authorities that will have an interest in assuring safe management of industrial chemicals. Moreover, a new paradigm of sound chemicals management is emerging in which industry is being recognized as an essential partner for success. Industry shares many of the same goals of governments and society when it comes to minimizing risks from chemicals mismanagement. Industry must carry the main responsibility for ensuring safe use of chemicals. Tapping into these shared interests is crucial for progress.

- Bayer, D.S. and Hexter, E.S. (2009). Managing Reputation Risk and Reward, Report R-1442-09-RR, The Conference Board, Inc. New York. Available from <http://www.conference-board.org/publications/publicationdetail.cfm?publicationid=1612>.
- Becker, G. (2010). *U.S. Food and Agricultural Imports: Safeguards and Selected Issues*. Congressional Research Service 7-5700. RL34198. 17 March.
- Berliner, B. (1982). *Limits of Insurability of Risks*. Prentice Hall, Upper Saddle River, New Jersey, United States.
- Bianchi, F.J.J.A., Booij, C.J.H., Tscharrntke, T. (2006). Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proceedings of the Royal Society B: Biological Sciences*, 273, 1715–1727, Available from DOI:10.1098/rspb.2006.3530.
- Brigden, K., Labunska, I., Santillo, D., Johnston, P. (2008). Chemical contamination at e-waste recycling and disposal sites in Accra and Korforidua, Ghana. Greenpeace International, Available from www.greenpeace.org/...2/.../chemical-contamination-at-e-wa.pdf.
- Brookshire, D. S., and Whittington, D. (1993). Water resource issues in developing countries, *Water Resources Research*, 29, 7, 1883-1888.
- Brunnermeier, S.B., Levinson, A. (2004) Examining the evidence on environmental regulations and industry location. *Journal of Environment and Development*, 13, 6–41.
- Butt, M.S., Sharif, K., Bajwa, B.E., Aziz, A. (2005). Hazardous effects of sewage water on the environment: Focus on heavy metals and chemical composition of soil and vegetables, *Management of Environmental Quality: An International Journal*, 16, 4, 338-346.
- Bwalya, S.M. (2010). Sound Management of Chemicals in Zambia: A cost benefit analysis of agricultural chemical use in the Kafue Basin. Preliminary report (do not circulate). Environmental Council of Zambia.
- Canton, J. (2006). Finding prosperity: The innovation economy, in *The Extreme Future – The top trends that will reshape the world in the next 20 years* The Institute for Global Futures, Plume (Penguin Group Inc.), New York.
- Carneiro, P.A., Umbuzeiro, G.A., Oliveira, D.P., Zanoni, M.V.B. (2010). Assessment of water contamination caused by a mutagenic textile effluent/dyehouse effluent bearing disperse dyes, *Journal of Hazardous Materials*, 174, 694-699.
- Carruthers, J. I. and Mundy, B. (eds.) (2006). *Environmental Valuation: Interregional and Intraregional Perspectives*, Ashgate Publishing Limited, Hampshire, England.
- Carson, R.T., Mitchell, R.C., Hanemann, W.M, Kopp, R.J., Presser, S., Ruud, P.A. (2003). Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez Oil Spill, *Environmental and Resource Economics*, 2, 257–286.
- CEFIC (2011). *Facts and Figures 2011: The European chemical industry in a worldwide perspective* Available from http://www.cefic.org/Global/Facts-and-figures-images/Graphs%202011/FF2011-chapters-PDF/Cefic_FF%20Rapport%202011.pdf

- Centemeri (2008). *Informational and Normative Uncertainty in Communities Confronting Chronic Technological Disasters: the Case of Seveso*. Centre for Social Studies (CES), University of Coimbra, Portugal.
- Chalmin P. and Gaillochet C. (2009). From waste to resource, an abstract of world waste survey, Cyclope, Veolia Environmental Services, Edition Economica, France.
- Chauzat, M.P., Faucon, J.P., Martel, A.C., Lachaize, J., Cougoule, N., Aubert, M. (2006). A Survey of Pesticide Residues in Pollen Loads Collected by Honey Bees in France, *Journal of Economic Entomology*, 99, 2, 253-262.
- Cole, D. and Mera-Orces, V. (2003). Intoxicaciones Por Plaguicidas Incidencia E Importo Económico, in *Los Plaguicidas: Impactos en producción, salud y medio ambiente en Carchi*, Ecuador, Yanggen, D., Chrissman, C., Espinosa, P.(eds). Centro Internacional de la Papa.
- Commission of the European Communities (2003). *Commission Staff Working Paper: Regulation of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restrictions of Chemicals (REACH), establishing a European Chemicals Agency and amending Directive 1999/45/EC and Regulation (EC) {on Persistent Organic Pollutants}: Extended Impact Assessment*, SEC (2003) 1171/3. Available from http://ec.europa.eu/governance/impact/ia_carried_out/docs/ia_2003/sec_2003_1171_en.pdf
- Cordy, P., Veiga, M.M., Salih, I., Al-Saadi, S., Console, S., Garcia, O., Mesa, L.A., Velásquez-López, P.C., Roeser, M. (2011). Mercury contamination from artisanal gold mining in Antioquia, Colombia: The world's highest per capita mercury pollution, *Science of the Total Environment*, 410, 154-160.
- Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.J., Sutton, P., Van Den Belt, M. (1997). The Value of the World's Ecosystem Services and Natural Capital, *Ecological Economics*, 24, 253-260.
- Crutchfield, S., Feather, P. M., Hellerstein, D. (1995). *The Benefits of Protecting Rural Water Quality: An Empirical Analysis*. United States Department of Agriculture, Economic Research Services, Agricultural Economic Report. No. 701. Washington, DC. Available from <http://www.ers.usda.gov/publications/aer701/AER701.PDF>.
- Cuyno, L.C.M., Norton, G.W., Rola, A. (2001). *Economic Analysis of Environmental Benefits of Integrated Pest Management: A Philippine Case Study*. *Agricultural Economics*, 25, 2-3, 227-233.
- Dasgupta, S., Meisner, C., Wheeler, D. (2004). *Is Environmentally-Friendly Agriculture Less Profitable for Farmers? Evidence on Integrated Pest Management in Bangladesh*. Development Research Group. World Bank, Washington, DC. <http://www.eldis.org/vfile/upload/1/document/0708/DOC16950.pdf>
- De Souza Porto, M.F. and de Freitas, C.M. (1996). Major Chemical Accidents in Industrializing Countries: The Socio-Political Amplification of Risk, *Journal of Risk Analysis*, 16, 1, 19-29.
- Dehoust, G., Schüler, D. (2007). Ökobilanzielle Untersuchung zur Verwertung von FCKW- und KW-haltigen Kühlgeräten. Öko-Institut e.V., Darmstadt, Germany.
- Diamond, P.A. and Hausman, J.A. (1994). Contingent valuation: Is some number better than no number? *Journal of Economic Perspectives*, 8, 4, 45-64.

- Diekmann, J.E. and Featherman, D.W. (1998), Assessing Cost Uncertainty. Lessons from Environmental Restoration Projects. *Journal of Construction Engineering and Management*, 124, 6, 445-451.
- Dixon, S.A. (1996). *Lessons in Professional Liability: DPIC's Loss Prevention Handbook for Environmental Professionals*. DPIC Co. Inc., Monterey, California, United States.
- Dlugolecki, A. and Cochran, L. (2012). *Risks to the Financial Sector from Chemicals*. UNEP, Geneva. Available from http://www.chem.unep.ch/unepsaicm/mainstreaming/GlobChemOutlook_SteeringCommittee_Meeting5.htm
- Economic Policy Institute (2011). Regulation, employment, and the economy: Fears of job loss are overblown, Available from http://www.epi.org/publication/regulation_employment_and_the_economy_fears_of_job_loss_are_overblown/.
- Ederington, J., Levinson, A., Minier, J. (2005). Footloose and pollution-free. *Review of Economics and Statistics*, 87, 92-99.
- Ederington, J., Minier, J. (2003). Is environmental policy a secondary trade barrier? An empirical analysis, *Canadian Journal of Economics*, 36, 137-154.
- EEA (2005). Progress in Management of Contaminated Sites (CSI 015), Assessment Draft Created July 2006. European Environment Agency, Copenhagen.
- Fabbrocini, Triassi, M.G., Mauriello, M.C., Torre, G., Annunziata, M.C., De Vita, V., Pastore, F., D'Arco, V., Monfrecola, G. (2010). Epidemiology of Skin Cancer: Role of Some Environmental Factors, *Cancers*, 2, 1980-1989. Available from <http://www.mdpi.com/2072-6694/2/4/1980>.
- FAO (2006). The Global Mechanism, *Report on the International Workshop on the Cost of Inaction and Opportunities for Investment in Arid, Semi-Arid and Dry Sub-Humid Areas*, FAO, Rome.
- FAO (2009). *The state of world fisheries and aquaculture 2008*. Available from <http://www.fao.org/docrep/011/i0250e/i0250e00.htm>.
- Fewtrell, P. and Hirst, I.L. (1998). A review of high-cost chemical/petrochemical accidents since Flixborough 1974, *IchemE Loss Prevention Bulletin*, 140.
- FM Global (2011). *Supply Chain Risk Study*. FM Global, Johnston, Rhode Island, United States.
- Foulon, J. Lanoie, P., and Laplante, B. (2002), Incentives for pollution control: Regulation or information? *Journal of Environmental Economics and Management*, 44, 169-187.
- Frano, A.J. (1991). Pricing Hazardous-Waste Risk Revisited, *Journal of Management in Engineering*, 7, 4, 428-440.
- Freeman, A. M. (1993). *The Measurement of Environmental and Resource Values. Theory and Methods*. Resources for the Future, Washington, DC.
- Freeman, P.K. and Kunreuther, H. (1997). *Managing Environmental Risk Through Insurance*, Kluwer Academic Publishers: Boston, MA.

- French, H.F. (2000). *Vanishing Borders: Protecting the Planet in the Age of Globalization*. 1st ed., W.W. Norton, New York.
- Government of India (2006). *Cost Benefit Analysis for Changeover of Hg-Cell to Membrane Cell Technology, in Chlor-Alkali Industry Central Pollution Control Board, Ministry of Environment and Forests, Information Manual On Pollution Abatement And Cleaner Technologies Series, Impacts, 14, 2006-2007*. Available from www.cpcb.nic.in/Highlights/2007/179-180.pdf.
- Greenaway, D. and Kneller, R. (2004). New Perspectives on the Benefits of Exporting. *Economie Internationale*, 100, 99-110.
- Greenstone, M. and Justin, G. (2005). *Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program*, NBER Working Paper 11790.
- Grosse, S.D., Matte, T.D., Schwartz, J., Jackson, R.J. (2002). Economic Gains Resulting from the Reduction in Children's Exposure to Lead in the United States. *Environmental Health Perspectives*, 110, 6, 563-639.
- Guria, L. (2005). The Willingness to Accept Value of Statistical Life Relative to the Willingness to Pay Value: Evidence and Policy Implications, *Environmental & Resource Economics*, 32, 2005, 113-127.
- Haefliger P., Mathieu-Nolf, M., Locicero, S., Ndiaye, C., Coly, M., Diouf, A. et al. (2009). Mass Lead Intoxication from Informal Used Lead-Acid Battery Recycling in Dakar, Senegal. *Environmental Health Perspectives*, 117, 1535-1540.
- Hagemann, S., Brasser, T., Beier, F., Mieth, C., Gutberlet, D., Borongan, G.H. (2011). *Analysis of options for the environmentally sound management of surplus mercury in Asia and the Pacific*. GRS, April. Available from http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/supplystorage/Analysis%20of%20options%20for%20the%20environmentally%20sound_EDITED%20CLEAN_May2011.pdf.
- Hamilton, J.T. (1993). Politics and Social Costs: Estimating the Impact of Collective Action on Hazardous Waste Facilities, *The RAND Journal of Economics*, 24, 1, 101-125.
- Hamilton, J.T. and Viscusi, W.K. (1999). How Costly Is Clean? An Analysis of the Benefits and Costs of Superfund Site Remediations, *Journal of Policy Analysis and Management*, 18, 1, 2-27.
- Heinberg, R. (2011). *The End of Growth: Adapting to Our New Economic Reality*, New Society Publishers, Canada. Available from www.endofgrowth.com.
- Hiles, A. (2010). *The Definitive Handbook of Business Continuity Management*, 3rd Edition, John Wiley and Sons. E-book. Available from <http://as.wiley.com/WileyCDA/WileyTitle/productCd-0470710799.html>.
- Hoagland, P. and Scatasta, S. (2006). The Economic Effects of Harmful Algal Blooms, *Ecological Studies*, 189, F, 391-402. Available for purchase at <http://www.springerlink.com/content/h488w02w46508760/>.
- HSE (2010). *Statistics 2009/10*. Health and Safety Executive, Caerphilly, United Kingdom.
- HSE (2011). *Agriculture. Work related injuries and ill health*. Health and Safety Executive, Caerphilly, United Kingdom.
- Huiru, L. (2007). Severe PCDD/F and PBDD/F Pollution in Air around an Electronic Waste Dismantling Area in China, *Environmental Science and Technology*, 41, 5641-5646.

- Huo, X., Peng, L., Xu X., Zheng, L., Qi B. et al. (2007). Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. *Environmental Health Perspectives*, 115, 7, 1113–1117.
- Hylander, L.D. and Goodsite, M.E. (2006). Environmental costs of mercury pollution, *Science of the Total Environment*, 368, 1, 352-370.
- IAASTD (International assessment of agricultural science and technology for development) (2009). IAASTD global report: summary for decision makers, Island Press, Washington, DC. Available from <http://www.agassessment.org/>.
- ICCA (International Council of Chemicals Association) (2009). *Innovations for Greenhouse Gas Reductions: A life cycle quantification of carbon abatement solutions enabled by the chemical industry*, July. Available from www.americanchemistry.com/ClimateStudy.
- ICCA (International Council of Chemicals Association) (2010). Global Product Strategy - ICCA Guidance on Chemical Risk Assessment. Product Stewardship in action: Sound chemicals management is a global responsibility, July. Available from <http://www.icca-chem.org/ICCADocs/ICCA---Global-Product-Strategy.pdf>.
- ICS (2006) *Implications of REACH for the developing countries – possible ways and means to preserve their interests*, International Chemicals Secretariat, March. Available from http://www.chemsec.org/images/stories/publications/ChemSec_publications/Implications_of_REACH_layout.pdf.
- IEHN (2008). *Toxic Stock Syndrome*. Lewis, S. et al. The Investor Environmental Health Network, Falls Church, Virginia.
- IIED (2011). Adapting agriculture with traditional knowledge, October. Available from <http://pubs.iied.org/pdfs/17111IIED.pdf?>
- ILO (2009). Key Indicators of the Labour Market: KILM 4. Employment by sector. Available from <http://kilm.ilo.org/2011/download/kilm04EN.pdf>. 16 November 2011.
- ILO (2011). *Children in hazardous work What we know, What we need to do*, International Programme on the Elimination of Child Labour (IPEC), Geneva.
- Leigh, J.P. et al. (2002). Costs of Occupational COPD and Asthma, *Chest: Official Publication of the American College of Chest Physicians*, 121, 264-272. Available from <http://www.chestjournal.org/content/121/1/264.abstract>.
- Jackson, T. (2009). *Prosperity without Growth: Economics for a finite planet*, Earthscan, London.
- Jaffe, A.B., Peterson, S.R., Portney, P.R., Stavins, R.N. (1995). Environmental regulation and the competitiveness of U.S. manufacturing: what does the evidence tell us? *Journal of Economic Literature*, 33, 132-163.
- Japan Environment Agency (1991). *Pollution in Japan, Our Tragic Experiences: Case Studies of Pollution-related Damage at Yokkaichi, Minimata, and the Jinzu River*, Study Group for Global Environment and Economics, Office of Policy Planning and Research, Planning and Coordination Bureau, Environment Agency, Government of Japan.
- Jasanoff, S. (2008). Foreword: Looking back to look forward: Bhopal's trials of knowledge and ignorance, *New England Law Review*, 42, 4.

- Johnson, B.L. and DeRosa, C.T. (1997). The Toxicologic Hazard of Superfund Hazardous Waste Sites, Agency for Toxic Substances and Disease Registry, *Reviews on Environmental Health*, 12, 4, 235-251.
- Judy, M.L. and Probst, K.N. (2009). Superfund at 30 *Vermont Journal of Environmental Law*, 11, 191-27. Available from <http://www.vjel.org/journal/pdf/VJEL10117.pdf>.
- Kahn, M.E. and Yoshino, Y. (2004). Testing for pollution havens inside and outside of regional trading blocs. *Advances in Economic Analysis & Policy*, 4, 2.
- Kakani, V.G., Reddy, K.R., Zhao, D., Sallaja, K. (2003). Field crop responses to ultraviolet-B radiation: a review, *Agricultural and Forest Meteorology*, 120, 1-4, 191-218. Available from http://www.sciencedirect.com/science?_ob=PublicationURL&_hubEid=1-s2.0-S0168192300X02249&_cid=271723&_pubType=JL&view=c&_auth=y&_acct=C000228598&_version=1&_urlVersion=0&_userid=10&md5=1dc418e5e3b8915f99b8a9e7c1689300.
- Kannan, K., Tanabe, S., Iwata, H., Tatsukawa, R. (1995). Butyltins in muscle and liver of fish collected from certain Asian and Oceanian countries, *Environmental Pollution*, 90, 3, 279-290.
- Kateregga, E. (2010). *Economic Analysis of Actions Proposed for Strengthening the Governance of Chemicals Management for the Agriculture Sector Under the Uganda/UNDP/UNEP Strategic Approach to International Chemical Management (SAICM) Project*. Makerere University Faculty of Economics and Management, Uganda.
- Keller, M. (2006). Assessment of gold recovery processes in Bangalore, India and evaluation of an alternative recycling path for printed wiring boards. Diploma Thesis, ETH Zürich.
- Krugman, P. (1994). Competitiveness: A dangerous obsession, *Foreign Affairs*, 2, 28-44. Available from <http://www.ecb.int/stats/exchange/hci/html/index.en.html>.
- Kunreuther, H. C. and Michel.Kerjan, E.O. (2007). Climate Change, Insurability of Large-Scale Disasters and the Emerging Liability Challenge, NBER Working Paper 12821, ENV/EPOC(2007)16.
- Kunst, R.M. and Marin, D. (1989). On Exports and Productivity: A Causal Analysis, *The Review of Economics and Statistics*, 71, 4, 699-703.
- Labatt, S. and White, R.R. (2002). *Environmental Finance: A Guide to Environmental Risk Assessment*, John Wiley and Sons, London.
- Leigh, J.P. (2008) *Costs of Toxic Chemical-induced Occupational Diseases Among Adults and Environmental Diseases Among Children within California Materials*, submitted by J. Paul Leigh to the California Department of Toxic Substances Control In Fulfilment of Agreement Number 07-T3388. Available from http://coeh.berkeley.edu/docs/news/leigh_calculations.pdf.
- Liu, H., Probst, A., Liao, B. (2005). Metal contamination of soils and crops affected by the Chenzhou lead/zinc mine spill (Hunan, China), *The Science of the Total Environment*, 339, 1-3, 153-166.
- Liu, X., Tanaka, M., Matsui, Y. (2006) Electrical and electronic waste management in China: progress and the barriers to overcome, *Waste Management and Research*, 24, 1, 92-101.
- Luken, R.A. and Van Rompaey, F. (2007). *Environment and industry in developing countries: assessing the adoption of environmentally sound technology*, UNIDO/ Edward Elgar Publishing.

- Maumbe, B. M. and Swinton, S. M. (2003). Hidden health costs of pesticide use in Zimbabwe's smallholder cotton growers, *Social Science and Medicine*, 57, 9, 1559-1571.
- Mocarelli, P. (2011). Perinatal Exposure to Low Doses of Dioxin Can Permanently Impair Human Semen Quality, *Environmental Health Perspectives*, 119, 5, 713–718. Available from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3094426/>.
- Minato, T. and Ashley, D.B. (1998). Data-driven Analysis of “Corporate Risk” Using Historical Cost-Control Data, *Journal of Construction Engineering and Management*, 124,1, 42-47.
- Munich Re (2009). Asbestos: Anatomy of a Mass Tort. Munich Re. Available from <http://www.globaltort.com/2010/01/global-asbestos-claiming-report-on-asbestos-litigation-in-nine-nations-munich-res-major-compilation-of-information/>.
- Munich Re (2010a). Topics 1/2010. Lessons from a long-term risk. Munich Re, Munich.
- Munich Re (2010b). Chinese drywall triggers a wave of lawsuits, *Schadenspiegel*, 1/2010, Munich Re. Available from http://www.munichreamerica.com/pub_underwriting_schadenspiegel_2010_1.shtml.
- Munich Re (2011). Dam bursts in Hungary, *Schadenspiegel*, 1/2011, Munich Re. Available from http://www.munichreamerica.com/publications/underwriting/schadenspiegel_2011_1.shtml.
- Muoghalu, M.I., Robison, D.H., Glascock, J.L. (1990). Hazardous Waste Lawsuits, Stockholder Returns, and Deterrence, *Southern Economic Journal*, 57, 2, 357-370.
- Murray, R. (1990). Asbestos: a chronology of its origins and health effects, *British Journal of Industrial Medicine*, 47, 361-365. Available from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1035183/pdf/brjindmed00042-0001.pdf>
- Nameroff, T.J., Garant, R.J., Albert M.B. (2004) Adoption of green chemistry: an analysis based on US patents, *Research Policy*, 33, 959-974.
- Neşer, G., Ünşalan, D., Tekoğul, N., Stuer-Lauridsen, F. (2008). The shipbreaking industry in Turkey: environmental, safety and health issues, *Journal of Cleaner Production*, 16, 350-358.
- Nguyen, H. D. and Tran T. D. (2003). *Economic and Health Consequences of Pesticide Use in Paddy Production in the Mekong Delta, Vietnam*, Economy and Environment Program for South East Asia (EEPSEA), Singapore. Available from <http://sd-cite.iisd.org/cgi-bin/koha/opac-detail.pl?biblionumber=14558>.
- OAS Secretariat (2005). *Estimating Economic Benefits of Environmental Health Interventions within the Context of the Health and Environment Ministers of the Americas (HEMA) Initiative*. Prepared by the OAS Secretariat Office for Sustainable Development and Environment, Government of Canada/Environment Canada, August.
- OECD (2005). The Valuation of Environmental Health Risks to Children: Environmental and Methodological and Policy Issues, Working Party on National Environmental Policy, Paris, 2 September 2005.
- OECD (1996). The Global Environment Goods and Services Industry, OECD, Paris.
- OECD (2001). OECD Global Forum on International Investment: New Horizons and Policy Challenges for Direct foreign investment in the 21st Century, Mexico City, 26-27 November 2001.

- OECD (2007). The Costs of Environmental Policy Inaction: Summary for Policymakers, Environment Directorate, Environmental Policy Committee, 29-30 November 2007.
- OECD (2011). *Development at a Glance*. Statistics by Region. 2. Africa. Available from <http://www.oecd.org/dataoecd/40/27/42139250.pdf>.
- Organisation for Economic Co-operation and Development (2011). *Development at a Glance. Statistics by Region. 2. Africa*, OECD. Available from <http://www.oecd.org/dataoecd/40/27/42139250.pdf>
- Oka, I.N. (1995). *Success and Challenges of the Indonesian National Integrated Pest Management Program in the Rice-based Cropping System, Crop Protection*, 10, 3, 163-65.
- Öko Institut (2010). Socio-economic assessment and feasibility study on sustainable e-waste management in Ghana, commissioned by the Inspectorate of the Ministry of Housing, Spatial Planning and the Environment of the Netherlands (VROM-Inspectorate) and the Dutch Association for the Disposal of Metal and Electrical Products (NVMP), August, Freiburg, Germany.
- Oltra, V., Kemp, R., de Vries, F. (2010). Patents as a measure of eco-innovation, *Journal of Environmental Technology and Management*, 13, 2. Available from <http://www.merit.unu.edu/MEI/papers/Patents%20as%20a%20measure%20of%20eco-innovation.pdf>.
- Orloff, K. and Falk, H. (2003). An international perspective on hazardous waste practices, *International Journal of Hygiene and Environmental Health*, 206, 4-5, 291- 302.
- Osinubi, O.Y., Gochfeld, M., Kipen, H.M. (2000). Health effects of asbestos and nonasbestos fibers. *Environmental Health Perspectives*, August, 108, (Suppl. 4), 665–674. Available from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1637680/pdf/envhper00313-0064.pdf>.
- Paek, J.H. (1996). Pricing the risk of liability associated with environmental clean-up projects. *Trans American Association of Cost Engineers*, CC4.1-CC4.5.
- Palmer, K., Oates, W.E., Portney, P.R. (1995). Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm? *Journal of Economic Perspectives*, 9, 4, 119-132.
- Parades, H. (2010). *Economic/Cost Benefit Analysis and Policy Instruments for The Implementation of Good Agricultural Practices in Belize for the Belize SAICM Initiative Mainstreaming into Development Plans for the Sound Management of Chemicals (SMC)*, Priorities for Key Development Sectors in Belize and Associated SMC Governance Project. Development of the Concept Papers, Policies and Cost Benefit Analysis. Submitted to the Project Coordinator Belize SAICM Initiative Department of the Environment.
- Pataranawat, P., Parkpian, P., Polprasert, C., Delaune, R.D., Jugsujinda, A. (2007). Mercury emission and distribution: Potential environmental risks at a small-scale gold mining operation, Phichit Province, Thailand, *Journal of Environmental Science and Health Part A*, 42, 1081–1093.
- Pearce, D., Atkinson, G., Mourato, S. (2006). *Cost Benefit Analysis and the Environment: Recent Developments*, OECD, Paris.
- Pedersen, F., Samsøe-Petersen, L. Gustavson, K., Höglund, L., Koundouri, P., Pearce, D. (2005). *The impact of REACH on the environment and human health*. Report to DG Environment. DHI Water and Environment, Denmark. Available from http://ec.europa.eu/environment/chemicals/reach/background/docs/exec_summary_en.pdf.

- Pesticide Action Network, UK, on-line. *Hidden Costs of Pesticide Use in Africa*. Available from <https://secure.virtuality.net/pa-nukcom/PDFs/Hidden%20Costs.pdf>.
- Pickvance, S., Karnon, J., Peters, J., El-Arifi, K. (2005). *The Impact of REACH on Occupational Health with a focus on skin and respiratory diseases*. Final report, September 2005, prepared for the European Trade Union Institute for Research, European Trade Union Technical Bureau for Health & Safety. Available from <http://hesa.etui-rehs.org/uk/newsevents/files/reach-sheffield-complet.pdf>.
- Pimentel, D. (2005). *Environmental and Economic Costs of the Application of Pesticides Primarily in the United States*. *Environment, Development and Sustainability*, 7, 229-252. Available from <http://www.beyondpesticides.org/documents/pimentel.pesticides.2005update.pdf>.
- Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A., D'Amore, M. (1992). Environmental and Economic Costs of Pesticide Use, *BioScience*, 42, 10, 750-760.
- Pirrone, N., Cinnirella, S., Feng, X., Finkelman, R. B., Friedli, H. R., Leaner, J., Mason, R., Mukherjee, A. B., Stracher, G. B., Streets, D. G., Telmer, K. (2010). Global mercury emissions to the atmosphere from anthropogenic and natural sources, *Atmos. Chem. Phys.*, 10, 5951-5964.
- Portney, P. R. (1994). The Contingent Valuation Debate: Why Economists Should Care, *Journal of Economic Perspectives*, 8, 4, 3-17.
- Portney, P.R. (1991). *Siting hazardous waste treatment facilities: the NIMBY syndrome*, Auburn House, Boston, MA.
- Poulin, J. and Gibb, H. (2008). *Mercury: Assessing the environmental burden of disease at national and local levels*, *Environmental Burden of Disease Series*, no. 16. World Health Organization, Geneva.
- Pretty, J. and Waibel, H. (2005). Paying the price: the full cost of pesticides, in *The Pesticide Detox. Towards a more sustainable agriculture*, Pretty, J. (ed.), Earthscan, London.
- Prochemics (2008). Economic Evaluation of switching the Operation of a Mercury Cell Chlor-Alkali Plant to a Membrane Cell Plant, prepared for Euro Chlor by Prochemics, March.
- PWC (2011). *Risks and rewards in eastern Africa. Spotlight on financial services. 2011 Risk Survey*. PricewaterhouseCoopers Kenya Limited, Nairobi.
- RAND (2005). *Asbestos Litigation*. RAND Corporation, Santa Monica, California.
- Resosudarmo, B.P. (2001). Impact of the Integrated Pest Management Program on the Indonesian Economy. Economy and Environment Program for Southeast Asia, IDRC.
- Resources for the Future (2010). *Deepwater Horizon and the Patchwork of Oil Spill Liability Law*, May. Available from <http://www.rff.org/rff/documents/RFF-BCK-Richardson-OilLiability.pdf>.
- Rosenzweig, P. (2007). *The Halo Effect and the eight other business delusions that deceive managers*, Free Press, New York.

- SAICM Global Plan of Action 2006. Available at: http://www.saicm.org/documents/saicm%20texts/SAICM_publication_ENG.pdf (21 November 2011).
- Schulz, R. (2001). Rainfall-induced sediment and pesticide input from orchards into the Lourens River, Western Cape, South Africa: importance of a single event, *Water Research*, 35, 8, 1869-1876.
- Schumpeter, J. (1950). *Capitalism, Socialism and Democracy*, 3rd Edition, Harper Torchbooks, New York. Available from http://agoraproject.eu/papers/Schumpeter_chapter_7%20-%20Capitalism,%20Socialism%20and%20Democracy.pdf.
- Shah, T., Burke, J., Villholth, K. (2007). Groundwater: A Global Assessment of Scale and Significance, in *Water for Food, Water for Life: A Comprehensive Assessment of Water Management*, Molden, D. (ed.), Earthscan, London.
- Shaik, B., Prem Singh, M.G., Ravikumar, B.T., et al. Heavy metal content of suspended particulate matter at world's largest ship-breaking yard, Alang-Sosiya, India, *Water, Air & Soil Pollution*, 178, 1-4, 373-384.
- Shrivastava, P. (1987). *Bhopal: Anatomy of a Crisis*. Ballinger, Cambridge, MA.
- Sly, P.D. and Pronczuk, J. (2007). Guest editorial: Susceptibility of Children to Pollutants, *Paediatric Respiratory Reviews*, 8, 4, 273-274.
- Spadaro, J.V. and Rabl, A. (2008). Global Health Impacts and Costs Due to Mercury Emissions, *Risk Analysis*, 28, 603-613.
- Stafford, L.S. (2007). Can consumers enforce environmental regulations? The role of the market in hazardous waste compliance, *Journal of Regulatory Economics*, 31, 83-107
- Stockdale, E.A., Lampkin, N.H., Hovi, M., Keatinge, R., Lennartsson, E.K.M., Macdonald, D.W., Padel, S., Tattersall, F.H., Wolfe, M.S., Watson, C.A. (2001). Agronomic and environmental implications of organic farming systems, *Advances in Agronomy*, 70, 261-262.
- Sundseth, K., Pacyna, J.M., Pacyna, E.G., Munthe, J., Belhaj, M., Astrom, S. (2010). Economic benefits from decreased mercury emissions: Projections for 2020, *Journal of Cleaner Production*, 184, 386-94.
- Swain, E.B., Jakus, P.M., Rice, G., Lupi, F., Maxson, P.A., Pacyna, J.M. et al. (2007). Socioeconomic consequences of mercury use and pollution, *Ambio*, 36, 46-61.
- Swenson, J.J., Carter, C.E., Domec, J.C., Delgado, C.I. (2011). Gold Mining in the Peruvian Amazon: Global Prices, Deforestation, and Mercury Imports, *PLoS ONE*, April, 6, 4, e18875.
- Swiss Re (2008). Natural catastrophes and man-made disasters in 2007. *Sigma* 1/2008. Swiss Re, Zurich.
- Swiss Re (2009). Commercial liability: a challenge for corporations and insurers, *Sigma* 5/2009. Swiss Re, Zurich.
- Swiss Re (2010). *Insights from the 4th International Conference on the Globalization of Collective Litigation*, December 2010, Swiss Re, Zurich. Available from http://media.swissre.com/documents/Summary_Miami_conf_Global_Litigation_10Dec2010.pdf.

- Swiss Re (2011a). Natural catastrophes and man-made disasters in 2010, *Sigma* 1/2011. Swiss Re, Zurich.
- Swiss Re (2011b). State Involvement in Insurance Markets, *Sigma* 3/2011, *Swiss Re*, Zurich.
- TEEB (2008). *Costs of Policy Inaction: The case of not meeting the 2010 biodiversity target*. Available from <http://www.teebweb.org/>.
- Telmer K. and Veiga M. M. (2009) World mercury emissions from small scale artisanal gold mining in 2008, in *Mercury Fate and Transport in the Global Atmosphere*, Pirrone, N. and Mason, R. (eds.), DOI: 10.1007/978-0-387-93958-2_6, © Springer Science.
- Telmer, K. and Stapper, D. (2007). *Evaluating and Monitoring Small Scale Gold Mining and Mercury Use: Building a Knowledge-base with Satellite Imagery and Field Work*, UNIDO PROJECT EG/GLO/01/G34.
- Tewari, Al., Joshi, H.V, Trivedi, R.H. et al. (2001). The effect of ship scrapping industry and its associated wastes on the biomass production and biodiversity of biota in insitu condition at Alang, *Marine Pollution Bulletin*, 42, 6, 62-469.
- The Economist*. (2011). Solar Power: A Painful Eclipse, 15 October, 61-62.
- Toman, M. (1998). Why Not Calculate the Global Value of the World's Ecosystems and Natural Capital, *Ecological Economics*, 25, 57-60.
- Trasande, L., Landrigan P.J., Schechter C., (2005). Public health and economic consequences of methylmercury toxicity to the developing brain, *Environmental Health Perspectives*, May, 113, 5, 590-596.
- Trasande, L., Schechter, C., Haynes, K.A., Landrigan, P.J. (2006). Applying cost analyses to drive policy that protects children: mercury as a case study. *Annals of the New York Academy of Sciences*, September, 1076, 911-23.
- Trasande, L., Cortes, J.E., Landrigan, P.J., Abercrombie, M.I., Bopp, R.F., Cifuentes, E. (2010). Methylmercury exposure in a subsistence fishing community in Lake Chapala, Mexico: an ecological approach, *Environmental Health*, January, 11, 9, 1. Available from <http://www.ncbi.nlm.nih.gov/pubmed/20064246>.
- Trasande, L. and Liu, Y. (2011). Reducing The Staggering Costs of Environmental Disease In Children, Estimated at \$76.6 Billion in 2008. *Health Affairs*, May, 30, 5.
- Tsai, P.L. and Hatfield, T.H. (2010). Green Chemistry and the Phaseout of Leaded Fuel. Available from www.csun.edu/~vchsc006/lead.pdf.
- Turner, R.K, Bateman, I., Adger, W.N. (eds.) (2000). *Economics of coastal and water resources: valuing environmental functions*, *Studies in Ecological Economics*, 3, Springer. Available from <http://www.springer.com/economics/environmental/book/978-0-7923-6504-4>.
- U.S. GAO (2008). Superfund: Funding and Reported Costs of Enforcement and Administration Activities GAO-08-841R, August 18, 2008. Available from <http://www.gao.gov/products/GAO-08-841R>.
- U.S. GAO (2011). Superfund: Information on the Nature and Costs of Cleanup Activities at Three Landfills in the Gulf Coast Region GAO-11-287R, February 18, 2011. Available from <http://www.gao.gov/products/GAO-11-287R>.

UK National Ecosystem Assessment (2011). The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.

UN Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being: A Framework for Assessment*. Available from <http://www.millenniumassessment.org/en/Framework.aspx>, retrieved 30 August 2009

UN WTO (2002). *World Ecotourism Summit – Final Report* World Tourism Organization, Madrid. Available from <http://www.unwto.org/sdt/IYE/IYE/quebec/anglais/Final-Report-QuebecSummit-web.pdf>

UNDP (2009). *How is the Sound Management of Chemicals related to the MDGs?* Available from http://www.beta.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/chemicals-management/how-is-the-sound-management-of-chemicals-related-to-the-mdgs/banner_A3_web1.pdf.

UNDP (2010). Integrating the Sound Management of Chemicals into MDG-Based Development Planning, UNDP Environment and Energy Group, December. Available from <http://www.undp.org/chemicals/initiative-undp-unep.shtml>

(UNDP-UNEP PEI (2008). *Making the Economic Case: A Primer on the Economic Arguments for Mainstreaming Poverty-Environment Linkages into National Development Planning*, Geneva, Switzerland.

UNEP (2005). *Reflecting Sustainable Development and Special and Differential Treatment for Developing Countries in the Context of New WTO Fisheries Subsidies Rules, An Issue and Options Paper*, United Nations Environment Programme, Geneva.

UNEP (2009). *Supplemental Cost-Benefit Economic Analysis Guide*. Available from http://www.chem.unep.ch/unepsaicm/mainstreaming/Documents/UNDP-UNEP%20PI_Economic%20Analysis%20Supplement_Revised%20draft.pdf.

UNEP (2010). *Squeezing Gold from a Stone*, United Nations Environment Programme, Geneva. Available from http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/Publications/UNEP_Squeezing_gold%20april%202010.pdf.

UNEP (2011). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication – A Synthesis for Policymakers*. Available from www.unep.org/greeneconomy.

UNEP (2011a). *Case Study on APELL Implementation in China Promoting Safer Operations and Emergency Preparedness in the Value Chain of the Chemical Sector*, United Nations Environment Programme (DTIE Sustainable Consumption and Production Branch), Paris.

UNEP (2011b). *Environment for Development Perspectives: Mercury Use in Artisanal and Small Scale Gold mining*, August 2011. Available from <http://new.unep.org/hazardoussubstances/EnvironmentforDevelopment/tabid/56182/Default.aspx>.

UNEP (2011c). *Reducing Mercury Use in Artisanal and Small-Scale Gold: A Practical Guide*. Available from http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/ASGM/Techdoc/UNEP%20Tech%20Doc%20APRIL%202012_120608b_web.pdf

UNEP (2011d). *Analysis of formalization approaches – Associated case studies*. Available from http://new.unep.org/hazardous-substances/Portals/9/Mercury/Documents/ASGM/Formalization_ARM/Case%20Studies%20Compendium%20Sept%2015%202011.pdf.

UNEP (2011e). *Recycling Rates of Metals – A Status Report, A Report of the Working Group on the Global Metal Flows to the International Resource Panel*. Available from http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metals_Recycling_Rates_110412-1.pdf

- UNEP/SBC Basel Convention (2010). *Meeting the challenge of e-waste in Africa*. Available from <http://ewasteguide.info/files/SBC-eWaste-Africa.pdf>.
- UNEP/EPO/ICTSD (2010). *Patents and clean energy: bridging the gap between evidence and policy*, United Nations Environment Programme, European Patents Office and the International Centre for Trade and Sustainable Development. Available from <http://www.epo.org/news-issues/issues/clean-energy/study.html>
- UNEP/GRID-Arendal (2011). Agriculture in Africa, value added out of GDP, *UNEP/GRID-Arendal Maps and Graphics Library*, http://maps.grida.no/go/graphic/agriculture_in_africa_value_added_out_of_gdp.
- UNEP/PRI (2011). *Universal Ownership. Why environmental externalities matter to institutional investors. UNEP Finance Initiative and The Principles for Responsible Investment (PRI)*. Available from http://www.unepfi.org/fileadmin/documents/universal_ownership.pdf
- UNEP/UNCTAD Capacity-building Task Force on Trade, Environment and Development (2008). Organic Agriculture and Food Security in Africa, UNCTAD/DITC/TED/2007/15. Available from http://www.unep-unctad.org/cbtf/publications/UNCTAD_DITC_TED_2007_15.pdf
- UNEP/UNIDO (2010). *Pre-SME Promoting Resource Efficiency in Small-to-Medium Enterprises: Industrial Training Handbook*. Available from http://www.unep.org/pdf/PRE-SME_handbook_2010.pdf.
- UNEPFI (2009). The global state of sustainable insurance. Insurance Working Group of the United Nations Environment Programme Finance Initiative. job no. DTI/1207/GE UNEP, Geneva.
- UNGC/Accenture (2010). *A New Era of Sustainability: UN Global Compact-Accenture CEO Study 2010*. Available from http://www.unglobalcompact.org/docs/news_events/8.1/UNGC_Accenture_CEO_Study_2010.pdf: 34.
- UNIDO GMP (2006). *Environmental and Health Assessment Report/Removal of barriers to the introduction of cleaner artisanal gold mining and extraction technologies*, UNIDO Global Mercury Project, United Nations Industrial Development Organization (UNIDO), Vienna.
- UNIDO, 2003. Agro-Industries in Rural Areas. Available from <http://www.un.org/Docs/ecosoc/meetings/hl2003/issues.paper.UNIDO.1.July.pdf>
- UNSD (2010). *World population prospects: The 2010 revision*. US EPA, 1997. Drinking Water Infrastructure Needs Survey: First Report to Congress. EPA 812-R-97-001, USEPA, Washington, DC. Available from <http://esa.un.org/unpd/wpp/index.htm>.
- US GAO (2009). Superfund: Litigation has decreased and EPA needs better information on site cleanup and cost issues to estimate future program funding requirements GAO-09-656, 14 August. Available from <http://www.gao.gov/products/GAO-09-656>.
- Vannuccini, S. (2004). Overview of fish production, utilization, consumption and trade (based on 2002 data) (FAO, 2004), Appendix 6 (The relative importance of trade in fishery products in 2002).
- Veiga, M.M., Metcalf, S.M., Baker, R. F., Klein, B., Davis, G., Bamber, A., Siegel, S., Singo P. (2006). *Manual for Training Artisanal and Small-Scale Gold Miners*, Global Mercury Project, GEF/UNDP/UNIDO.

- Volans/JWT. (2011). *The Future Quotient: 50 Stars in Seriously Long Term Innovation* First Edition 2011, Volans Ventures Ltd. and J. Walter Thompson Company, London. Available from http://www.volans.com/wp-content/uploads/2011/01/The-Future-Quotient_Final-10-Nov-2011.pdf.
- Voorhees, J. and Woellner, R.A. (1997). *International Environmental Risk Management*, Lewis Publishers, Boca Raton, Florida.
- Wagner, J. (2007). Exports and Productivity: A Survey of the Evidence from Firm-Level Data, *World Economy*, 30, 1, 60-82.
- Waitzman, N.J. et al. (1995). Economic Costs of Congenital Anomalies, *Morbidity and Mortality Weekly Report*, September, 44, 37.
- Waitzman, N.J. et al. (1996). *The Cost of Birth Defects: Estimates of the Value of Prevention*, University Press of America, Lanham, MD.
- Warner, John C., Amy S., Dye, C., Dye, K.M. (2004). Green chemistry, *Environmental Impact Assessment Review*, 24, 775-799.
- WBCSD 2010. *Vision 2050: Key Messages*. World Business Council for Sustainable Development. Available from www.wbcsd.org/web/projects/bzrole/V2050keymessages.pdf.
- Weick, K. E. (1988). Enacted sensemaking in crisis situations. *Journal of Management Studies*, 25, 305–317.
- Weick, K. E. (2010). Reflections on enacted sensemaking in the Bhopal disaster. *Journal of Management Studies*, 47, 3, 537-550.
- Weiss, J. et al. (2006). Children with Orofacial Clefts in Massachusetts: Hospital use and associated costs, Scientific session presented at the American Public Health Association (APHA) meeting, Available from http://apha.confex.com/apha/134am/techprogram/paper_130078.htm.
- White, A. L. and Ratick, S.J. (1989). Risk, compensation, and regional equity in locating hazardous facilities, *Papers of the Regional Science Association*, 67, 29-42.
- WHO (1989). *Environmental Health Criteria 86: Mercury-Environmental Aspects*. International Program on Chemical Safety, Geneva.
- WHO (1990). Acute Pesticide Poisoning: A Major Global Health Problem, J. Jeyaratnam, *World Health Statistics Quarterly*, 43, 3, 139-144. Available from <http://www.communityipm.org/toxictrail/Documents/Jeyaratnam-WHO1990.pdf>.
- WHO (2004). Selected occupational risk factors. M. Concha-Barrientos et al, in *Comparative quantification of health risks: global and regional burden of diseases attributable to selected major risk factors*, 1651-1801. M. Ezzati et al. (eds.), WHO, Geneva.
- WHO (2010). *Global Status Report on Non-communicable Diseases*, WHO, Geneva. Available from http://www.who.int/nmh/publications/ncd_report_full_en.pdf.
- WHO/UNEP (2008). *Health Environment: Managing the Linkages for Sustainable Development: A Toolkit for Decision-Makers: Synthesis Report*. [2. Thailand: reducing environmental risks and enhancing health through sustainable agriculture]. WHO/UNEP Health and Environment Linkages Initiative, Geneva. Available from http://whqlibdoc.who.int/publications/2008/9789241563727_eng.pdf.

Wilson, M.P., Schwarzman, M.R., Malloy, T. F., Fanning, E.W., Sinsheimer, P.J. (2008). *Green Chemistry: Cornerstone to a Sustainable California*, The Centers for Occupational and Environmental Health, University of California, California, United States. Available from http://coeh.berkeley.edu/docs/news/green_chem_brief.pdf.

Wilson, M.P. and Schwarzman, M.R. (2009). Green Chemistry: Wilson and Schwarzman Respond, *Environmental Health Perspectives*, September, 117, 9, A386. Available from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2737034/>.

World Bank (1998). *Phasing out lead from gasoline: worldwide experiences and policy implications*, World Bank Technical Paper no. 397, Pollution Management Series. Available from <http://siteresources.worldbank.org/INTURBANTRANSPORT/Resources/b09phasing.pdf>.

World Bank and State Environmental Protection Administration, P.R. China (2007). Cost of Pollution in China. Economic Estimates of Physical Damages. Rural Development, Natural Resources and Environment Management Unit, East Asia and Pacific Region, The World Bank, Washington, DC. Available from <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/EXTEAPREGTOPENVIRONMENT/0,,contentMDK:21252897~pagePK:34004173~piPK:34003707~theSitePK:502886,00.html>

Yasuma, T. (2010). Minamata and the Global Treaty on Mercury: Honor Minamata, Learn From Minamata and Build a Strong Mercury Treaty! Version No.110210. Citizens Against Chemicals Pollution (CACP).

Young, S., Balluz, L. and Malilay, J. (2004). Natural and technologic hazardous material releases during and after natural disasters: a review, *Science of the Total Environment*, 322, 3-20.

Zheng, Y., Gao, W., Slusser, J.R., Grant, R.H., Wang, C. (2003). Yield and yield formation of field winter wheat in response to supplemental solar ultraviolet-B radiation, *Agricultural and Forest Meteorology*, 120, 1-4, 279-283. Available from <http://www.sciencedirect.com/science/article/pii/S0168192303001886>.

Endnotes

- ¹ Many ecosystem services are essential to continued human existence and total values associated with these are therefore underestimates of infinite proportions (UK NEA Technical Report 2011, Chapter 22).
- ² See UNEP (2009).
- ³ Baumol and Oates (1988) are the authoritative reference on this discussion. However, while challenging, it is possible to value and integrate these costs and benefits into CBA frameworks using non-market valuation Stated Preference and Revealed Preferences techniques. Contingent Valuation (CV) is the best-known and most widely employed of the former approach, while hedonic pricing is an example of the latter. See Bateman et al. (2002) for more information.
- ⁴ Cost Benefit Analysis (CBA) is the typical economic assessment framework used to weigh costs of policy implementation against financial and monetized non-market impacts, positive and negative, of that policy change, in theory reflecting economic values of all stakeholders over distance and time. The overall impact on society is assessed against a 'social welfare criterion' – the measure by which policies can be accepted or rejected. This is usually the point where the policy change in question makes people better off while leaving nobody else worse off, known as Pareto Optimality. For a project or policy to pass this test, compensation must be paid by the "winners" to the "losers" so that they are indifferent to the policy change. A second social criterion is based on a principle of potential compensation, where once the potential exists for compensation to be transferred, the action is considered efficient regardless if the compensation is actually paid. See Freeman (1993).
- ⁵ See Arrow and colleagues (1993; 1996); Diamond and Hausman (1994); Ackerman and Heinzerling (2002), for example.
- ⁶ It should be noted that, as with Chapter I, this study does not currently include economic implications for inappropriate use or disposal of 'pharmaceuticals'. Moreover, given that there is no scientific consensus on the mode of interaction of multiple chemical exposures, these too cannot be considered in this discussion, though they warrant further exploration.
- ⁷ See UNEP/PRI (2011).
- ⁸ OECD (2008). *OECD Environmental Outlook to 2030*. Chapter 18: Chemicals.
- ⁹ ESG issues means environmental, social and governance issues which may affect a company's value , but which are generally omitted from the analysis of the company's value to investors.
- ¹⁰ SRI investors are socially responsible investors, who do give appropriate weight to ESG issues in their asset management strategy and operations.
- ¹¹ OECD (2011). *Development at a Glance. Statistics by Region. 2. Africa*. Available from <http://www.oecd.org/dataoecd/40/27/42139250.pdf>.
- ¹² Capital investment: Funds invested in a firm or enterprise for the purposes of furthering its business objectives. Capital investment may also refer to a firm's acquisition of capital assets or fixed assets such as manufacturing plants and machinery that is expected to be productive over many years. Sources of capital investment are manifold, and can include equity investors, banks, financial institutions, venture capital and angel investors. While capital investment is usually earmarked for capital or long-life assets, a portion may also be used for working capital purposes. Investopedia.com.
- ¹³ See [UNEP Guidance on the Development of Legal and Institutional Infrastructures for Sound Management of Chemicals and Measures for Recovering Costs of National Administration \(LIRA-Guidance\)](#).
- ¹⁴ See [UNEP Guidance on the Development of Legal and Institutional Infrastructures for Sound Management of Chemicals and Measures for Recovering Costs of National Administration \(LIRA-Guidance\)](#).
- ¹⁵ Swiss Re (2010).

- ¹⁶ FM Global (2011).
- ¹⁷ Association for Sustainable & Responsible Investment in Asia (ASRIA) *Toxic Chemicals – Asian Investors are At-Risk* January 2007, Available from http://www.asria.org/publications/lib/070212_toxic_report.pdf :para 1:7.
- ¹⁸ See The Geneva Association (2009). *The Insurance industry and climate change – contribution to the global debate* The Geneva Reports: Risk and Insurance Research No. 2. Available from http://www.genevaassociation.org/PDF/Geneva_Reports/Geneva_report%5B2%5D.pdf. Accessed 9 January 2012.
- ¹⁹ Swiss Re's *Sigma* reports on natural catastrophes and man-made disasters for the years 2001 to 2010 focus primarily on events whose duration is relatively short and for which the consequences (number of deaths/ cost of losses) can be quickly ascertained. The acknowledged bias is therefore towards the reporting of property damage and related business interruption losses arising from natural disasters. Man-made disasters are under-represented in these reports as their impacts can often take far longer to emerge, are generally subject to greater uncertainty and/or dispute regarding causation and the costs (if known) will tend to mount up over a number of years. The biases and gaps in these reports highlight one of the main issues affecting the insurance of chemical- related activities, namely the lack of reliable information regarding the frequency and cost of significant incidents (insured or otherwise). Whereas the insurance industry will generally respond positively to demand for first-party property insurances that protect businesses from the effects of weather-related or other accidental damage, the response to demand for liability insurances is always more circumspect; particularly so when the handling of chemicals and incidents involving gradual pollution or contamination may be anticipated.
- ²⁰ As a caveat, in the longer-term, the workers affected may receive further compensation (possibly funded by insurance but not necessarily) if the company was held to have been negligent.
- ²¹ This case study is adapted from the report *Case Study on APELL Implementation in China Promoting Safer Operations and Emergency Preparedness in the Value Chain of the Chemical Sector*, published by UNEP DTIE Sustainable Consumption and Production Branch, which manages UNEP's programme on Awareness and Preparedness for Emergencies at Local Level (APELL). The APELL programme focuses on identifying possible industrial hazards at the local level, raising safety awareness, and establishing local capacity for immediate and multi-party responses in the event an emergency should occur. The APELL process promotes a community-oriented framework to identify and create awareness of risks in industrialised communities, initiate measures for risk reduction and mitigation, and develop coordinated preparedness between industries, local authorities, and communities by building local partnerships between relevant stakeholders. The above mentioned report was published and launched in November 2011 at UNEP's Global APELL 25th Anniversary Forum held in Beijing, China on 14-18 November 2011. Further contributions are made by data presented at APELL Workshop 26-27 April, 2010, Zhangjiagang.
- ²² Information presented by China Petroleum and Chemical Industry Federation (CPCIF) at Global APELL 25th Anniversary Forum, 14-18 November 2011, Beijing, China.
- ²³ The events at the TEPCO-owned Fukushima nuclear plant after the 9.0 magnitude Tōhoku earthquake and tsunami on 11 March 2011 means this risk is strongly present in the minds of those engaged in governance of hazardous material risks in 2012.
- ²⁴ Unfortunately, recognition of its adverse health effects was not made public: as early as 1918, major US life insurance companies refused to cover workers exposed to asbestos, but it was not until the 1970s when the true level of knowledge within the asbestos industry was revealed through litigation. Munich Re (2009).
- ²⁵ Munich Re (2010a). The article cites ILO, but the underlying reference is WHO (2004)
- ²⁶ This section relies heavily upon Munich Re (2009) and Munich Re (2010a).

- ²⁷ The tort system has proved to be a singularly ineffective mechanism for compensating victims of asbestos-related diseases: the difficulties involved in establishing causation and attributing responsibility serve to lengthen the elapsed time between the manifestation of the disease and the receipt of compensation (on the assumption that the claim is eligible under limitation rules). (RAND 2005).
- ²⁸ Munich Re (2010a).
- ²⁹ Munich Re (2010a).
- ³⁰ Orloff and Falk, (2003).
- ³¹ See <http://www.epa.gov/superfund/about.htm>
- ³² US GAO (2008) *Superfund: Funding and Reported Costs of Enforcement and Administration Activities* GAO-08-841R, August 18, 2008. Available from <http://www.gao.gov/products/GAO-08-841R>.
- ³³ The following discussion draws on Munich Re (2011) and Swiss Re (2011a). Also see information posted at <http://www.wwf.eu/index.cfm?uGlobalSearch=kolontar>.
- ³⁴ See The Ministry of Public Administration and Justice of Hungary for more information. Available from <http://www.kormany.hu/en/ministry-of-public-administration-and-justice/news/the-company-responsible-for-the-hungarian-red-sludge-tragedy-has-received-a-record-penalty>.
- ³⁵ The Guardian, Thursday 14 May (2009) *Papers prove Trafigura ship dumped toxic waste in Ivory Coast*; See also <http://basel.int/ratif/protocol.htm>.
- ³⁶ See Further written evidence from Alan Rusbridger, *The Guardian (PS 131)*. Available from <http://www.publications.parliament.uk/pa/cm200910/cmselect/cmcomeds/memo/press/m13102.htm>.
- ³⁷ IEHN (2008).
- ³⁸ Swiss Re (2008).
- ³⁹ Dlugolecki and Cochran (2012).
- ⁴⁰ First party insurance means that the contract covers the person and /or assets specified in the contract. It is not a contract for liability to third parties or their assets.
- ⁴¹ UNEPFI (2009) gives a global overview, and PWC (2011) has a survey of insurance in East Africa as an example.
- ⁴² Jardine Lloyd Thompson insurance brokers reviewed the position after the Japanese tsunami in 2011 – See *Fukushima Daiich may slow nuclear renaissance because of political issues* 21 March 2011. Available from <http://www.jltgroup.com/risk-and-insurance/news/fukushima-daiich-may-slow-nuclear-renaissance-because-of-political-issues-says-jlt/>.
- ⁴³ In October 2011, UNEPFI published a paper on sustainable banking *UNEPFI Guide to Banking & Sustainability*. It is hoped that this will extend the recognition of ESG factors into all aspects of banking, but the number of signatories is under 200, although it includes some household names.
- ⁴⁴ Reuters, 9 January 2012, 'Exclusive: Borrowers turn lenders as banks tap firms for cash'. *"Blue-chip names like Johnson & Johnson, Pfizer and Peugeot are among firms bailing out Europe's ailing banks in a reversal of the established roles of clients and lenders."* Available from <http://www.reuters.com/article/2012/01/09/us-banks-companies-repo-idUSTRE80813T20120109>.
- ⁴⁵ See the work of AccountAbility for further information on CSR reporting in business. Available from <http://www.accountability.org/about-us/index.html>.

- ⁴⁶ See http://www.msci.com/products/esg/about_msci_esg_research.html.
- ⁴⁷ See Uncovering Financial Risks and Opportunities of Chemical Regulation. September 8, 2011, MSCI webinar.
- ⁴⁸ Swiss Re (2009).
- ⁴⁹ Becker (2010).
- ⁵⁰ The GATT establishes the core legal principles of the WTO with which all Parties must endeavor to comply.
- ⁵¹ The justification must be scientifically based and the need for trade measure clearly demonstrated. States can not require another country to adopt a certain technology; differences in conditions prevailing in other countries must be shown to have been taken into account; negotiations must precede unilateral measures; foreign countries must be given time to adjust; and, due process must be followed.
- ⁵² See http://www.wto.org/english/tratop_e/gatt_e/gatt_e.htm, last accessed 30 March 2011. For relevant case law, see Australia – Salmon (& Article 21.5 – CANADA)1 (DS18), EC – Asbestos 1 (DS135) http://www.wto.org/english/res_e/booksp_e/dispu_settlement_e.pdf; http://www.wto.org/english/tratop_e/dispu_e/dispu_agreements_index_e.htm?id=A19#selected_agreement.
- ⁵³ Bloomberg Businessweek . (2007)What Price Reputation? Available from http://www.businessweek.com/magazine/content/07_28/b4042050.htm.
- ⁵⁴ Economist Intelligence Unit *Reputation: Risk of risks* An Economist Intelligence Unit white paper sponsored by Ace, Cisco Systems, Deutsche Bank, IBM and KPMG, December 2005: 2. Available from <http://www.acegroup.com/eu-en/assets/risk-reputation-report.pdf>.
- ⁵⁵ ASrIA.(2007).
- ⁵⁶ See *Product Recall – a looming threat for all manufacturers*. August 2011. Available from <http://www.swissre.com/clients/newsletters/asia/>.
- ⁵⁷ See WHO Expert meeting to review toxicological aspects of melamine and cyanuric acid, 1-4 December 2008 for further information on health impacts of melamine. Available from http://www.who.int/foodsafety/fs_management/infosan_events/en/index.html.
- ⁵⁸ ASrIA(2007).
- ⁵⁹ Berliner B. (1982). *Limits of Insurability of Risks*. Prentice Hall, cited in Swiss Re (2011b), *State Involvement in Insurance Markets*.
- ⁶⁰ Stated Preference valuation techniques assess willingness to pay (WTP) for a given health or environmental improvement (or prevention of environmental degradation) or willingness to accept (WTA) compensation for a corresponding health or environmental cost by surveying individuals or households using hypothetical market scenarios (Pearce et al. (2006). 42). A second group of non-market valuation techniques is Revealed Preference valuation, of which hedonic pricing methods are the most established. Hedonic pricing methods are used to estimate economic values for ecosystem services that can have a direct effect on market prices (e.g. measuring the economic value of a clean environment based on its effect on housing prices. For an overview of hedonic pricing methods, see http://www.ecosystemvaluation.org/hedonic_pricing.htm). A third technique is to use Benefits Transfer methods to extrapolate valuation estimates from existing studies without having to do any new data gathering. The goal is to identify the *hypothetical* willingness to pay (WTP) of an individual to avoid chemical related health and environmental consequences. Or, if they must bear the external costs associated with no policy improvement, the aim is to identify their willingness-to-accept (WTA), a *hypothetical* compensation.

- ⁶¹ One key difficulty is the use of discounting and the choice of specific discount rates. Discounting is a technique that makes it possible to compare sums of money in the present with sums of money in the future. Poor discount rate selection can lead to paradoxical choices between protecting well-being of present generations and protecting that of future generations, and bias economic analysis results towards maintaining the ‘status-quo’.
- ⁶² For example, per patient costs such as excess medical care (direct costs) or lost economic productivity (indirect costs) for the number of patients with the disease of environmental/chemical origin.
- ⁶³ See WHO (2009).
- ⁶⁴ European Trade Union Institute for Research, European Trade Union Technical Bureau for Health & Safety.
- ⁶⁵ See Sly, P.D. and Pronczuk, J. Guest editorial: Susceptibility of children to pollutants. *Paediatric Respiratory Reviews*. (2007), 8, 4, 273-274; Martinez, F.D. The Origins of Asthma and Chronic Obstructive Pulmonary Disease in Early Life. *Proc Am Thorac Soc*. (2009), 6, 3, 272-277.
- ⁶⁶ Citing Leigh, J.P. (2008) *Costs of Toxic Chemical-induced Occupational Diseases Among Adults and Environmental Diseases Among Children within California* Materials, submitted by J. Paul Leigh to the California Department of Toxic Substances Control In Fulfillment of Agreement Number 07-T3388, 25 April, 2008. Available from http://coeh.berkeley.edu/docs/news/leigh_calculations.pdf.
- ⁶⁷ Philip J. Landrigan, Clyde B. Schechter, Jeffrey M. Lipton, Marianne C. Fahs, and Joel Schwartz, “Environmental Pollutants and Disease in American Children: Estimates of Morbidity, Mortality, and Costs for Lead Poisoning, Asthma, Cancer, and Developmental Disabilities,” *Environmental Health Perspectives* Vol. 110, No. 7, July 2002, pgs. 721-728, available from <http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1240919&blobtype=pdf>.
- ⁶⁸ See Appleton et al. (1999); Trasande et al. (2010). Small amounts of mercury entering the natural environment over time are bio-magnified in marine food chains. Even with moderate levels of contamination, mercury concentrations for local fish consumers appear to contribute significantly to body burden in this population. Even with moderate levels of local environmental contamination, mercury concentrations for fish consumers appear to contribute significantly to body burden.
- ⁶⁹ See http://www.nmfs.noaa.gov/fishwatch/trade_and_aquaculture.htm.
- ⁷⁰ See WHO (2009).
- ⁷¹ See Khan (2001); Fisher et al. (2009).
- ⁷² See OECD (2005) and Guria (2005) for further discussion.
- ⁷³ “These services include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.” UN Millennium Ecosystem Assessment (2005), <http://www.millenniumassessment.org/en/Framework.aspx>.
- ⁷⁴ Carson et al. (2003) is a seminal test case of the use of contingent valuation to ascertain lost passive use values associated with the Exxon Valdez oil spill of 1989. Carruthers and Mundy (2006) provide an authoritative discussion on environmental valuation from the intergenerational and interregional perspectives.
- ⁷⁵ Where environmental pollution impacts on human health (as opposed to occupational exposures, for example), health cost impacts could be included in this list, increasing the economic impacts for environmental damage. However, since health costs are discussed above, the focus for this exploration is largely on the costs of ecosystem services and goods.
- ⁷⁶ Hamilton and Viscusi (1999), cited in OECD (2008).

- ⁷⁷ See Greenstone and Gallagher (2005).
- ⁷⁸ See PAN UK activities and publications with African partners in the African Stockpiles Programme and other work on pesticide impacts. Available from www.pan-uk.org/Projects/Obsolete/index.htm
- ⁷⁹ See <http://www.blacksmithinstitute.org/our-strategy.html> for more information.
- ⁸⁰ Case studies were identified from 'Success Stories' publicized on the Blacksmith Institute's website that are relevant under the scope of chemicals and chemical pollution for the Global Chemicals Outlooks. Available from <http://www.blacksmithinstitute.org/success-stories.html>. Accessed 31 October 2011.
- ⁸¹ Adapted from UNEP (2011a). Based on sources: Hylander and Goodsite (2006): 361-363; Takeshi Yasuma. (2011). Citizens Against Chemicals Pollution (CACPP), Japan. MoE Minamata Meeting on June 26, 2011; SOSHISA, the Supporting Center for Minamata Disease. Available from <http://www.soshisha.org>.
- ⁸² See Yasuma (2010).
- ⁸³ See Costanza, R. et al. (1997) and Toman, M. (1998) for further information.
- ⁸⁴ See UK NEA Technical Report (2011).
- ⁸⁵ These disaggregated costs attributable to mercury and VOC pollution alone were calculated courtesy of TruCost Ltd., consultants for the UNEP/PEI (2010) study.
- ⁸⁶ See Turner and colleagues (2000) for further discussion.
- ⁸⁷ See UK NEA Technical Report (2011).
- ⁸⁸ See http://www.who.int/water_sanitation_health/dwq/dwchem_safety/en/
- ⁸⁹ It is worth noting that a total of US\$ 12.1 billion was needed in 1995 to meet the safe drinking water regulations: 84% to protect against microbiological contamination that pose an acute risk to human health.
- ⁹⁰ See UK NEA Technical Report (2011).
- ⁹¹ See Brookshire and Whittington (1993).
- ⁹² Vital Water Graphics 2. Available from <http://www.grida.no/publications/vg/water2/page/3245.aspx>.
- ⁹³ US\$ 119.6 billion total overseas development assistance was contributed by DAC members in 2009, representing 0.31 per cent of the DAC members' combined gross national incomes. *OECD Development Co-operation Directorate. Development at a Glance. Statistics by Region. 2. Africa.* Available from <http://www.oecd.org/dataoecd/40/27/42139250.pdf>.
- ⁹⁴ See Kakani et al. (2003) and Zheng et al. (2003).
- ⁹⁵ One-year damage expenses for crop loss due to soil pollution through cadmium in the Jinzu River Basin in Japan amounted to 882 million Yen FY1989 (Japan Environment Agency, 1991). Liu et al. (2005) document how metal contamination by the Chenzhou lead/zinc mine spill degraded soils and crops production in Hunan, China.
- ⁹⁶ This study also produces an estimate of US\$ 4 million/year in recreation and tourism impacts.
- ⁹⁷ Kannan and colleagues (1995) for example detected butyltin compounds in most of the samples of fish collected from local markets and sea food shops in India, Bangladesh, Thailand, Indonesia, Vietnam, Australia, Papua New Guinea and the Solomon Islands. Their results suggest widespread contamination in fish trade of Asia and Oceania.

- ⁹⁸ See, for example: The Economist, 'A spreading cloud of economic and human costs', 7 April 2011; BBC World News, 'India bans imports of all Japanese food', 6 April 2011; Financial Times, 'Farmers reel as outbreak hits demand', 3 June 2011.
- ⁹⁹ This discussion works from the principle that countries do not compete in the same way as firms (See Krugman, 1994), and so 'competitiveness' refers to how individual enterprises and collective sectors compete internationally.
- ¹⁰⁰ See also Palmer and colleagues (1995) and Jaffe et al. (1995) for the seminal discussion and analysis on this contentious debate in the US context.
- ¹⁰¹ See for example Jackson (2009); OECD work on Green Growth, Available from http://www.oecd.org/document/10/0,3746,en_2649_37465_44076170_1_1_1_37465,00.html; Heinberg (2011); UNEP (2011).
- ¹⁰² United Nations (2011). *World Economic and Social Survey -The Great Green Technological Transformation*. Available from http://www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf.
- ¹⁰³ United Nations Environment Programme (2011). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. Available from www.unep.org/greeneconomy.
- ¹⁰⁴ See Manhart (2007, 2009); UNEP (2011e).
- ¹⁰⁵ Increased productivity creates the opportunity for increased exports, all other things being equal. Greenaway and Kneller (2004) and Wagner (2007) conclude that 1) exporters are more productive than non-exporters, 2) the more productive firms self select into export markets and 3) exporting does not necessarily improve productivity. See Kunst and Marin(1989) for further evidence on this latter point.
- ¹⁰⁶ Of a total of 61 governments; Australia, Canada, and USA did not fully approve.
- ¹⁰⁷ UNEP/GRID-Arendal, Agriculture in Africa, value added out of GDP, *UNEP/GRID-Arendal Maps and Graphics Library*, http://maps.grida.no/go/graphic/agriculture_in_africa_value_added_out_of_gdp.
- ¹⁰⁸ International Development Research Centre.
- ¹⁰⁹ Adapted from UNEP (2011a).
- ¹¹⁰ The term 'artisanal' is used to encompass all small, medium, large, informal, legal and illegal miners who use rudimentary processes to extract gold from secondary and primary ore bodies. The term 'small-scale' suggests a degree more of organization and mechanization; and in many cases, more severe health and environment consequences as artisanal production scaling-up.
- ¹¹¹ Telmer and Veiga (2009) estimate annual production from ASGM at approximately 330 tonnes. Supply has averaged approximately 2,497 tonnes per year over the last several years according to World Gold Council *Demand and Supply Statistics*. These figures form the basis of related calculations.
- ¹¹² Telmer and Veiga (2009):137. The example given is that if 20 g of mercury is consumed to produce 1 g of gold, then 19 g of mercury are discharged to water and 1 g of mercury is emitted to the atmosphere. See also Pirrone et al. (2010).
- ¹¹³ See for example – Philippines: Appleton (1999); Thailand: Pataranawat et al. (2007); Global:Telmer and Veiga (2009).
- ¹¹⁴ Larmer, B. (2009) The real price of Gold. *Nat Geo*. Jan 2009; Keane L. (2009). Rising prices spark a new gold rush in Peruvian Amazon. 19 December. Washington DC, U S A: Washington Post. Available from <http://www.washingtonpost.com/wp-dyn/content/article/2009/12/18/AR2009121804139.html>. Jennifer J. Swenson, Catherine E. Carter, Jean-Christophe Domec, Cesar I. Delgado. (2011). Gold Mining in the Peruvian Amazon: Global Prices, Deforestation, and Mercury Imports. Volume 6, Issue 4, e18875.

- ¹¹⁵ See WHO (1989); ILO (2011).
- ¹¹⁶ In South Africa, the US, Canada and Australia from 1,260 tonnes in 2000 to 756 tonnes.
- ¹¹⁷ The amount of mercury used and lost during mining depends on the amalgamation approach used. See Telmer and Stapper (2007).
- ¹¹⁸ Prices on world markets for mercury trebled in 2010, from US\$ 650 per flask to US\$ 1,850 per flask (35 kilos) – rising from about US\$ 20 to US\$ 50/kilo. Calculating on the basis of the average gold price to date for 2010/11 (US\$ 1,416.34) and the 70 per cent supply model, if 1g of gold earns roughly US\$ 46 on the market, artisanal and small-scale site bosses down the chain might get US\$ 32. The mercury input cost to produce this 1g gold could be anything between US\$ 4-10 (based on 20g of mercury being used). This is highly variable however as sometimes mercury is used as a currency within gold supply chain transactions making it seemingly free to miners.
- ¹¹⁹ See Veiga et al. (2006); Telmer and Stapper (2007).
- ¹²⁰ Swiss Agency for Development and Cooperation (2009), SAM Project Annual Report 2008. Available from http://www.sam.mn/images/documents/Bornuur%20%20Mercury%20Free%20Gold%20Recovery%20Plant%20Operational%20Information_Final_ENG.pdf. The 50% basis is a conservative figure – See UNEP (2011b) *Environment for Development Perspectives: Mercury Use in Artisanal and Small Scale Gold mining*, August 2011. Available from <http://new.unep.org/hazardoussubstances/EnvironmentforDevelopment/tabid/56182/Default.aspx>.
- ¹²¹ The Government of India has banned the commissioning of new mercury cell based chlor-alkali plants since 1991. Under the Charter on Corporate Responsibility for Environment Protection. (CREP) programme, chlor-alkali plants are to phase out mercury technology by 2012. UNEP Global Mercury Partnership *Business Plan of the Mercury Reductions from the Chlor Alkali Sector partnership area* (7 August 2008). For a typical plant for one to one conversion with 100 per cent capacity utilization. All the annual operating costs, i.e. labour, maintenance, brine treatment, energy, were considered in this calculation.
- ¹²² Available from <http://www.chemicalleasing.com/index.htm>.
- ¹²³ See UNIDO case studies available from <http://www.chemicalleasing.com/index.htm>. -
- ¹²⁴ UNEP SBC Basel Convention *Meeting the challenge of e-waste in Africa*. Available from <http://ewasteguide.info/files/SBC-eWaste-Africa.pdf>.
- ¹²⁵ Institute for Global Environmental Strategies. Cited as 'Tsydenova, O. and Bengtsson, M. (2010). Review: Chemical hazards associated with treatment of waste electrical and electronic equipment *Waste Management* 31 (2011) 45–58' in the reference list.
- ¹²⁶ Adapted from the Oko-Institut (2009) study in Ghana and IGES (2010).
- ¹²⁷ There is no evidence of this practice in Ghana.
- ¹²⁸ See USGS fact Sheet: FS-060-01 2001. Available from <http://pubs.usgs.gov/fs/fs060-01/>.
- ¹²⁹ Depending on the applied treatment technology, between 96 per cent and 99 per cent of the ferrous and between 80 per cent and 92 per cent of the non-ferrous metals can be recovered in the recycling processes. See Dehoust and Schüler (2007).
- ¹³⁰ See World Economic Forum (2012); Canton (2006).
- ¹³¹ See <http://docount.com/bout-us/>.
- ¹³² Discussed in Wilson, M.P. and Schwarzman, M.R. (2009). Green Chemistry: Wilson and Schwarzman Respond Environmental Health Perspectives, 2009 September, 117(9): A386. Available from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2737034/>.

- ¹³³ See UNGC/Accenture (2010) for a discussion of rice husk water filters developed by India-based Tata Group as an example of this type of innovation.
- ¹³⁴ Patents are also just an indicator of capacity for protecting intellectual property rights. Many companies in developing and emerging economy contexts are as innovative (if not more in the case of *constraint-based* innovation). However, they may not have the resources or the need to protect their inventions with patents.
- ¹³⁵ Nameroff and colleagues (2004) present an analysis of the adoption of green chemistry based on US patents and identify 3,235 green chemistry US patents granted in the chemicals technology, polymer, plastic and rubber patent classifications. Over 3200 green chemistry patents were granted in the US patent system between 1983 and 2001, with most assigned to the chemical sector, though university and government sectors place greater emphasis on green chemistry.
- ¹³⁶ This discussion was inspired by the following article posted on TriplePundit. Available from http://www.triplepundit.com/2011/10/defense-environmental-regulations/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+TriplePundit+%28Triple+Pundit%29&utm_content=Google+Reader. See *The Wall Street Journal* 9 January 2012, How Some Avoid Innovation's Terrible Toll: asia.WSJ.com; Chapter VII: The Process of Creative Destruction in Schumpeter, J (ed.) (1950) *Capitalism, Socialism and Democracy*, 3rd Edition, Harper Torchbooks, New York. Available from http://agoraproject.eu/papers/Schumpeter_chapter_7%20-%20Capitalism,%20Socialism%20and%20Democracy.pdf.
- ¹³⁷ See <http://www.pikeresearch.com/newsroom/green-chemicals-will-save-industry-65-5-billion-by-2020>.
- ¹³⁸ See <http://www.pikeresearch.com/research/green-chemistry>.
- ¹³⁹ See <http://www.unep-unctad.org/cbtf/>.
- ¹⁴⁰ Based on a qualitative semi-structured telephone interview with CEFIC/ICCA representative, Mr. Rene van Sloten, in May 2009 as part of UNEP Chemicals Branch work on economic instruments in chemicals management.
- ¹⁴¹ See <http://www.icca-chem.org/en/Home/Responsible-care/>.
- ¹⁴² UNEP DTIE Sustainable Consumption and Production Branch (2011). *Case Study on APELL Implementation in China Promoting Safer Operations and Emergency Preparedness in the Value Chain of the Chemical Sector*.
- ¹⁴³ See www.biotrade.org for further information.
- ¹⁴⁴ See an assessment of potential biotrade native products and services in Indonesia at the following weblink for example: Available from http://www.biotrade.org/MeetingsEvents/jakarta2/4_N%20Barwa_first%20assessment%20of%20BioTrade.pdf.
- ¹⁴⁵ UNGC/Accenture (2010) survey of 766 United Nations Global Compact (UNGC) member CEOs, extensive interviews with an additional 50 member CEOs and further interviews with more than 50 business and civil society leaders.
- ¹⁴⁶ See ICCA (2009).
- ¹⁴⁷ The *Decent Work* concept was formulated by the International Labour Organization's constituents – governments and employers and workers – as a means to identify the ILO's major priorities. It is based on the understanding that work is a source of personal dignity, family stability, peace in the community, democracies that deliver for people, and economic growth that expands opportunities for productive jobs and enterprise development.
- ¹⁴⁸ See Stockdale et al. (2001).

Global Chemicals Outlook

Chapter III: Instruments and Approaches for the Sound Management of Chemicals

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1. Introduction

Chemicals are fundamental building blocks of modern economies. They are used in the production of millions of products and services that lie at the heart of national economies and make up the commodities of international trade. Millions of people throughout the world lead richer, more productive and more comfortable lives because of the products of the international chemical industry. However, many of these same chemicals can pose significant risks to human health and disrupt and compromise the careful balances of natural ecosystems. To assure a sustainable future, it is essential that chemicals are managed safely and soundly.ⁱ

Many nations throughout the world have established legal structures and competent authorities for managing chemicals in their different forms as commodities, constituents of products, environmental pollutants, occupational and public health hazards and wastes. Many businesses today have developed effective policies and practices for manufacturing and using chemicals safely and responsibly managing them as emissions and wastes. There is also a growing body of international agreements, treaties and conventions that seek to address chemicals globally. Significant progress has been made, particularly over the past 40 years in developing national, international and local capacities for managing chemicals safely and soundly.

However, there remain many and varied gaps, lapses and inconsistencies in government policies and corporate practices that fuel growing international concerns that hazardous chemicals pose a serious threat to the health of communities and ecosystems. This is particularly the case in industrializing economies that face a challenging set of priorities as they implement policies to encourage economic development and reduce poverty.

The problems faced by developing countries and countries with economies in transition arise from the increasing chemical intensification of their economies. Three factors are critical:

- Shifts in chemical production. The chemical manufacturing and processing industry, once largely located in the highly industrialized countries, is now steadily expanding into developing countries and countries in economic transition. Some of the fastest growing segments of the bulk and agricultural chemical industries are now located in China, India, Russia and Brazil where growth rates far exceed the growth rates for the chemical industries conventionally located in the United States, Japan and Europe. New chemical manufacture and processing facilities can today be found in countries ranging from Indonesia and Thailand to Nigeria and South Africa. Indeed, it is projected that by 2020, 31 per cent of global chemical production and 33 per cent of global chemical consumption will be in developing countries.¹
- Shifts in product composition. Even faster has been the penetration into local economies of products made from specialized synthetic chemicals. Agricultural chemicals and pesticides used in farming were among the first synthetic chemicals to diffuse into developing countries. Today, it is increasingly likely that highly formulated chemical personal care products, paints, adhesives, textiles, lubricants and chemically complex articles such as cell phones and laptops are being purchased and used in regions of the world recently thought to be underdeveloped and remote. In some instances, the majority of human and environmental exposures are coming from the use and disposal of these products, rather than from manufacturing.
- Composition of production. Developing countries and countries in economic transition increasingly attract the development of economic sectors that are among the most polluting. In many developing countries, agriculture is the largest economic sector, and accounts for the most significant use and release of chemicals in the economy. Chemical contamination and waste associated with industrial sectors of importance in development include pesticide contamination of water sources resulting from agricultural runoff; heavy metal pollution associated with cement production; dioxin contamination associated with electronics recycling; mercury and other heavy metal contamination associated with mining; butyl tins, heavy metals, and asbestos contamination associated with ship breaking; heavy metal contamination from tanneries; and mutagenic dyes and heavy metals associated with textile production.

ⁱ The term chemical is used in this document to mean manufactured chemical substances and compounds.

As this chemical intensity increases in developing countries and countries in economic transition, the prospects for widespread and multifaceted exposures of communities and the environment to chemicals of high and unknown concern also increases. Because the consequences of broad population exposures to this wide mix of synthetic chemicals is beyond the predictive capacities of current science, it is prudent to move expeditiously towards legal, economic and technical instruments and approaches that can assure that chemicals are used safely and sustainably. In addition to strengthening the chemical management capacities of national institutions and businesses, this will require comprehensive, broad-spectrum and preventive policies that link the many national agencies responsible for chemicals management into an integrated system for the sound management of chemicals.

The United Nations Conference on Environment and Development in 1992 focused international attention on the need for the sound chemical management in countries in economic transition. The World Summit on Sustainable Development (WSSD), a decade later, set an ambitious goal for chemicals, that, by 2020, chemicals should be produced and used in ways that lead to the minimization of significant adverse effects on human health and the environment.² In order to meet this goal, the Strategic Approach to International Chemicals Management (SAICM) was adopted in 2007 as a global policy framework to support efforts to achieve the WSSD goal. Its scope includes environmental, economic, social, health and labour aspects of chemical safety, including agricultural, industrial chemicals, and chemicals at all stages of their life cycle. Since then, there has been important progress made by national governments, international and intergovernmental organizations and leading businesses on managing the risks of toxic and hazardous chemicals. However, the pace of this progress has been slow and the results are too often insufficient.

In considering this progress it is useful to review the five objectives listed as elements of the Overarching Policy Strategy of SAICM—Risk Reduction, Knowledge and Information, Governance, Capacity Building and Technical Cooperation and Illegal International Traffic in Chemicals.³ Table 1 presents each of the five objectives and identifies a sampling of current status and gaps.

Table 1. A Sample of the Status and Gaps in Meeting SAICM Objectives					
Objectives	International		National		Industry
	Status	Gaps	Status	Gaps	Status
A. Risk Reduction					
Bans & restrictions on production, import and use of chemicals	Stockholm Convention, Montreal Protocol	Slow, Limited, Single Chemical Approach	National Prohibitions	Slow, Single Chemical Approach	Restricted Substance Lists
Emission Regulation and Standards	FAO Code of Conduct on Pesticides		National Emission Standards	Limited Number of Chemicals Addressed	
Economic and Technical Programmes	Quick Start Projects	Limited Funding per Country	Cost internalization		
Limitation on Workplace Exposures	ILO Conventions, FAO Code of Conduct	Limited Compliance	National Workplace Standards	Limited Number of Chemicals Regulated;	Control Banding
Waste Reduction and Prevention	Basel Convention		Cleaner Production, Pollution Prevention	Limited Scale	Eco-Efficiency & Waste Recycling
Site Remediation and Stockpile Control			Remedial Site Clean-up Programmes	Insufficient Funding	“Polluter Pays”

Table 1. A Sample of the Status and Gaps in Meeting SAICM Objectives					
Objectives	International		National		Industry
Safer Alternatives & Products			Government research programmes, eco-labels, certifications	Insufficient funding	Life Cycle Assessment, Alternatives Assessments Green Chemistry
B. Knowledge and Information					
Test Guidelines	OECD Guidelines	Nanotechnologies, Chemical Mixtures	EU Test Methods Guidance	Non-standardized Testing	
Testing and Screening	OECD HPV	Insufficient Information	US ISIS, REACH	Insufficient Information	Increasing Corporate Testing
Characterization and Prioritization	Characterization under GHS		Product registers, PRIO, EU CLP, Column Model		Green Screen, Pharos, Greenlist
Public Reporting and Disclosure	PRTRs, e-Chem Portal, Rotterdam Con	Chemical Use Reporting		CBI limitations	Consumer Databases
Professional Education			University Degree Programmes	Underfunded in DCs and CIETs	Professional Training
Dissemination in the Supply Chain	Labeling under GHS	Insufficient Information on Articles	EU CLP	Insufficient Information on Articles	Supplier Declarations, Package Labeling
Cross National Reporting	PRTRs, Rotterdam Convention	Illegal Traffic, Single Chemical Approach	EU Export Reporting	Insufficient Information	
C. Governance					
International Conventions	MEAs, Montreal Protocol	Missing Treaties			
Authority			Laws and Legislation	Undefined Authorities and Underfunding in DCs and CIETs	
Enforcement	Compliance in Basel Convention, Montreal Protocol		Regulatory Authorities	Insufficient in DCs and CIETs	
Coordination and Integration	SAICM	Stovepipe Fragmentation	REACH, National Ministries	Stovepipe Fragmentation	
D. Capacity Building and Technical Cooperation					
Infrastructure Development	UNDP		ECHA, National Agencies	Missing Agencies	
Training	UNITAR		Universities and Training Centres	Insufficient in DCs and CIETs	

Table 1. A Sample of the Status and Gaps in Meeting SAICM Objectives

Objectives	International		National		Industry
Financing & Resource Development	Quick Start Programme	Insufficient Funding		Insufficient Funding	
Mainstreaming in Development Aide	UNDP/UNEP Partnership	Insufficient Awareness		Insufficient Awareness	
E. Illegal International Traffic in Chemicals					
Authority and Enforcement	Strengthening of Basel and Rotterdam Conventions	Absence of Sufficient Authority	Increasing Import Management Capacity in DCs and CIETs	Insufficient Enforcement	Market Incentives Encourage Non-compliance
Information Sharing	UNEP, Customs Networking,	Absence of protocols	Increasing Import Customs Networking	Insufficient Information	

1.1 Risk Reduction

The worldwide chemical intensification of economies has revealed the inadequacy of the single, chemical-by-chemical approach of conventional government legal instruments. Addressing chemicals one by one provides little recognition that neither people nor the environment are ever exposed to a single chemical at a time. Pesticides are addressed separately from industrial chemicals and chemicals in products are addressed separately from chemicals in wastes. Responsibility for chemical policies may be split among several government agencies, leaving some chemicals and chemical applications unaddressed. Standards set for specific chemicals may be significantly lower for workplace exposures than for community exposures. Regulatory enforcement and compliance and voluntary programme participation may vary substantially across chemicals and among differing chemical applications. Not only does this fragmentation lead to inconsistencies, gaps and omissions, it also creates substantial and costly inefficiencies.

The globalization of the chemical industry and the increasing number of chemicals warranting controls is challenging the efficacy of national chemical management authorities. The financial and administrative burden of testing, characterizing and regulating the thousands of understudied and poorly characterized chemicals lies beyond the resources of even the most developed countries.

Pesticide contamination and worker exposure to industrial chemicals remain significant problems throughout agriculturally-based developing countries. Asia and Latin America have the fastest growing pesticide markets in the world; however, pesticide regulation in many countries remains rudimentary. Industrial workers in many large, medium and small factories confront chemical exposures far above international standards. The problems emerging from the contamination of water supplies with industrial chemicals, pesticide residues, electronic wastes and heavy metals such as lead, mercury and cadmium found in consumer products remain unresolved. Many local ecosystems have lost their assimilative capacity and no longer provide healthy habitat. Drinking water supplies have been compromised because of mining wastes and the bays and estuaries of several oceans are now threatened by the chemicals loaded in urban wastes and agricultural runoff.

Both developed countries and developing countries have been challenged by the emergence of novel chemicals and chemical forms. Nanoscale chemistries and products of biochemistry, gene synthesis and synthetic biology stretch the authorities of conventional chemical regulatory structures. The OECD has organized international forums for assessing and coordinating policies on nanotechnologies, but few developed or developing countries have adopted new policies or moved toward specific regulations.⁴

1.2 Information and Knowledge

While industry is generating increasing amounts of health and environmental effects information for the largest production volume chemicals, thousands of lower production substances remain on the market with little or no information. Large information gaps exist nationally and internationally on where and how chemicals are transported and used. Although computational toxicology is providing new opportunities for rapid chemical screening, methods for assessing the risks of low dose chemical exposures, the effects of a “cocktail” of chemical mixtures, particularly on children, and the multiple, continuous and synergistic exposures to chemicals in common daily life have yet to be developed. Indeed, there remain no internationally accepted testing methods for assessing the risks of several important human health impacts including endocrine disruption.

Thousands of formulated products and assembled articles on the markets contain chemical constituents that are insufficiently tested. Information on the chemicals in these products is difficult to obtain even for large scale retailers and industrial users. Product labeling remains rare, confidential business protections are frequently overused, and chemical ingredient disclosure is limited in many industrial supply chains.

The establishment of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) provides an international standard for chemical classification, but its adoption has been slow. A host of new data sources that provide information on chemical hazards is available on the Internet, although expertise is needed to use the information effectively. For the millions without Internet access and for those who do not understand the majority languages, there is no access to such chemical information.

1.3 Governance

Multilateral Environmental Agreements (MEA's) such as the Montreal Protocol (Vienna Convention) and the Basel, Rotterdam and Stockholm conventions and the Code of Conduct on the Distribution and Use of Pesticides provide legal infrastructure for the international governance of chemicals and hazardous wastes, while SAICM provides the blueprint for international coordination. However, there are many separate MEAs and, although each now shows an impressive performance record, the number of organizations implementing MEAs leads to a fragmented approach to international chemicals management that is administratively inefficient. It is also incomplete: many chemicals of global concern do not match the Stockholm Convention criteria for POPs and the Rotterdam Convention only covers some 44 chemicals.

Because the international agreements have been largely driven by interests concerned to protect the environment, close integration with public health and economic development agreements and institutions has yet to be constructed. The lack of inter-organizational integration at the international level is similar to conditions at the national level where multiple and diverse agencies often share responsibility for chemicals management with limited inter-agency coordination. In addition, chemical management is typically neglected in public health and economic development planning.

Governments in developed countries have established a wide range of legal and economic instruments and governmental structures to address chemicals. The European Union's REACH regulation has created a cross-national approach to chemicals management that has become an internationally recognized model. However, in developing countries and countries in economic transition these capacities are often missing, legally limited, or so underfunded and marginal as to demonstrate little effect on chemical management.

1.4 Capacity Building and Technical Cooperation

Many developing countries and countries in economic transition lack jurisdictional authority and qualified personnel capable of monitoring and regulating the nation's chemical use and disposal. Often there is little to no budget for chemicals management and, while government ministries focus on chemical policy issues, they do not put in place adequate structures to monitor and implement those policies. Chemical safety is typically given low priority compared with pressing needs for economic development, national security and poverty eradication. Because national programmes neglect chemical safety issues, international donors and economic aid agencies overlook the need to finance chemical management programmes. The result is budgetary underfunding for chemicals management programmes leaving responsible agencies strapped for the resources that they need. Initial capacity building and technical cooperation is needed to enable these countries to create a strong programme of chemicals management.

1.5 Illegal International Traffic in Chemicals

Notwithstanding the progress made under the Rotterdam Convention to post import notices and under the Basel Convention to deter illegal waste shipments, a significant amount of trade in banned chemicals, electronic waste and hazardous waste occurs without record. Inadequate and unclear government enforcement responsibilities and perverse market incentives encourage non-compliance. It is estimated that international crime syndicates earn US\$ 22-31 billion annually by trading in toxic chemicals, hazardous wastes, ozone-depleting substances (ODS) and endangered species.⁵ Even with strong legislation in some regions, such as the EU, illegal trade in wastes continues to be a significant problem. An estimated 75 per cent of electronic waste (e-waste) generated in the EU (8 million tonnes) is not accounted for by recycling programmes.⁶

2. Government Instruments and Approaches

The foundation for sound chemical management has been laid in many developed countries through various statutory authorities, government institutions, economic instruments, and voluntary programmes and a wide array of chemical management approaches. Legal instruments such as laws and regulations set standards and provide authorities with inspection and enforcement powers. They are designed to assure compliance, deterrence and, sometimes, restitution. Economic instruments such as taxes, service fees, fines and targeted procurement programmes encourage safer chemicals markets that can provide financial incentives, cost recovery and revenue. Technical instruments provide assistance, training, technology transfer, demonstration and research while voluntary programmes may serve a multitude of functions such as awareness raising, education, modeling, incentive-building, rewards and recognition. Chemical management approaches may include broad national chemical policies and strategies and the establishment and functioning of government ministries and agencies (infrastructures) that are charged with the responsibility for chemical management.

2.1 Legal, Economic, Technical and Voluntary Instruments and Approaches

Since the 1970s national governments have been addressing the hazards of chemicals through the adoption of a wide assortment of these instruments and approaches (See Table 2). The earliest instruments in industrialized countries concentrated on remediating past pollution and controlling the emission of pollutants at “the end of the pipe.” These laws set discharge standards and required pollution or waste generating firms to operate under government negotiated permits. Some of these laws also regulated and, in some cases, banned chemicals in foods, drugs, products

and workplaces. By the 1990s, these efforts had expanded to treating and minimizing wastes and preventing pollution. Efforts largely initiated since 2000 have focused on improving chemical information and managing chemicals in products. Most recently, efforts have been made to promote the generation and adoption of safer chemicals and “green chemistry.”

Table 2: Instruments and Programmes for the Sound Management of Chemicals

Goal of instrument	Timeframe	Legal	Technical	Voluntary
Controlling Chemical Pollution Air quality and emission control Ambient water protection and waste water control Drinking water protection	1970s+	X X X		
Remediating Contaminated Sites and Managing Waste Chemicals Emergency response and spill management programmes Hazardous waste site remediation Hazardous and municipal waste management Legacy chemicals and stockpile management	1970s+	X X X X		
Controlling Dangerous Chemicals Food and drug safety Pesticide regulation and management Workplace health and safety Chemical regulation and restriction	1970s+	X X X X		
Preventing Chemical Pollution Pollution prevention and waste reduction Cleaner production programmes Chemical accident prevention programmes Sustainable agriculture and Integrated Pest/Vector Management	1980s+	X X X	X X X X	X X X X
Managing Chemical Information Chemical testing programmes Hazard communication and Right-to-Know Product ingredient disclosure/Product declaration Pollutant Release and Transfer Inventories (PRTRs) National Chemical Profiles Globally Harmonized System for Classification and Labeling	1980s+	X X X X	X X X X X	X X X
Managing Chemicals in Products Eco-labeling programmes Eco-design programmes Product safety (Cosmetics, Biocide, Toys) directives Product Stewardship/Extended Producer Responsibility (EPR) Programmes Environmentally Preferred Purchasing Programmes	1990s+	X X X	X X	X X X
Generating Safer Chemicals Green and sustainable chemistry programmes Green engineering programmes	2000s+		X X	X X

Legal instruments rely on the rule of law. They assure a legally uniform framework for all regulated entities; they provide clear rules of procedure for administrative agencies; and they are enforceable through conventional judicial proceedings. However, legal instruments are often rigid and inflexible, costly and complex to administer, and, while penalties and sanctions may be clear, politically difficult to enforce.

Recognizing the limits of employing legal instruments alone in promoting chemical management, some governments have supplemented them with various economic instruments. Economic instruments can increase safer chemical management, reduce externalities, and improve market efficiency. If well crafted, these instruments can also raise revenues to support government agencies responsible for sound chemical management. Economic instruments include prices, procurement policies and liability and information⁷ (See Table 3).

Price-based economic instruments raise the cost of resource use and environmental pollution, and/or create subsidies and tax incentives that reduce the cost of transitioning to environmentally preferable activities and technologies. Liability measures establish legal responsibility for pollution effects thereby ensuring that culpable parties pay clean-up, restoration costs and/or compensation. Targetted procurement instruments direct government or private sector purchasing towards products with preferred attributes. Information-based instruments such as labeling, environmental certification and public disclosure can raise consumer awareness and promote adoption of more environmentally sound production methods among product producers who wish to compete for ‘green segments’ of the market.

The production, transport, use and disposal of chemicals and products containing chemicals create a variety of costs that are generally not borne by the industries that carry out these activities. These include expenditures associated with the maintenance of emergency response infrastructure; cleanup of contaminated sites; emergency and long-term care for individuals harmed by toxic chemical exposures; depletion of water, soil, and biodiversity; loss of natural predator systems and resulting ecosystem disruption; loss of safe water supplies; and costs of water treatment and purification to remove chemical contaminants. When such costs are externalized they are not taken into account when companies make chemical management decisions. Economic instruments, such as fees, taxes, liability systems and extended producer responsibility, provide mechanisms to internalize these costs and create financial incentives to improve chemical management.

Table 3. Economic Instruments for the Sound Management of Chemicals

Category	Instruments
Price Instruments	Fees, taxes and user charges on production inputs, emissions, outputs or consumption User-charges on natural resource inputs, i.e. water charges Removal/reduction of perverse subsidies Subsidies or environmental funds for environmentally preferable activities Tax adjustments/breaks Chemical leasing, deposit-refund systems, tax-subsidy, refunded emissions fees
Liability Instruments	Environmental fines Liability systems Extended producer responsibility (EPR)
Procurement Instruments	In-house environmentally preferable procurement (EPP) Guidelines for market preferences
Information Instruments	Labeling for market creation and product differentiation Certification for market creation and product differentiation Environmental reporting Information disclosure Eco-design and green chemistry awards

Ref: Adapted from UNEP Chemicals Branch, An Analysis of Economic Instruments in Sound Chemical Management of Chemicals, Draft, May, 2011.

Economic instruments have become attractive to policy makers because they are seen to offer flexibility for industry and, potentially, to generate revenue for public cost recovery. However, in practice, fees, taxes and tradable permits have proven complex and difficult to administer and, in some cases, such as waste or emission fees, revenue generation can erode as chemical management practices improve. Economic instruments are not an alternative to legal instruments: to be effective and fair economic instruments require well established regulatory structures and strong enforcement capacities among authorities. Economic instruments are not always useful or appropriate, particularly in addressing the complexities of chemical uses and exposures where they tend to reduce rather than eliminate hazards.

Technical and voluntary instruments can provide the flexibility, appropriateness and situational sensitivity that is often lacking with legal and economic instruments and they are often an important complement to legal instruments in addressing small and medium-sized enterprises. The Cleaner Production Programme jointly sponsored by the United Nations Environment Programme (UNEP) and the United Nations Industrial Development Programme (UNIDO) provides many good examples. However, technical instruments that rely on enterprise or sector specific research, assistance or training are labour-intensive and costly and difficult to administer at a scale large enough to affect national or regional issues. Like economic instruments, technical programmes also require a solid set of legal instruments to encourage effective programme participation.

Voluntary programmes, typically appealing to industry, serve those firms or sectors that would volunteer (usually, the leaders). They can be useful in raising industry-wide standards and improving chemical management in supply chains. However, such programmes do little to address those (usually, the laggards) who, for lack of capacity or willingness, fail to volunteer. The US EPA offers several programmes such as Design for Environment and the PFOA Stewardship Program that demonstrate the positive benefits of governments working in collaboration with industries. Business trade associations and other private interests have developed various voluntary chemicals management programmes, but the effectiveness of these programmes has been mixed.⁸

2.2 Methods and Tools

To assist in chemicals management, governments in developed countries have created an array of decision-support methods and tools (See Table 4). Some methods and tools are designed to identify and screen out hazardous chemicals; some are designed to compare alternatives; and others are designed to identify preferred chemicals and products. Some of these methods provide decision-making frameworks that users can employ by supplying data and values that result in a hazard ranking. Others are simple tools such as databases and lists of chemical hazards that are accessible on the Internet.

Table 4: Methods and Tools developed by Governments for Chemical Hazard Assessment and Identification of Preferred Chemicals and Products

Type/Name of method/tool	Developed by	Purpose
General guidance tools		
Globally Harmonized System of Classification and Labeling of Chemicals (GHS)	United Nations Economic Commission for Europe (UNECE)	Addresses classification of chemicals by types of hazard and proposes harmonized hazard communication elements, including labels and safety data sheets
Chesar	European Chemicals Agency (ECHA)	Help companies conduct Chemical Safety Assessments (CSA) and prepare Chemical Safety Reports (CSR)
Manual for Assessment of Chemicals	Organisation for Economic Cooperation and Development (OECD)	Provides guidance for evaluating high production volume (HPV) chemicals

Database tools		
Chemical databases	Swedish Government	Various databases including N-class, H-class, and pesticides provide information on health and environmental impacts of chemicals, classification of physical chemical properties and chemicals in products reported to product registers
e-Chem Portal	OECD	Provide information on chemical properties, environmental fate, human toxicity and eco-toxicity
ACToR	US EPA	Provide an online warehouse of publicly available chemical toxicity data on over 500,000 chemicals searchable by chemical name and chemical structure
Chemical databases	US National Library of Medicine	Various databases including IRIS, TOXLINE, HSDB that provide information on exposure, environmental fate, emergency handling, industrial hygiene and human health and environmental effects
SPIN database	Nordic Council of Ministers	Database on use of substances in products from product registries in Sweden, Denmark, Norway and Finland. The SPIN Exposure Toolbox can be used to estimate exposure to humans and environment
Risk assessment		
Risk Assessment	SETAC and various others	Protocol for identifying the probable risks of a chemical or technology based on the intrinsic hazards and potential exposures.
Chemical screening and comparison tools		
PRIO	Swedish Government	To identify and screen out chemicals of concern to meet Swedish objective of a non-toxic environment
PBT Profiler and other screening tools	US EPA	Identify and screen out chemicals of concern and identify preferred chemicals
Column Model	German Institute for Occupational Safety	Compare chemical alternatives and identify preferred chemicals
Chemicals alternatives assessment	US EPA – Design for Environment program	Compare chemical alternatives and identify preferred chemicals
QSAR Toolbox	OECD	Fill gaps in eco-toxicity data needed for assessing the hazards of chemicals
NTP 712-substitution of hazardous chemicals	Spanish National Institute for Health and Safety at Work	Provide criteria for substitution and use the German Column Model as tool for evaluating alternatives
Occupational health and safety tools		
COSHH Essentials	UK Government	Help companies comply with occupational health and safety regulations by providing information on chemical exposure risks and controls
MAL Code	Danish Government	Protect workers using paints and coatings. Code provides information on protective measures to be taken for different exposure routes
Eco-label programmes		
European Eco-label – Flower logo	European Commission	Provide a voluntary certification for several product categories: cleaning products, appliances, paper products, textile and home and garden products, lubricants and some services
Nordic Eco-label	Nordic Council of Ministers	Voluntary eco-label for 63 product groups
National Eco-labels	Many countries	Voluntary certification for a range of product groups

Many government agencies in developed countries conduct risk assessments or require firms to prepare risk assessments for instance on pesticides, industrial chemicals, food additives and/or consumer products. Risk assessments provide a well-accepted, formalized protocol for determining human health and environment risks under likely exposure scenarios; however, they can be slow to produce, costly, and difficult to interpret where information is insufficient and uncertainties are high.

The OECD High Production Volume Chemical Programme has produced substantial data on heavily used chemicals and over the next decade the European Union's REACH Regulation will generate much more. The OECD Global Portal to Information on Chemical Substances (e-Chem Portal) has expanded Web-based access to authoritative, science-based information on chemical hazards. Many countries are currently adopting the GHS, while new International Chemical Safety Cards (ICSC) provide a globally harmonized information source for promoting workplace safety.⁹

The Swedish Chemicals Inspectorate (KemI) has developed "PRIO for Risk Reduction of Chemicals" to identify top priority "phase out chemicals" and lower priority "risk reduction chemicals" and to provide an Internet-based tool that can be used for comparing the hazards of other chemicals. The German Institute for Occupational Safety has also developed a decision support tool called the "Column Model" that can be used to compare several chemicals listed in the rows of a matrix against a set of health and environmental factors arrayed in the columns. Tools such as ACToR and the PBT Profiler developed by the US EPA provide practical tools for characterizing and classifying chemicals in terms of a broad range of hazard traits.

2.3 Institutional Arrangements

Chemical management is a cross-sector issue and, in most countries, responsibility for chemical management is divided among different authorities such as environmental protection ministries, public health agencies, labour ministries, agricultural departments, customs departments and natural resource management agencies (See Table 5). There is typically no central or independent chemicals management agency or integrated management structure for coordinating the multiple authorities. Without effective oversight and coordination this can lead to fragmented authorities that create opportunities for problematic redundancies, gaps and inconsistencies in chemicals management.

Table 5. Examples of Government Authorities for the Sound Management of Chemicals

Authority	Functions
Ministry of the Environment	Sets policy, supervises budgets, coordinates programmes
Environmental Protection Agency	Restricts hazardous substances, sets standards, regulates emissions, issues permits, conducts inspections, enforces compliance, public education
Public Health Agency	Sets standards, conducts inspections, regulates food and drug safety, enforces compliance, public education
Agriculture Agency	Sets standards, promotes agriculture
Natural Resource Agency	Sets standards, conducts research, issues permits, enforces compliance
Ministries of Industry and Trade	Sets standards, issues permits, regulates imports
Justice Agency	Conducts investigations, initiates litigation, prosecutes crimes
Occupational Safety Agency	Sets standards, conducts inspections, enforces compliance, worker education
Pesticide Bureau	Issues permits, administers programmes, enforces compliance
Customs Bureau	Issues permits, conducts inspections, enforces compliance
Independent Chemicals Bureau	Collects data, conducts research, coordinates programmes, issues reports
Research Laboratories	Conducts research on health and environmental impacts of chemicals
Product Safety Agency	Creates safety standards, recalls unsafe products

This multi-agency infrastructure for managing chemicals is typical of both developed and developing countries. For instance, countries in Northern and Southern Africa have central environmental ministries while Eastern African countries have created separate environmental protection agencies. Botswana and Zimbabwe each have four ministries responsible for chemicals management. The institutional infrastructure in Uganda provides a good example of the multiple agencies responsible for chemical policy in a developing country. Table 6 provides a general breakdown of responsibilities for chemicals among Uganda’s several agencies.¹⁰

Table 6: Responsibility for Chemical Management by Government Agency in Uganda

Agency	Import	Production	Storage	Transport	Distribution Marketing	Use/ Handling	Disposal
Environment	X	X	X	X	X	X	X
Health							
Agriculture	X		X	X	X	X	X
Labour			X	X	X	X	
Trade/Industry	X			X	X	X	
Finance	X						X
Transport				X			
Interior/Defense						X	X
Justice						X	
Customs	X						X
Foreign Affairs	X						
Other	X	X	X	X	X	X	X

Ref: Uganda National Environmental Management Authority, National Profile to Assess the Chemicals Management Infrastructure in Uganda, November, 2002.

Under Uganda's National Environmental Statute, the National Environmental Management Agency is given responsibility for nationwide environmental policy and agency coordination, including the regulation of industrial chemicals. The Control of Agricultural Chemicals Statute establishes the Agricultural Chemicals Board that is responsible for registering and regulating all importing, uses and licensing of agricultural chemicals. A Ministry of Energy and Mineral Resources has responsibility for energy and mining, while a Ministry of Lands, Water and the Environment is responsible for water and environmental protection. Under the Factories Act, the Labour Commission is given responsibility for industrial health and safety.

While there are benefits to government structures that address chemicals in their many different applications and life cycle stages, there is also the potential for policy fragmentation and inefficiencies that demonstrate the need for cross-agency coordination. This may be improved with the establishment of a lead chemical policy coordinating body; however, it will still be necessary to maintain a shared chemical management approach among agencies that stresses common, but differentiated responsibilities.

3. Corporate Methods and Tools

Governments are not alone in developing new instruments and approaches for the sound management of chemicals. Today, many corporations and business associations incorporate sound chemical management in their corporate policies and practices.

The International Council of Chemical Associations (ICCA) sponsors the High Production Volume (HPV) Challenge Program that has spurred chemical manufacturers to generate and make public a baseline set of health and environmental effects information on the largest production volume chemicals in the world. In addition, the international chemical industry has developed policies and programmes under its Responsible Care initiative for guiding chemical production companies in managing chemicals. Responsible Care is a global voluntary initiative, active in 52 countries and offering a broad set of guidelines that range from community education and emergency response to pollution prevention and workplace safety. The Responsible Care Global Charter promotes sustainable development by improving public knowledge and information about chemicals, reducing risks, and improving business and government capacities.

Responsible Care has supported the development of a Global Product Strategy (GPS) to improve chemicals management throughout industrial supply chains including improved communication about chemical risks. It includes a focus on increased transparency, a tiered approach to completing risk characterizations, improved product stewardship, and expanded engagement in public policy processes. In the GPS, participating member companies prioritize their chemicals according to recognized risks and designate high priority chemicals based on uses, exposures and toxicity and production volumes. Although still in construction, detailed risk characterizations are to be developed for each high priority chemical and chemical summaries for each are to be made publically available.¹¹

Two international business trade associations that address chemicals directly also maintain codes of conduct. The International Council on Mining and Metals maintains a voluntary code for the mining industry that contains ten principles ranging from upholding ethical business practices to extending responsibility for the design, use, recycling and disposal of metallic products.¹² CropLife International, the largest trade association for the international plant services industry, maintains a voluntary product stewardship programme that covers pesticide management issues ranging from manufacturing and responsible use of pesticides to integrated pest management and management and disposal of obsolete stocks of pesticides.¹³

In addition to these chemical industry associations, various business organizations and multi-stakeholder groups have developed programmes to encourage corporate social responsibility. Most of these initiatives do not directly address chemicals management or the substitution of safer chemicals. The United Nations Global Compact, launched in 2000, is the largest voluntary corporate responsibility programme in the world. Over 6,000 businesses and other stakeholders participate, including government, labour and civil society organizations from over 130 countries. Convened by the United Nations, the Global Compact is a policy initiative for businesses that make a commitment to aligning their corporate operations with 10 universal principles that support human rights, environmental protection, labour rights and anti-corruption. Three of the 10 principles address environmental protection including support for “a precautionary approach,” “greater environmental responsibility,” and “the development and diffusion of environmental friendly technologies,” although none of the principles directly specify sound chemical management.¹⁴

These developments have extended into the finance sector as well with the United Nations-backed Principles for Responsible Investment (PRI), an investor initiative sprung from a partnership between the Global Compact and the United Nations Environment Programme’s Finance Initiative. The PRI presents six principles that “reflect the view that environmental, social and corporate governance issues can affect the performance of investment portfolios and therefore must be given appropriate consideration by investors if they are to fulfil their fiduciary (or equivalent) duty.”¹⁵

The Global Reporting Initiative (GRI), first released in 2000, has created a wide ranging reporting framework for sustainability that has been expanded and revised on a regular basis over the last decade. Over 1,800 companies filed

GRI reports in 2010. The environmental indicators in the GRI do not currently include a measurement of toxic chemical use or substitution, but the guidelines are under revision and elements on chemicals and chemicals safety may be added in the next iteration, due to be finalized in 2013.¹⁶

The World Business Council for Sustainable Development (WBCSD) is a global association of 200 global companies addressing issues of business and sustainable development. Led by corporate executive officers, the WBCSD promotes the business case for sustainable development by participating in policy development and demonstration projects. Its four focus areas on energy and climate, development, the business role, and ecosystems do not directly address chemicals management.¹⁷

Increasingly, large multi-national firms are adopting these corporate accountability measures and the measures, themselves, are becoming more detailed and specific. In some cases, firms are simply complying with standards that customers are requesting. In other cases, these initiatives are indicative of the broader global trend whereby some leading corporations are assuming increasing responsibility for social and environmental performance, especially where these measures enable global standardization and organizational and logistical efficiencies. However, with the exception of Responsible Care and the Global Product Strategy none of these efforts directly address the sound management of chemicals.¹⁸

Increasingly, some of the largest product manufacturers and retailers are adopting chemicals policies and developing methods and tools for identifying chemicals of concern and determining safer alternatives. These include restricted substance lists, chemical screening tools, risk assessment, life cycle assessment and alternatives assessment protocols (See Table 7).

Table 7: Methods and Tools developed by Corporations for Chemical Hazard Assessment and Identification of Preferred Chemicals and Products

Name of method/tool	Developed by	Purpose
Restricted substance lists (RSLs)	Many corporations	Screen out chemicals of concern in supply chains and products
Life Cycle Assessment	Formalized by ISO 14040	Identify environmental impacts of a chemical or material across its life cycle
Greenlist™	S.C. Johnson	Screen out hazardous chemical ingredients and compare alternatives
Green WERCS™	The WERCS	Evaluate the human health and environmental hazards of chemical ingredients in products
SciVera Lens™	SciVera	Evaluate the human health and environmental hazards of chemical ingredients in products
3E GPA™	3E company	Evaluate the human health and environmental hazards of chemical ingredients in products
iSustain™	iSustain Alliance	Assessment tool for scientists in the research and development phase of a product life cycle - generates a sustainability score for chemical products and processes based on 12 Principles of Green Chemistry
Sustainability Product Assessment Tool	Boots UK	Assess product sustainability during the development process by evaluating 20 attributes across 5 life cycle stages – raw materials/sourcing, production, distribution/retail, use, end of life
Responsible Care	Canadian Chemical Producers Association – now includes over 50 national chemical manufacturing associations	Global initiative to drive continuous improvement in the chemical industry in the areas of health, safety and the environment
Eco-Efficiency Analysis Tool	BASF	Compare sustainability of products and processes - evaluates raw materials consumption, energy consumption, land use, air and water emissions and solid waste, toxicity potential, and risk potential from misuse
BASTA	Swedish building companies, NCC, Skanska, JM and Peab, in association with the Swedish Construction Federation	Help contractors and designers select building products that do not contain chemicals of concern. Suppliers determine chemical constituents of products, ensure that they meet BASTA criteria, and register products
Eco-Check	Bayer Technology Services	Holistic assessment of products and processes, considering economy, health, environment, life cycle, technology and public value

Some corporate sustainability reports and corporate Internet sites provide sections on chemicals management and offer descriptions of how enterprises are working to reduce chemicals of concern in products and supply chains. Often these companies have developed restricted substances lists (RSLs) to screen out the use of priority chemicals of concern. RSLs generally include chemicals that are currently restricted by one or several government bodies or meet specific hazard criteria. Some companies maintain a separate watch list of chemicals under scrutiny by scientists and environmental advocates that are not yet regulated. For example, the automotive industry has developed a list of regulated chemicals and chemicals of concern that are not yet regulated called the Global Automotive Declarable Substances List (GADSL).¹⁹ The American Apparel & Footwear Association (AAFA) has developed a restricted substances list that provides information on chemicals that are restricted or banned in finished home, textile, apparel, and footwear products anywhere in the world.²⁰

Individual companies that closely interface with retail customers are often leaders in restricting chemicals of high concern:

- Nike, a US\$ 19 billion footwear and apparel company headquartered in Oregon has developed a “Considered Chemistry” programme. Through Considered Chemistry, Nike is committed to reducing or eliminating all chemicals harmful to human health or the environment. To accomplish this, the firm maintains a chemical review process to screen chemicals for hazardous properties, a list of restricted substance for suppliers, an initiative to reduce the use of hazardous chemicals in production operations and a research programme to develop safer chemicals. To assure conformity with the programme Nike annually identifies a list of materials and asks its suppliers to test products at Nike approved laboratories. In addition, Nike conducts random tests on products to assure full chemical disclosure.²¹
- Boots, a leading pharmacy retailer in the United Kingdom (UK), has conducted a systematic review of chemicals in all Boots brand products and prepared the Boots Priority Substances List (PSL). The PSL, updated annually, lists chemical ingredients of concern and their uses, regulatory actions that have been taken to restrict their use, the Boots UK position on each ingredient, and any precautionary actions deemed necessary. Progress toward published targets is reported as part of the annual environmental performance update of the corporate social responsibility section of the company’s Internet site.²²
- Sony, a leading electronics company headquartered in Japan, has developed global standards for the management of hazardous chemicals in the company’s products. Sony audits its suppliers to ensure that they meet its Green Partners standards for chemicals substance management. Suppliers are required to certify that their products do not contain prohibited substances and provide measurement data for high risk substances. In addition, Sony is promoting the reduction and replacement of chemicals of high concern such as polyvinyl chloride, brominated flame retardants, mercury, phthalates, beryllium and arsenic.²³
- In 2001, S. C. Johnson, a US-based home care products company, developed the Greenlist™ based on specific health and environmental profiles to score chemical ingredients used in S. C. Johnson products. Chemicals are evaluated and scored in 19 functional categories, such as surfactants, solvents, or preservatives. Chemicals with the lowest impact receive the highest scores and are considered preferable. The Greenlist™ has proven to be a useful tool for identifying problematic ingredients that require replacement and comparing substances to determine preferred chemicals or materials.²⁴

While many of these methods and tools provide useful guidance for individual companies the wide diversity among them in terms of goals, criteria and metrics makes it difficult to aggregate them into more general chemical management guidance systems.

A small number of product manufacturers have begun to routinely offer full disclosure of the chemical constituents of their products. Clorox, Volvo, Seventh Generation and S.C. Johnson are among these companies. In 2009, Wal-Mart, Sears, and K-mart began requiring suppliers of chemical products to disclose all intentionally added chemical ingredients to a third-party service provider called the WERCS. The WERCS keeps the formulation data confidential but lets the retailers know whether the products are regulated under federal or state environmental laws and how they should be handled and disposed. Wal-Mart has taken this effort further by requiring suppliers of chemical products to use GreenWERCS™, a screening tool that evaluates the hazards of chemical ingredients. Wal-Mart can, then, use these data to compare products and encourage suppliers to substitute safer ingredients for harmful ones.²⁵

Increasingly, private industrial standard setting organizations are also addressing health and environmental issues. The International Standards Organization (ISO) has developed numerous standards relating to chemicals, including requirements for test methods, labeling and performance requirements. The ISO 14000 series includes a set of standards regarding environmental management, auditing, life cycle assessment and eco-labeling. The widely used standard, ISO 14001, requires companies to create an environmental management system (EMS) that is designed to

improve environmental performance over time. This standard provides a framework for environmental management but does not specify performance requirements. Therefore, while an EMS may include a programme to identify chemical hazards and reduce their use, the standard does not specify this requirement.²⁶

In some cases, product standards provide specifications that conform to regulations, such as standards for toy safety (i.e., ASTM F963 in the United States and EN 71 in the European Union).²⁷ These standards primarily address physical safety, but, also, specify limits for a small number of chemicals that are hazardous to children such as heavy metals and phthalates. However, these standards do not require manufacturers to assess and more broadly reduce toxic chemical use in product design or production processes.

Some leading product manufacturers and retailers use life cycle assessment (LCA) to quantitatively estimate environmental impacts of chemicals, materials or products throughout their life cycle (including the stages of extraction, material processing, manufacture, use, and end of life). However, conducting an LCA is resource and time intensive and the quality of the assessment is dependent on data availability. While LCAs are useful for evaluating the impacts of energy and materials use, significant data gaps regarding the human and environmental health impacts of chemicals make these analyses difficult to use to estimate impacts from chemical exposures, especially in the use stage.

Chemical leasing and chemical management services present new models for changing the chemicals business model. With chemical leasing, intermediary chemicals and chemicals used for services such as cleaning can be leased for use and returned after use for recycling and reuse. The concept of chemical management services employs chemical leasing, but takes it further to involve contract chemical suppliers that are paid for the service performed (e.g., painting a car, degreasing metal parts) rather than the chemical consumed. Customers pay for the chemical services they want and avoid large chemical inventories and waste management expenses while chemical suppliers retain the chemicals for reuse which increases incentives for assuring that chemical uses are efficient.

Chemical leasing has been heavily promoted by the Austrian government with pilot projects in automobile painting, metal parts cleaning, paint stripping, powder coating and electroplating baths. In the United States, these practices are promoted by the Chemicals Strategies Partnership, a non-profit organization that has helped firms ranging from General Motors and Ford to Navistar and Delta Airlines in negotiating chemical management service contracts with chemical suppliers. Dow, Quaker, PPG and BASF have all opened chemical management services in Europe to broaden their market share, secure customers, and offer information management and technical services to the chemicals business. While these initiatives remain small, they suggest an innovative way to organize an industry that adds a new range of responsibilities for how chemicals are used and how they are managed as wastes.²⁸

4. Civil Society Organization Methods and Tools

Over the past decade, several international civil society organizations (CSOs) and other NGOs have taken on the sound management of chemicals. The International POPs Elimination Network (IPEN) emerged from the negotiations to draft and ratify the Stockholm Convention and has gone on to further engage the development of SAICM. This NGO represents a coalition of hundreds of grassroots community-based organizations (some large, most small) in many countries, particularly developing countries and countries with economies in transition. The international advocacy organization, Greenpeace, has long been a strong advocate for sound chemicals management. Its recent campaign focused on the apparel industry has set a goal of 2020 for the elimination of all hazardous chemical discharges across the textile industry supply chain. The Pesticide Action Network with regional offices around the world has focused heavily on developing economies with large agriculture sectors to advocate for safer pesticides and sustainable agriculture. Health Care without Harm, the World Federation of Public Health Associations, and the Health and Environment Alliance all focus some

of their efforts on improving chemicals management. The International Trade Union Confederation, SustainLabor, the Asia Monitor Resource Center, the Spanish Trade Union Institute of Work, Environment and Health (ISTAS) and many national trade union federations advocate for reducing chemical exposures and eliminating chemicals that are hazardous to worker health and safety.

Several of these organizations have developed methods and tools to assist governments, enterprises and the public in chemicals management. However, like the corporate and government methods and tools, the diversity of these instruments in terms of goals, terms and metrics makes it difficult to integrate them into a broader strategy. Table 8 lists a sample of these approaches.

Table 8: Methods and Tools developed by CSOs and NGOs for Chemical Hazard Assessment and Chemical and Product Prioritization		
Name of method/tool	Developed by	Purpose
RISCTOX	Spanish Trade Union (ISTAS)	Provide information about risks to human health and environment from chemicals in the workplace
Trade Union Priority List	European Trade Union Confederation (ETUC)	Contribute to REACH implementation by proposing substances of very high concern (SVHC) which, from a trade union perspective, should have priority for inclusion in the candidate list and potentially in the authorization list.
Black List of Chemicals	Spanish Trade Union (ISTAS)	Identify chemicals of high concern to be avoided or strictly controlled
SIN List	ChemSec	Identify chemicals that meet the REACH criteria for SVHC and therefore may be subject to restriction currently or in the future
Green Screen	Clean Production Action	Compare chemical alternatives and identify preferred chemicals
P2OASys	Massachusetts Toxics Use Reduction Institute	Help companies conduct systematic environmental and worker health and safety analyses of pollution prevention and toxics use reduction options
Eco-labels and Certifications	Many organizations	Provide voluntary certification for a range of product groups
Pharos	Healthy Building Network	Help commercial buyers evaluate product content, certifications and other relevant data about building materials against key health, environmental and social impact benchmarks
Skin Deep cosmetics database	Environmental Working Group	Help consumers assess the chemical hazards of personal care products
GoodGuide	GoodGuide	Help consumers evaluate products for their health, safety, environmental and social impacts
CleanGredients	GreenBlue	Encourage the design of cleaning products that are safer for human and the environment. Provide information on physical and chemical properties of ingredients

The SIN (Substitute It Now!) List was developed by the International Chemicals Secretariat (ChemSec), a non-profit organization based in Sweden. The list includes chemicals that meet REACH criteria for Substances of Very High Concern and other chemicals considered to pose serious risks.²⁹ Building on the SIN List, a group of European trade unions have developed a European Trade Union Restricted Substances List.³⁰ The Spanish ISTAS has developed RISCTOX to provide clear and easily accessible information about risks to human health and environment posed by chemicals in the workplace. For each hazard category, the database includes a description of the hazard, the EU risk phrases and GHS hazard statements, written practice guidelines for managing chemicals in the category, and current regulations.³¹

Clean Production Action, a NGO in the United States, has developed a chemical screening method called the Green Screen for Safer Chemicals. The Green Screen provides a publicly accessible tool designed to reliably and consistently screen and rank chemicals and materials for their human health and environmental hazards. The Green Screen includes threshold values derived from the GHS to determine a level of concern for each hazard endpoint and a set of four benchmarks that provide a decision framework for screening chemicals based on their hazard characteristics.³²

A US-based non-profit institute called GreenBlue has created CleanGredients[®], an online database of cleaning product ingredients, to encourage chemical product formulators to design safer cleaning products and to provide a market-based incentive for chemical manufacturers to invest in safer chemical research and development. In managing the database, GreenBlue develops the requirements for each chemical class through a consensus-based stakeholder process. Currently, surfactants, solvents, and fragrances are listed in the database, and some chelating agents are under review.³³

Third-party eco-labels and certifications have been developed by a variety of organizations to identify greener and safer products. Today, there are more than 300 eco-labels worldwide.³⁴ Some are sponsored by governments, but most, including the German Blue Angel and the Nordic Swan, are maintained by professional bodies. Since 1989, Green Seal, a US non-profit organization, has managed life cycle-based sustainability standards and an eco-label that cover almost 200 product and service categories. EcoLogo, first developed by the government of Canada in 1988 and now managed by Underwriters Lab Canada, has developed standards for over 120 product categories that include specific health and environmental criteria. Recently, both Underwriters Laboratories Environment division (ULE) and Green Seal have developed sustainability standards for manufacturers that include requirements for safer chemical management.³⁵

There are an increasing number of useful databases placed on the Internet by NGOs that identify hazardous chemicals in commercial products. Skin Deep is a database maintained by the Environmental Working Group to provide consumers with information on the hazardous constituents of cosmetics. GoodGuide is a “for-benefit corporation” that provides information on the environmental, social, and health performance of products and companies. The GoodGuide database includes more than 100,000 products, including food, household and personal care products, pet food, apparel, cell phones, appliances and cars. It provides both a summary score for the health, social, and environmental attributes of each product and individual scores so that consumers can review a product holistically or evaluate a particular attribute. GoodGuide users can download an application to a smart phone so that they have access to these ratings while shopping.³⁶

This broad survey of government, business and civil society initiatives demonstrates the enormous range of instruments and approaches and methods and tools that are now available for promoting sound chemical management. The range of these tools is so broad that the challenge is not whether to adopt such mechanisms, but how to select among them. Indeed, the proliferation of these mechanisms is so diverse and varied that it tends to add confusion for government policy makers rather than assist them. This is particularly true in developing countries and countries in economic transition, where resources are limited and the chemical intensity of economies is steadily increasing. In these countries it is important to be strategically discerning and clear on goals and objectives in selecting appropriate instruments and approaches. There is a clear need for a comprehensive assessment of the efficacy and value of these measures that compares them in terms of potential goals and identifies strategies where some or a combination of these tools might be most effective. Such an assessment should also generate manuals and guidance documents that provide processes for policy makers and corporate decision makers to sort these measures and select those that appear most appropriate for the intended goal.

5. National Responses

5.1 Adopting Integrated and Comprehensive Chemicals Strategies

Many nations have adopted legal, economic, technical and voluntary instruments for responding to the risks of chemicals (See Table 2). Some of these authorities are parts of omnibus environmental statutes; however, most are independent laws addressing chemicals separately in wastes, emissions, agriculture, industrial settings and commerce. This traditional, fragmented approach to chemicals management has led to the proliferation of uncoordinated – and sometimes contradictory – policies that have failed to provide a coherent framework for maximizing the sustainable development benefits of chemicals. Achieving the sound management of chemicals requires a more comprehensive, broad spectrum and prevention-oriented approach for managing chemicals. Comprehensive means addressing all chemicals at every step in their life cycles from production to disposal. This requires a broadened focus on systems of chemical production, use, and disposal, on families of chemicals, on specific economic sectors, and on collections of firms. Broad-spectrum means developing an integrated approach that coordinates a wide array of inter-sectoral instruments and approaches across many agencies and authorities. National governments need a full chain of policy instruments and approaches that stretch across the life cycle from the entry of chemicals onto the market to chemicals management at the end of their useful life. Preventive means creating an anticipatory, proactive and precautionous approach that seeks to reduce, minimize and eliminate threats to human health and the environment before significant damage is done. This involves substituting hazardous chemicals with safer alternatives where appropriate and reducing exposure to hazardous chemicals where safer alternatives are unavailable.

Countries with emerging or transitional economies can learn lessons from the fragmented sector-by-sector chemical management approaches (in workplaces, emissions, wastes, products, etc) that have characterized conventional chemicals policies in developed countries. Adopting more comprehensive, broad-spectrum chemicals strategies allows governments to address chemicals more holistically by integrating and coordinating legal regimes and government institutional structures.

However, a comprehensive chemicals strategy must not focus solely on chemicals. Since the 1992 UN Conference on Environment and Development, the United Nations has been committed to integrating environmental issues with economic development priorities. Because chemicals are fundamental to national economies, it is now argued, chemicals policy needs to be closely linked with national social and economic policies and programmes.

However, conventional approaches to national social and economic development provide little consideration for chemical management. This limited attention to chemicals safety in national planning derives in part from the lack of coherent risk reduction strategies among the various government authorities responsible for chemicals and wastes. In order to develop more coherent risk management strategies, cross sector coordination is needed on chemicals management among these agencies. But, this limited attention also arises from conventional policy approaches that do not recognize that industries and businesses are best positioned to promote safe chemicals management. In many countries corporations have the most complete information on chemicals and wastes and the most technical capacity to launch effective risk management strategies; however, they are too often viewed as the object of chemical management policies rather than as a participating, responsible party. By making chemical and product manufacturers the first line of safe chemical management, the responsibility and costs for social and economic development are more fairly shared between private and public sectors.

Indeed, a broad-spectrum approach to chemicals management is inherently inclusive, knitting together and coordinating government policies and instruments with industry skills and resources and linking in the popular participation of civil society and NGOs. However, this approach must also be comprehensive, addressing chemicals throughout their life cycle, and proactive and precautionous, anticipating risks, promoting safer alternatives and adopting measures to prevent accidents and unintended outcomes. Thus, laws regulating chemical use can be paired with programmes

for clean technology transfer, programmes to reduce industrial chemical exposures can be aligned with programmes to prevent workplace injury and disease, and programmes for managing pesticides can be partnered with supports for sustainable agriculture. Cleaner production programmes can be integrated into industrial development strategies and tailored to meet the needs of industrial parks and economic development zones. Systems for providing public information on chemical releases and transfers can be aligned with requirements for product labeling and public education. Achieving the sound management of chemicals requires a many-faceted and coordinated effort.

5.2 Integrating Chemical Management and Economic and Social Development

Chemicals are fundamental elements of national economies. There is a strong relationship between safe chemical management and sustainable social and economic development. Not only can chemical mismanagement limit development by increasing health costs and resource damage and decreasing worker productivity, poorly implemented development programmes can increase chemical risks. A comprehensive strategy assumes that the most effective means of reducing the risks of dangerous chemicals is to design an economy that promotes safer chemicals and chemicals management while reducing the risks and uses of hazardous chemicals.

In the Dubai Declaration of SAICM the international community made a clear commitment to integrating the sound management of chemicals into economic development strategies. In 2006, shortly after SAICM was adopted, a meeting of OECD Development Ministers agreed that sound chemicals management should be better integrated into national and local development policies and plans. Later that year, the 53 countries of the African region called for African governments to include the sound management of chemicals in requests for development assistance, and the 23 countries of the Central and Eastern Europe region called for "...strengthening chemicals management capacity through bilateral and multilateral technical, financial and development assistance cooperation..."³⁷ However, these commitments have yet to be fulfilled.

A number of obstacles have contributed to the slow progress of fully integrating sound chemicals management with national development strategies. These include the perception that chemicals safety is strictly an environmental issue rather than a public health or development issue; the absence of a legally binding instrument linking chemical safety to social and economic development; gaps in communication among government agencies preparing applications for development assistance; a lack of coordination between environment and health ministries; and a focus in public health assistance on treating infectious diseases, rather than preventing chemical-related diseases.

The UNEP has addressed this challenge through its Chemicals Mainstreaming Programme which includes partnerships with the UNDP and the WHO and specific initiatives such as the Global Chemicals Outlook, the Cost of Inaction Report and a guidance document for nations seeking to develop legal and economic strategies for sound chemicals management. Since 2006, UNDP has focused on building links between chemical safety and sustainable development by creating a guide called *Integrating the Sound Management of Chemicals into MDG-based Development Planning*,³⁸ along with a report on *Managing Chemicals for Sustainable Development*.³⁹ UNDP has also organized special Country Teams to identify and assess local opportunities for integrating chemical management into national development planning processes. These projects have engaged development planning officials

Case Study: Mainstreaming in Uganda

With funding from the Quick Start Programme and support from the UNDP/UNEP Partnership Initiative, the National Environmental Management Agency of Uganda brought together the Ministries of Environment, Health and Planning and Finance with industry and civil society organizations to integrate chemical management priorities into the new Five Year National Development Plan (NDP). Recognizing that Uganda's Poverty Eradication Action Plan (PEAP) provided the basis for the NDP, the participants broke into two efforts: one fast track team to integrate short-term chemical priorities into the PEAP, and the other normal speed team to identify needs and gaps in the current chemical management infrastructure that could be staged into the longer term NDP plans and programs.

in taking chemicals and waste management into account so as to improve human and environmental health, increase economic security and create income opportunities for the poor.

In terms of institutional infrastructure, traditional environmental protection agencies, public health agencies and workplace safety agencies all play significant roles in chemical management; however, agencies responsible for agriculture, industrial development and customs and trade also need to play important roles. Because most countries today have established multiple agencies with diverse responsibilities for managing chemicals, a central, inter-agency coordinating body provides a critical mechanism for addressing gaps and inconsistencies, coordinating worthy programmes and resolving institutional frictions. A single coordinating entity is important in assuring that laws and programmes work together and support common goals. For instance, Brazil has established a National Commission on Chemical Safety (CONASQ) to foster consultation and coordination among government agencies, enterprises and civil society organizations, while Costa Rica created a Technical Secretariat for the Coordination of Management of Chemical Substances.⁴⁰

Integrating chemical management into social and economic development planning and poverty reduction programmes creates opportunities for additional resources for chemical management. Linking chemicals safety priorities to national development priorities raises the profile of chemicals and sets the issues of chemical hazards and risks into the context of other pressing human, environmental and economic needs. However, potentially more important is the prospect that a wider awareness of the costs of chemical mismanagement will result in more precautionous economic investments, more sustainable agricultural practices and safer and cleaner industrial development. Mainstreaming sound chemical management into national development planning and international development aid programmes could be the most effective means of preventing pollution and assuring safer workplaces.

5.3 Developing a Legal and Institutional Framework

Most all developing countries and countries in economic transition have adopted some legal instruments and created some agency infrastructure focused on chemical safety. For instance, South Africa enacted its National Environmental Management Act in 1998, Kenya passed the Environmental Management and Coordination Act in 1999 and similar national environmental protection statutes have been enacted in Ghana, Egypt, Uganda and Tanzania, all of which include national authorities for managing chemicals. More recently, developing countries have been adopting laws specific to chemicals safety. Kenya enacted its Controlled Substances Regulation in 2007, Vietnam issued a Chemical Safety Government Decree in 2008 to empower its new national chemicals agency, and Malaysia passed a law requiring notification and registration of hazardous substances in 2009.

It is difficult to assess the current range of chemical management authorities or the adoption of instruments, approaches, methods and tools in developing countries and countries in economic transition. Some surveys have been completed on specific instruments, such as PRTRs, laboratories and the use of economic instruments; however, there is no broad international reporting or survey of the full range of measures. The most broad-ranging efforts to survey developing country status involve SAICM implementation. The SAICM Secretariat assembled a baseline estimate report on SAICM implementation from 2006 to 2008 and, more recently, conducted a systematic survey of nations' progress on implementation of SAICM for 2009 and 2010.⁴¹

Both reports organize information around the five SAICM Overarching Policy Strategy objectives. Both provide responses organized by international regions rather than individual country, although the progress report also breaks out the survey results by groups of developing countries within each region. In total, the progress report describes responses from 145 countries, of which 39 to 40 (depending upon the response) are developing countries or countries in economic transition. Each of the five SAICM objectives is further broken down into more specific indicators such that there is a total of 20 indicators covered by the survey. The table in the Appendix of this report presents the findings from the section of the progress report covering responses from the (39 to 40) developing countries. The data from

the survey responses has been summarized to identify the number of countries that report initiating at least one of the SAICM policy objectives and, for each indicator, identifying the top three examples of specific projects. These results provide some general conclusions:

- A large majority of the responses indicate significant progress in implanting at least some of the SAICM objectives (all of the countries indicated several to many initiatives);
- The highest levels of progress reported involve;
 - making formal commitments to implementing SAICM;
 - engaging stakeholders in coordination mechanisms;
 - ratifying the Basel, Rotterdam and Stockholm Conventions;
 - applying for SAICM Quick Start funding;
 - monitoring environmental and health data on priority chemicals; and
 - prioritizing categories of chemicals for risk management.
- Just over half of the responses indicate programmes in place for managing priority chemical risks;
- Only half of the responses indicate implementation of the GHS;
- Less than a third of the responses indicate implementation of public pollutant release and transfer registries or other chemical information transfer instruments; and
- Less than half of the responses indicate development assistance programmes that include chemical management.

While these survey findings do not provide even a suggested status report on the adoption of chemicals management instruments and approaches, they do indicate levels of government awareness and activity on the sound management of chemicals. Even here these findings need to be considered with caution. The limited sample of developing country responses to this survey probably over represent those developing countries actively engaged in SAICM and under represent developing countries with more limited engagement.

As chemical intensification increases in developing countries and countries in economic transition, governments in these countries need to strengthen existing laws and institutions, and develop new instruments and institutional infrastructures for chemicals management. Efforts to implement such programmes require planning. Developing a good baseline analysis is often the first best step in the process, but the process needs to go on to identify and select the most appropriate instruments and approaches and develop a plan for adoption. The UNEP Chemicals Branch has developed a valuable guidance document that identifies four generic steps for assisting countries in planning and implementing such strategies.⁴²

Preparing a Baseline Analysis. A baseline analysis provides the foundation for identifying gaps in programmes and significant problem areas where chemicals and wastes are poorly managed or where chemical exposures are high. Where this involves a situation analysis and needs assessment the findings can be linked to parallel economic and public health needs. Information can be drawn from many sources including national chemical profiles or reports on the state of the environment and reports such as the National Implementation Plan under the Stockholm Convention, Millennium Development Goal reports and Poverty Reduction Strategy Plans. Such tools provide a means of clarifying critical roles and relationships in a management system, locating important information flows, discovering bottlenecks and inconsistencies and identifying opportunities for new and better coordination. The United Nations Institute for Training and Research (UNITAR) has developed a manual for conducting such assessments.³⁴

Identifying and Selecting Instruments and Approaches. The baseline analysis lays the foundation for considering new or amended instruments and approaches. This may require the enactment of new statutes, the development or tightening of appropriate regulations, the development of new or improved economic instruments, the generation and management of chemical information, the strengthening of enforcement and compliance assurance capacities,

the creation of various technical, educational and voluntary programmes, the consolidation of existing authorities or the establishment of new ones, and the development of budgetary allocations and other sources of financing. This might also include adopting the new tools and methods that are being developed by developed countries, leading corporations and civil society organizations and encouraging their use by local industries and government agencies (See Tables 4, 7 and 8).

Developing a Plan. Preparing a development-integrated action plan provides the opportunity to integrate and coordinate the many existing agencies and stakeholders. For instruments and approaches to be effective they are best integrated throughout various levels of government structures:

- Environmental and health protection should be located in the provisions of national constitutions;
- Sound chemicals management should be integrated into national plans and priorities;
- Policy and legislative frameworks should provide comprehensive authorities for chemicals management;
- Institutional structures should clearly delegate responsibilities that ensure coherent, consistent and efficient administrative systems;
- A complete set of legal, technical and economic instruments should be available; and
- Provision should be made for effective stakeholder and civil society participation.⁴⁴

In addition, the development of an integrated action plan should include a resource mobilization strategy to identify funding within the national budget allocation processes or external sources derived from donors or cost recovery mechanisms.

Assuring Approval and Financing. Implementing a plan requires commitments and resources. Commitments by high level government officials and support from leading corporations, trade unions and civil society organizations can be valuable. Legislative or parliamentary review and approval is often important as well to enact new legal instruments and transform government structures and to commit budgetary allocations or empower the use of other sources of financing.

These are generic steps. The specifics of how a comprehensive chemicals strategy is adopted and how the appropriate instruments, approaches, methods and tools are integrated into it may vary considerably as determined by each nation's unique political processes and institutional structures.

5.4 Selecting Appropriate Instruments and Approaches

While chemicals are critical to economic development, the principle challenges associated with sound management of chemicals differ by type of economy. For example, an economy based on small scale agriculture may face chemicals safety challenges primarily associated with pesticides, fertilizers and other agricultural chemicals. Concerns may include lack of data and information; lack of capacity for safe management of pesticides; and lack of government capacity for managing imports and trade. Appropriate instruments might include import restrictions, worker health and safety protections, pesticide management, sustainable agriculture training and government capacity building.

Alternatively, the problems facing a consumer/service economy may include exposure to hazardous metals, carcinogens and reproductive toxins in consumer products, contaminated waste sites from past industrial activities, and the generation of large amounts of hazardous waste that may be shipped to less economically developed regions. Here appropriate instruments might include hazard communication and right to know provisions, product labeling, product reuse and recycling, chemical screening and alternatives assessment, extended producer responsibility and waste export regulation.

However, the condition of an economy and its government capacity should not dictate adopting older instruments and approaches now recognized as ineffective. The concept of “leapfrogging” suggests that countries with developing and transitioning economies should avoid obsolete policies in favour of what are recognized as “best practices.” In confronting emerging industries in developing economies, heavy investments in end of pipe pollution control regulations may not be as cost effective as production process changes that reduce or eliminate wastes and hazardous chemicals. Restrictions on the importation of hazardous wastes may be more effective than investments in waste site management regulations. Countries with developing economies should draw lessons from the past experiences of more developed countries and adopt instruments and approaches that are today deemed the most preventive and cost effective.

Some chemical management activities and instruments are best accomplished regionally or internationally. Chemicals that threaten the atmosphere and chemicals that present serious trans-boundary impacts are better addressed internationally. This includes ozone depleting chemicals and persistent organic compounds. The Montreal Protocol, Stockholm Convention and the Convention on Long Range Trans-boundary Air Pollution address these problems. Some activities such as chemical testing and characterization are well advanced in industrialized countries that have resources for sophisticated laboratory infrastructures. Countries with developing economies can effectively use such information and need not replicate these activities. In some cases it may be most effective for countries with limited resources to develop regional approaches that rely on the capacities of several countries to manage information, set priorities, develop regulations and implement enforcement programmes. However, the management of chemical effluents, emissions and wastes in any country is best accomplished at the national, sub-national and local levels. It is important for developing countries with limited resources to be strategically discerning in selecting the most effective and appropriate instruments and approaches for promoting sound chemicals management.

In identifying opportunities, governments in developing countries and countries in economic transition need to focus where they have the most leverage, and this, typically, appears at the point where chemicals first come on to the market.⁴⁵ Here, the baseline information on chemicals can be collected; chemicals can be treated with similar legal instruments; preventive measures can be adopted; and fees can be levied that can generate revenues for covering administrative costs. At this critical point in a chemical’s life cycle, where a substance first enters a national market as a manufactured chemical, an imported chemical or a chemical constituent in an imported mixture or article, the purveyor of the chemical has a strong incentive to comply with government requirements. This is particularly true for chemicals such as pesticides that need registrations prior to use and imported chemicals that need a custom’s certificate prior to marketing, where the customs regulations of many countries may set criteria for those chemicals. For example, Peru sets such criteria for imported pesticides and the Argentinean trade law prohibits the importation of wastes that do not have sanitary certificates.⁴⁶

Addressing chemical management at the point of chemical or product market entry provides an opportunity to interface with other national importation requirements and harmonize with international trade standards and requirements. While importation conditions can usefully advance public safety and environmental protection, nations need to be careful in restricting chemicals in the context of international trade. Here Sound chemical management policy must be carefully crafted to be integrated into international trade conventions and practices.

A focus on the point of market entry is important because the most cost effective means for assuring chemical safety appears where the chemical supplier bears the primary responsibility for chemical management. This includes pre-market testing and classification, labeling and developing safety sheets, providing information to downstream users, and assuring responsible management during chemical use and disposal. Here, firms can make use of the many methods and tools listed in Table 4, 7 and 8 to screen chemicals, avoid or substitute unnecessary hazardous chemicals, and select or develop safer alternatives. When the burden for generating chemical information and planning for effective chemical management lies with the chemical manufacturer or importer, government agencies with limited resources can focus on setting policies, negotiating permits and licenses, verifying information and monitoring compliance. Table 9 provides an example of an effective division of responsibilities between government agencies and regulated enterprises.⁴⁷

Table 9: Responsibilities of National Governments and Enterprises in the Promoting the Sound Management of Chemicals

Responsibilities of Enterprises

- assessing the hazards, potential exposures and risks of chemicals to be marketed and used;
- providing chemical information and safe practices to customers, governments and the public; and
- assuring safe use, storage, and transport and appropriate disposal of chemicals.

Responsibilities of Governments

- enacting laws, policies and regulations on the sound management of chemicals;
- collecting and verifying information and setting standards and priorities;
- negotiating permits, licenses and agreements on chemical management; and
- monitoring and inspecting enterprises to assure compliance.

Once progress has begun on managing chemicals at the point of market entry, governments can turn to examining the need for legal, economic and technical instruments and improved institutional infrastructure at other points in the chemical life cycle. In making such decisions it is important to select points that have the potential for significant impacts, while also increasing coordination and cooperation among agencies, broadening implementation and generating revenue.

5.5 Setting Priorities for Sound Chemicals Management

Governments need tools and methods for sorting and classifying chemicals according to the hazards and potential risks that are appropriate to their economies. For instance, Canada's efforts to screen the 21,000 chemicals on its Domestic Substance List identified some 4,100 hazardous chemicals for risk reduction consideration. There are a host of government and science-based lists that identify chemicals by significant hazard traits and health endpoints. Efforts by states in the United States to use such lists to identify high priority chemicals for government attention have resulted in lists ranging from 1,700 to 2,100 substances. These lists typically include heavy metals, carcinogens, mutagens and reproductive toxins, and persistent, bioaccumulative and toxic chemicals.⁴⁸

As a part of their baseline analysis, countries with developing and transitional economies could develop useful classification frameworks that array the chemicals on their domestic markets by level of hazard ranging from the least to the most concerning. Classifying chemicals into hazard-based frameworks can both inform markets about those substances most important to avoid and prioritize substances in need of government regulation, restriction or substitution. The new *GHS and the WHO Recommended Classification of Pesticides by Hazard* provide well-constructed, internationally recognized criteria for characterizing and classifying chemicals.⁴⁹

Many of the decision support methods and tools noted above can be used to characterize and classify chemicals and compare them in order to set priorities. For instance, the Swedish Chemicals Inspectorate's "PRIO" or the German Institute for Occupational Safety's "Column Model" can be used for comparing and prioritizing chemicals of concern. In addition, the guidance documents for preparing Stockholm Convention National Implementation Plans and SAICM national chemicals profiles provide guidelines for prioritizing chemicals by hazard and exposure potential. While most of these tools have been created by developed countries or international organizations, they are all available on the Internet and can be downloaded and used by anyone with Internet access.⁵⁰

A systems approach can be useful in mapping the stocks and flows of an economy's chemicals in order to identify the range of uses and exposures of the most hazardous substances and to set national priorities. For instance, while progress has been made in Africa under the World Bank's Clean Air Initiative for sub-Saharan Africa and the UNEP Partnership for Clean Fuels and Vehicles in phasing out leaded gasoline, mapping the many diverse uses of lead in Africa would reveal the unaddressed sources of lead used elsewhere, for instance in paints and toys.⁵¹

Risk assessments that characterize the hazard, potency and exposure potential of chemicals can be of further value in setting priorities. Well-constructed risk assessments can indicate the probable effects of a hazardous chemical in a given context and comparative risk assessments can indicate which hazardous chemicals may present the greatest threat to human health or the environment. However, developing countries need not conduct sophisticated and costly risk assessments; often a more streamlined exposure assessment will be sufficient. In some cases countries could review existing risk assessments from developed countries and adjust them to approximate local conditions. In other cases, priorities can be set by a simple consideration of the highest volume chemicals on the national market.

At a minimum, the MEAs including the Basel, Stockholm and Rotterdam Conventions, the Montreal Protocol, the ILO Conventions, the European Union's REACH Regulation and other international agreements provide all nations with a growing list of high priority "substances of very high concern". Governments in developing economies would do well to domesticate these conventions and use the lists to build a baseline of priority chemicals.

5.6 Developing and Presenting Information

There has been significant progress in generating chemical information and increasing its availability since the United Nations Conference on Environment and Development in 1992. The ICCA HPV Program has generated baseline health and environment screening information for several thousand high volume chemicals. Over the next several years the European Union's REACH will be augmenting this with chemical profiles on thousands of lower production chemicals. There has been a proliferation of many Internet-based databases and data analysis tools, some of which are noted above. In addition, the Basel Convention provides global information on the shipment of hazardous wastes and the Rotterdam Convention provides for valuable pre-importation notice on some international chemical (pesticide) transfers.

However, substantial work remains in chemical testing, characterization and classification, much of which should be carried out by chemical manufacturers or developed countries with sufficient resources. In all countries there is a need to strengthen chemical use and release inventories, promote product labelling, and encourage information exchange through chemical supply chains. While enterprises have the primary responsibility for generating chemical information, classifying chemicals, labeling products, creating Chemical Safety Cards and making information available, government agencies need to set standards and provide oversight to ensure the veracity of information.

In developing countries and countries in economic transition the generation and management of chemical information can be challenging as testing laboratories are typically limited and the retention of trained personnel is difficult. There is often an overarching need to harmonize data collection and establish information retention infrastructure to effectively monitor trends and identify significant problem areas across regions within a country. Local scientific and professional associations, trade unions and civil society organizations can play an important role here. The UNEP sponsored Chemical Information Exchange Network has been working steadily to build these capacities and foster broad information dissemination.⁵²

Case Study: Using Information to Eliminate Lindane in Mexico

Convinced of the excessive risks of lindane, the National Institute of Ecology (NIE) in Mexico conducted a five state survey of the uses, prices and alternatives to lindane. Based on this research, the NIE convened 3 national meetings of government agents, scientists, physicians and business representatives to consider the feasibility and costs of restricting lindane uses. Recommendations from these conferences resulted in an action plan for a priority-staged phase out. Recognizing that this sound research could be used internationally, the NIE developed a case report for federal government officials to nominate lindane as a candidate for review at the Stockholm Convention where it was subsequently added to Annex A (Elimination).

Integrated chemical surveillance and information management systems need to be organized in a manner that broadens awareness and understanding of chemicals, particularly in sectors such as public health, community development, resource protection and economic development. For instance, surveys of pollutant releases and community health can provide early warnings of potential public health crises and environmental sampling for chemicals can identify threats to water, food and fisheries. Biomonitoring for exogenous chemicals in human fluids can track trends in chemical exposure. Registries for collecting information on chemical spills and accidents can identify industrial vulnerabilities before they become crises. Studies of the costs of chemical wastes and mismanagement can be used to encourage economic development agencies to support chemical management programmes.

Adopting methods and tools for providing chemical information to the public is also important because such information raises public awareness of chemical issues, informs consumer choices, builds public support for multi-lateral agreements, and encourages public participation in government policy making. Improving access to chemical information for civil society organizations provides opportunities for their involvement and support in promoting sound chemicals management. Experience under the Aarhus Convention demonstrates that access to information is not enough; such information must be received in forms appropriate to use, particularly in developing countries and countries in economic transition. Attention to language, media and technology are important here.

Central to these efforts, is the establishment of effective PRTRs and other worker and consumer right to know instruments. Today, some 50 countries have or are planning national or regional PRTRs.⁵³ Chile has recently established a national PRTR and Georgia and Togo are using Quick Start funds to plan PRTRs, while a regional PRTR is being considered by five countries in Latin America (Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras and Nicaragua).⁵⁴

5.7 Strengthening Regulatory Enforcement and Compliance

Effective chemical management laws and policies require a body of well-crafted regulations and standards. Rather than start *de novo*, many developing countries have found efficiencies in adopting regulations and standards from international agencies such as the ILO, the FAO, or from more developed countries. Regulations from the United States, Japan and European countries have often been adopted in whole or modified to meet local conditions.

In many cases chemical laws must be enacted at the national level. This is particularly the case for the domestication of ratified MEAs where national regulations need to be modified to conform to international requirements. In other cases, laws can be adopted at the national level with minimum standards that can be elevated at provincial or local levels. The provincial or local level may be best for monitoring, inspection and enforcement. If legal proceedings are required, strict liability standards are needed to enforce the Polluter Pays Principle.

The African Stockpiles Programme (ASP) and the US Superfund hazardous waste dumpsite clean-up programmes provide models for managing the hazards of orphaned and legacy chemicals. Where there are no responsible parties, poorer countries need international sources of financing. The ASP programme relies on World Bank, Global Environmental Facility and industry funding. In waste management, strict, joint and several standards may be necessary to assure that appropriate parties share responsibilities. Brazilian environmental law prescribes criminal penalties where a chemical user endangers the public and criminal penalties escalate where the harm is significant or industry is the responsible party.³⁹

While small and medium sized enterprises often make up a significant share of chemical and waste mismanagement, regulation of these firms is particularly difficult and costly. Their marginal finances and limited technical capacities make them better candidates for a mix of regulatory enforcement, technical assistance in cleaner production and voluntary, sector-specific programmes. These programmes often engage professional and business associations, trade unions and educational institutions to help build business capacity and collectively seek regulatory compliance.

Construction and facility operating permits and waste manifests and treatment permits provide a means by which government agents and enterprise managers can negotiate agreements on safe levels of chemical management, but only where there is a reasonable set of regulations and standards that provide legal authority. While government agencies are often effective in issuing initial permits, it is important to assure that permits are periodically renewed and permitted equipment is maintained and updated.

Good regulations require effective enforcement programmes that provide the means for identifying and penalizing miscreants, creating a common floor of compliance, deterring future non-compliance and assuring the rule of law. However, compliance assurance programmes are costly and they suffer most when resources are insufficient. Countries with limited resources for chemicals management often need assistance to maintain consistent enforcement programmes and retain qualified personnel for monitoring and inspections. Regional approaches that develop collaborative regulatory enforcement and compliance programmes among neighboring countries offer a promising means for increasing efficiencies and deterring cross boundary pollution and illegal chemical and waste shipments. For example, the nations of East Africa are working regionally to harmonize their legal instruments and enforcement programmes.⁵⁶

Case Study: African Stockpiles Program (ASP) as Regional Partnership

The ability to address the estimated 50,000 tonnes of obsolete and unwanted pesticides stored across Africa is beyond the capacities of many nations. Beginning in 2005 a regional, multi-stakeholder partnership was created uniting the African Union, World Bank, FAO, CropLife and the Pesticide Action Network. With commitments for a 15 year program the ASP is working country by country to develop plans, build capacity and implement collection, treatment and disposal projects. The ASP has focused on raising community and government awareness of pesticide risks and the construction and improvement of long term storage facilities for unwanted pesticides. Recognizing that managing obsolete pesticide stockpiles would not succeed unless better pesticide management practices were developed, the APS has helped to draft new pesticide legislation and encourage Integrated Pest Management training programs for current farmers.

Countries with developing and transitional economies need to identify cost effective programmes for regulatory enforcement and compliance assurance that clearly delineates responsibilities between industry and government authorities. Where governments have limited resources for implementing regulatory programmes, industrial enterprises need to shoulder more of the burden for assuring regulatory compliance through restricted substance lists, self-assessments and supplier certifications. In such cases, government agencies may be most effective in conducting audits and targeting inspections.

5.8 Promoting Innovation and Safer Alternatives

With the basic infrastructure in place for soundly managing chemicals, governments in developing countries and countries in economic transition can invest in the development of safer alternatives. There is a critical opportunity for demonstrating how environmental and health benefits can promote economic and social benefits. This may involve supporting research on safer chemicals and pesticides, developing and using decision support tools that select safer chemicals or technologies, or promote the importation of cleaner technologies. A comprehensive chemicals strategy that links chemical innovation to economic development can attract private investments that generate employment opportunities and link the adoption of safer chemicals with programmes to reduce worker injury and lost productivity. Chemical leasing and chemicals management services offer innovative avenues for assuring commercial and technical accountability for chemical use.

Chemical innovation can support the development of new enterprises and new “greener” export oriented products and services. New “green” or “clean” enterprises are arising throughout developed countries fulfilling high-end consumer markets with products and services low in hazardous chemical constituents. In developing economies there are many firms that already successfully export greener products such as natural fiber products, organic produce, bio-based formulations and handicraft-produced articles.

In developed countries new tools such as rapid chemical screening and alternatives assessment are being used to assist government agencies and businesses in designing and selecting safer alternatives. The use of life cycle assessment has also become more common where governments or businesses are seeking to make decisions about the environmental impacts of products. Governments and enterprises in developing countries and countries in economic transition can use the results of these tools to identify safer chemicals and technologies and help local businesses to adopt the safest technologies, rather than accept obsolete chemicals and equipment being phased out of developed countries.

Many public institutions in developed countries, ranging from school districts and government public works departments to hospitals and military branches, are using the buying power of their product procurement programmes to promote safer chemicals. By specifying products free of chlorofluorocarbons, mercury, lead, cadmium, bisphenol A, polystyrene, polyvinyl chloride or highly volatile solvents, these procurement programmes promote safer substitutes. Schools, hospitals, municipalities, airports and government maintenance departments in developing economies could also implement procurement programmes that avoid chemicals of high concern, particularly where safer products are not more expensive and out of the range of limited budgets.

In many developing countries and countries in economic transition safer chemical and non-chemical alternatives are already available. Cleaner production and pollution prevention strategies in small and medium-sized business have been used to eliminate the use of hazardous metals and solvents in production processes and reduce the generation of hazardous wastes. Some 45 countries have National Cleaner Production Centers (NCPCs) that dispense training and technical assistance in sound chemical practices to small and medium-sized enterprises. These programmes have been instrumental in reducing the use of chemicals of high concern such as ozone-depleting substances, mercury, lead and chlorinated solvents and some maintain dedicated programmes for chemical intensive industries such as food processing, metal plating and chemicals. For instance, the South African NCPC provides programmes specifically tailored for the chemical industry while the centre in Ethiopia offers a dedicated programme for tanneries and centres in Egypt and Morocco have promoted new business models like chemical leasing.⁵⁷

Through the emergence of green chemistry, chemists throughout the world have been encouraged to consider the hazards of the chemicals that they synthesize. Green chemistry refers to a set of principles designed to reduce or eliminate the use or generation of hazardous substances in the design, manufacture and application of chemical products.⁵⁸ Today, many universities and colleges throughout the world offer education in green chemistry and there are green chemistry networks in some 26 countries. In developing economies, green chemistry education can be introduced into school and college curricula. Chinese universities now offer green chemistry principles in college curricula and India has a pilot programme to advance education in green chemistry as a required part of the chemistry curriculum in the colleges of Delhi. The principles of green chemistry can also be used in business training programmes, public health seminars and technical workshops for professionals.

Integrated pest management (IPM), Integrated Plant Nutrient Management (IPNM), conservation agriculture, and sustainable agriculture practices are being adopted in many countries to reduce the dangers of hazardous pesticides in food and fibre production. The successful re-introduction of organic and sustainable agricultural programmes along with integrated pest management programmes document how changes in practice can reduce the reliance on hazardous pesticides.

Low-till agriculture, crop rotation, inter-cropping of different species and carefully timed or tailored uses of fertilizers and biocides have been shown to reduce the use of pesticides and increase agricultural yields. Government and university-based agricultural service programmes offer IPM and IPNM training and assistance throughout many rural areas around the world. This is particularly successful where national ministries of agriculture promote IPM, IPNM and low chemical input agriculture.⁵⁹

5.9 Building Capacity in Developing Countries and Countries with Economies in Transition

Notwithstanding the progress that has been made to improve chemicals management since the United Nations Conference on Environment and Development in 1992, many developing countries and countries in economic transition still lack the capacity to manage chemicals and hazardous wastes soundly. In many countries, a full range of government institutions have not been established, important legal instruments have not been adopted, and sufficient financial resources have not been allocated. Now, 20 years after the Rio Conference, capacity-building and technical assistance in developing countries and countries in economic transition still remain essential to the achievement of the sound management of chemicals.

Capacity development means more than professional training and consultative services. It needs to be seen in the context of national economic development goals and include the stability of government institutions, the rule of law, an effective judicial system, the promotion of a culture of transparency and accountability, the development of trained and qualified professionals, the cooperation of the business community, the encouragement of civil society organizations, and the development of stable and sufficient financial resources. The UNDP conceives of capacity building at three levels:

- Individual Level - providing conditions that allow individuals, (e.g., resource users, consumers, practitioners, community and political leaders and private and public sector managers) to build and enhance existing and new knowledge and skills;
- Institutional Level - providing assistance to existing institutions and supporting them in forming sound policies, organizational structures and effective methods of management and budgeting; and
- Societal Level - providing support for interactive public administrations that are responsive and accountable.

The Inter-Organization Programme for the Sound Management of Chemicals (IOMC) has proposed a seven part strategy to assist countries in strengthening their national chemicals management capacities. The IOMC strategy focuses on:⁶⁰

- (i) *Strengthening capacities for engagement*: strengthening capacities to engage proactively and constructively with one another in sound chemicals management;
- (ii) *Increasing capacities to generate, access and use information and knowledge*: increasing capacities to research, acquire, communicate, educate and make use of pertinent information, to be able to diagnose and understand chemicals management challenges and identify potential solutions;
- (iii) *Enhancing capacities for policy and legislation development*: enhancing capacities to plan and develop effective policies and legislation, related strategies and plans – based on informed decision-making processes for sound chemicals management;
- (iv) *Strengthening capacities for programme development*: strengthening capacities to develop and implement effective programmes for integrated and sound chemicals management;
- (v) *Strengthening capacities for management and implementation*: strengthening capacities to enact chemicals management policies and/or regulation decisions, and to plan and execute relevant sustainable chemicals management actions/solutions;
- (vi) *Increasing capacities to monitor and evaluate*: increasing capacities to effectively monitor and evaluate project and/or programme achievements against expected results and to provide feedback for learning and adaptive management and to suggest adjustments to the course of action if necessary to achieve sound chemicals management; and
- (vii) *Improving capacities to mobilize resources*: improving capacities to effectively mobilize resources at the national level to support actions to strengthen implementation of chemicals management activities.

Effective capacity building programmes involve baseline assessments, programme planning, training and skill building and technical assistance. The UNDP/UNEP Partnership Initiative envisions a six step process similar to the process identified above for introducing comprehensive chemicals strategies.⁶¹

- Step 1: Develop a Baseline Analysis;
- Step 2: Conduct a Diagnostic/Needs Assessment;
- Step 3: Identify National Opportunities and Priorities;
- Step 4: Evaluate the Economics of Selected Priorities;
- Step 5: Develop Policy and Regulatory Responses for the Selected Priorities; and
- Step 6: Integrate the Sound Management of Chemicals into National Development Planning Processes.

This process has been effectively piloted in several countries where it has been possible to locate specific “points of entry” for integrating sound chemicals management into national development planning and sector based strategies.

Integrating chemicals management into human health initiatives offers valuable opportunities to reduce the prevalence of injury and disease caused by the risks of chemical exposure. The UNEP-WHO Health and Environment Strategic Alliance (HESA) programme is designed to build the capacity of environment and health professionals and policy makers in Africa to understand and act jointly on health and environmental protection. This programme helped to convene African leaders in 2008 to draft the Libreville Declaration that lays out a broad commitment for capacity building on public health and environmental protection across Africa and includes sections on chemical safety. A year later the Luanda Commitment further strengthened this collaborative effort.⁶²

In promoting capacity building, the use of e-courses, video classes and distance learning activities open opportunities for low cost, far-ranging programmes that can be effective in decentralized economies. For instance, programmes like UNITAR's e-course on treaties and conventions provide information on implementing MEAs. The Environmental Governance Programme at UNITAR provides training and support to strengthen capacities for the effective engagement of governmental and non-governmental stakeholders in environmental policy-making and implementation. While this programme largely focuses on the Aarhus Convention and strengthening public participation, the focus could easily encompass chemical management governance issues. The translation of these training programmes and curricula into diverse languages is important in reaching professionals in multilingual countries and improving legal and environmental literacy.

Programmes such as these must be well managed, objective driven, transparent and accountable. Solid programme planning must be guided by clear goals, measurable objectives and periodic reports and assessments. However, capacity building cannot be done to a country. It is critical that capacity building strategies are demand driven, results-oriented and "country owned" where government leaders, local industry professionals and civil society organizations participate in planning strategies and directing the implementation of the resulting programmes. Civil society organizations can be particularly helpful in raising awareness, providing training and lobbying for strengthening existing government laws and institutions. Targeted funding is often critical to effectively integrate civil society organizations into such planning.

Much of this work must be done by the countries themselves. However, closing the capacity gap between developed countries and developing countries benefits developed countries and international institutions and, therefore, technical and financial support from both make a sound investment. Enhanced cooperation and partnerships with developed countries is important in strengthening capacities for managing chemicals and hazardous wastes and promoting the transfer of cleaner and safer technology. Technology transfer should focus on the safest and most efficient technologies that minimize the use of chemicals of concern and the generation of hazardous wastes and avoid older and more polluting technologies.⁶³

Capacity building programmes, however, as noted above, need to encourage chemicals policy instruments and approaches that are appropriate to the economic conditions and strategies of developing countries and countries with economies in transition. While respecting the capacity building needs of these countries, such efforts need to be integrated with the international MEAs and linked together into broad-spectrum chemical management strategies that complement and support local sustainable social and economic development.

Case Study: CSO Advocacy for Capacity Building in Tajikistan

In 2008 the Fund for Support of Citizens' Initiatives (FSCI) conducted a study of DDT availability and found DDT sold as a household "dust" in many local marketplaces. With assistance from the Moscow-based Eco-Accord Program, the group collected data, conducted a survey and released a report. Based on this report, FSCI sponsored a workshop that included a visit to an unmanaged obsolete pesticide burial site that contained DDT. FSCI then organized a roundtable on the national television, Channel One, which included government officials, scientists and citizens. With this new public attention, government agencies increased their attention to DDT and strengthened their regulatory oversight.

5.10 Financing Chemicals Management at the National Level

The cost of institutional infrastructures for effectively managing chemicals and hazardous wastes at the national level is a key obstacle for developing countries and countries in economic transition in achieving the WSSD goal. Even where substantial portions of the burden for assuring that chemicals are safely managed falls on chemical producers and suppliers, significant government monitoring and enforcement costs remain.⁶⁴ Today, many of these countries are relying on external funding sources such as the Quick Start Programme Trust Fund and the Global Environmental Facility, which are limited and not sustainable. Effective chemicals management requires other financing schemes.

National budgets provide the most conventional sources of funding for national authorities and most countries provide some appropriations for chemicals management. However, because chemicals management is so often dispersed across multiple agencies, funding for any one agency is limited. Efforts to consolidate programmes in order to achieve more comprehensive strategies for chemicals management could better employ these limited resources, but resistances among agencies can offer significant barriers. For instance, national budgets could be reorganized to limit inconsistencies, such as those arising where government costs for health care are rising due to the absence of preventative programmes for reducing chemical exposures or where agricultural ministries are promoting pesticides while, environmental agencies are restricting them.

Additional funding opportunities also exist where chemicals management is mainstreamed into broader national initiatives. In developing countries and countries in economic transition the development plan is a core organizing document for national priorities, and the objective of mainstreaming is to place chemicals management into such plans in order to attract economic development and donor assistance resources.

Case Study: Pesticide Taxes in Denmark

Beginning in the 1980s, Denmark introduced a 3 per cent value added tax on pesticide container sales to complement its regulatory requirements in order to reduce the use of pesticides by 50 per cent and to raise revenues for research on pesticide alternatives and farmer training. The levy achieved a 50 per cent reduction in pesticide use over a ten year period. In 1995, a new differential tax scheme was implemented based on the intensity of pesticide use. Some 60 per cent of the revenue is channeled back into agricultural assistance including the promotion of organic farming with the remainder used for public research programs and pesticide monitoring.

To augment national budgets, countries can also look to adopt promising economic instruments that generate revenue. The SAICM agreement in 2006 made clear references to the use of economic instruments that cover the cost of sound chemicals management and the use of economic instruments that internalize the external costs of chemicals.⁶⁵

Such economic instruments can be used to internalize the costs of chemicals management and create financial incentives to improve chemical safety. If these instruments are well-crafted they may also generate public revenues and provide resources needed to fund agency programmes. For instance, Gabon charges a 10 per cent tax on exported wastes to

Europe that is returned to the nation's treasury, while China charges a fee on industrial pollution that exceeds a base level and invests a portion of that revenue in pollution abatement programmes.⁶⁶ In Sweden the costs of the National Chemicals Agency (KemI) are to a large extent borne by fees on chemicals paid by the pesticides and general chemicals industries.⁶⁷ In the United States, the Massachusetts Toxics Use Reduction Act (TURA) requires facilities that use more than a specified amount of a toxic chemical to pay an annual fee. This fee is used to fund various chemicals management activities including enforcement, training, research and technical assistance. California levies a fee on the sale of perchloroethylene (PCE), a garment care solvent, to provide grants and training to help garment cleaners make the transition to safer processes.⁶⁸

While not designed specifically to internalize costs, private-public partnerships that link government agencies and corporations in providing specific services have been promoted as a means of sharing costs, reducing conflicts and promoting efficiencies. Such partnerships range from government-corporate programmes to clean up polluted rivers to the development of software to help small and medium-sized firms with regulatory compliance. Sasol in South Africa offers product specific capacity building workshops and technical assistance for customers and government agencies on managing high-risk chemicals, while Arch Chemicals has provided funding and training to government agencies on water treatment through a jointly managed New Forests Project in Guatemala, Honduras and El Salvador.⁶⁹

Where developing countries and countries in economic transition seek to adopt appropriate economic instruments it is important to be clear on objectives. In some cases the goal may be to change economic behaviors; in others, it may be to raise revenue. More often, it is both.

- Fees on targeted chemical of concern collected at the point of importation or use provide the most direct instruments for generating resources and encouraging improved chemical management practices, because they add costs to the use of hazardous chemicals.
- Waste disposal fees and user charges on sewer discharges and waste treatment raise revenues and encourage better waste management because they increase the costs of waste.
- Site clean-up and spent chemical stockpile management fees may generate revenue needed for programme costs, but, because they involve past practices, they have less direct effect on current chemical management.
- Equipment installation and operating permit fees and licensure programmes such as those required for pesticide applicators can raise revenue, but unless they are differentiated to favor preferred practices, they provide little incentive to improve chemical management.
- Corporate taxes can also raise revenue for chemical management programmes, but they do not influence chemical management.

Each of these economic instruments has the potential to generate revenue. However, if improvements in chemicals management are to be achieved, it is important that the retained revenue generated by these instruments be used to support the administration of the government agencies responsible for promoting sound chemicals management.

Governments in developing countries and countries with economies in transition have a range of opportunities for cost recovery and revenue generation in managing chemicals. However, for many countries in the foreseeable future, the costs will continue to exceed these revenues. There exists today, and will remain for some time, a pressing need for financial assistance from developed countries and international agencies and donors.

6. International Responses

The commitment to a comprehensive, broad spectrum and preventive strategy for chemicals management does not apply only at the national level. Because the increasing chemical intensification of all economies, including the shifts in chemical production, penetration of chemical intensive products into local markets and presence of pollution-prone industries, is driven by international trade and the globalization of markets, achieving sound chemicals management requires a well-coordinated international response.

As the UNEP Governing Council observes, “the challenges posed by chemicals and wastes are global, enduring and constantly evolving and....they are interrelated with crucial environmental issues such as environment-dependent human health, the health of ecosystems and better ecosystem management, the preservation of biodiversity, and the link between poverty and environment, environmental disasters, climate change and sustainable consumption...”⁷⁰ National governments, alone, cannot assure the sound management of chemicals. Multinational corporations and international civil society organizations can mobilize resources and diffuse ideas across sovereign boundaries, but these efforts need to be supported and coordinated through international bodies.

Intergovernmental organizations and international organizations responsible for chemicals management must be integrated with and linked to international treaties and organizations focused on human health, ecosystem protection and social and economic development. Despite significant progress in developing international instruments and authorities in the past decades, the fragmentary approach that has characterized international chemicals policy and management needs to be reconciled if the WSSD goal is to be reached.

6.1 Global and Multilateral Instruments

Today, there may be as many as 500 MEAs. Some argue that this has resulted in a kind of “treaty congestion” that is not only costly and inefficient, but also, leads to a plethora of single issue approaches. The result is too often a lack of international integration and coordination that is mirrored at the national level where many separate offices and programmes abound. Working within this decentralized and multi-faceted environment is particularly difficult for developing countries and countries in economic transition that often lack the resources to attend to so many different agreements and agencies.⁷¹

Since the early 1920s, international organizations ranging from the ILO to the International Maritime Organization have been drafting global agreements for managing chemicals. The International Code of Conduct on the Distribution and Use of Pesticides was one of the first international codes of conduct on chemicals.⁷² The sound management of chemicals, first articulated at the UN Conference on Environment and Development and reinforced at the WSSD, places significant responsibilities for chemicals management on international agencies. Over the past two decades, the United Nations’ MEAs addressing the trans-boundary movement of chemical emissions and wastes have been augmented with the Rotterdam and Stockholm Conventions directly addressing the regulation of chemicals as commodities.

The Montreal Protocol of the Vienna Convention is noted as a particularly successful agreement. Not only have ratifications been nearly universal and the administrative units effective; the results, in terms of reductions in the production and use of ozone depleting substances, have also been dramatic. However, the other conventions have also seen successes. The Rotterdam Convention has now been ratified by 140 parties and provides a legally binding prior informed consent procedure that is widely used to track the 44 chemicals listed in its Annex III. The Basel Convention, now ratified by 175 parties, has driven its environmentally sound management (ESM) of wastes and its waste management hierarchy into a wide range of trade agreements and waste transfer protocols. In addition, there are several regional waste agreements such as the Bamako Convention for Africa, the Waigami Convention for the Pacific, and the Izmir Protocol for the Mediterranean Sea. One hundred and seventy three countries have ratified the Stockholm Convention, which began with

a list of 12 persistent organic pollutants slated for international elimination or restriction. In 2009 another nine chemicals were added to the list, and endosulfan was added in 2011.

Notwithstanding the important progress that has been accomplished under these international agreements, it is important to recognize that their legal authorities are limited, their coverage of the number of chemicals and the volume of wastes remains small, and their procedures are complex and cumbersome. If the WSSD goal is to be reached it is important that the implementation of these agreements be streamlined and expanded, and that new agreements provide for more broad-spectrum authorities.

Most developing countries and countries in economic transition have acceded to and ratified the International Code of Conduct on the Distribution and Use of Pesticides and the four primary MEAs on chemicals (Basel, Montreal Protocol, Rotterdam and Stockholm). As of 2009, 50 of the 54 African countries had ratified the Stockholm Convention, while the Rotterdam Convention had 41; the Basel Convention, 48; and the Montreal Protocol, 53. However, the domestication of the conventions in African nations' policies and the development of national implementation plans have been slow.⁷³

Throughout the past decade there has been growing pressure for a legally binding agreement on heavy metals. In 2009, the UNEP Governing Council approved the commencement of negotiations for an international agreement on mercury. An international binding treaty to curb mercury pollution was agreed to by more than 140 countries in January 2013. The Convention will open for signature in October in Minamata, Japan. Strong industry resistance has stalled further discussion on emerging initiatives on lead and cadmium.

6.2 Intergovernmental Agencies

At the global level there are a host of intergovernmental agencies that address chemical management. Table 10 lists several of the leading agencies.

Table 10. Leading Intergovernmental and International Government Organizations Promoting the Sound Management of Chemicals	
Agency	Programmes
Food and Agriculture Organization	Pesticides Code of Conduct, Rotterdam Convention
International Labour Organization	ILO Chemicals Conventions (No. 170)
Organisation for Economic Cooperation and Development	Chemicals Committee, working groups on nanotechnologies
United Nations Environment Programme	Chemicals Branch, Secretariat for MEAs, Quick Start Programme, Ozone Action, APELL, Global Chemicals Outlook
United Nations Development Programme	UNDP/UNEP Partnership Initiative, UNDP/UNEP Poverty Environment Initiative
United Nations Industrial Development Organization	National Cleaner Production Centers
United Nations Institute for Training and Research	Chemicals and Waste Management Programme, GHS, PRTRs
United Nations Economic Commission for Europe	GHS
World Bank	Economic assistance financing
World Health Organization	WHO/UNEP Health and Environment Strategic Alliance, risk assessment
Global Environment Facility	Stockholm Trust Fund
International Organization for Standardization	Process and product standards

The OECD has maintained a critical role in addressing chemical management. OECD's Chemicals Committee has been important in the development of international chemical testing standards, while the Environment Committee has prepared periodic projections on the state of the environment and the state of the chemicals industry. More recently, the Chemicals Committee has taken an international lead on evaluation of nanotechnology. Its Working Party on Manufactured Nanomaterials has developed a database of research on the health and environmental effects of nanotechnology and promoted national risk assessments and voluntary reporting schemes.

An additional initiative on nanomaterials by the IOS seeks to develop international voluntary standards in areas where government policy and regulations have not developed. There are now a technical committee and four working groups. Two groups have completed guidance documents—one on terminology and definitions, and one on occupational safety and health considerations.

The WTO plays a significant role in managing international trade. Through its negotiated and ratified agreements, the WTO strives to expand international market access, improve global competitiveness, discourage unfair practices, and increase transparency and predictability. WTO agreements permit measures to protect the environment and public health, but not where they may prove discriminatory or unfairly protectionist. The WTO has not moved to review the international conventions' authority to manage chemicals and wastes; however, this leaves open important opportunities to raise and harmonize chemical standards internationally by integrating chemical management into trade considerations. Creating a "level playing field" in international markets can serve both developed and developing countries.

Responsibility for promoting sound chemical management is divided among many of the United Nations agencies. This broadly adopted commitment has important benefits as it prevents the WSSD goal from becoming an isolated initiative. However, the involvement of many agencies makes for many differing strategies and programmes with significant coordination challenges.

The FAO shares responsibility with the WHO for the management of pesticides. The Joint (FAO/WHO) Meeting on Pesticide Residues recommends maximum pesticide residue levels on food products to the Codex Alimentarius that then adopts them as global standards recognized by the WTO. When the FAO endorsed SAICM, it created a pesticide management programme focused on defining highly hazardous pesticides (HPPs) and assisting countries to either severely restrict their use or ban their production, importation and use.

The ILO has a large inventory of workplace health and safety conventions that address the risks of chemical exposure such as the Chemicals Convention and the Prevention of Major Industrial Accidents Convention. The ILO has a special convention on the Worst Forms of Child Labour that lists chemicals of concern to child health and safety and a Green Jobs Initiative that links ILO with UNEP in promoting safe work in a green economy.

The United Nations agencies have worked to build cross agency partnerships to promote sound chemical management. FAO and the WHO have been working together on the International Code of Conduct on the Distribution and Use of Pesticides since 1985. The International Programme on Chemical Safety is a collaborative effort among UNEP, WHO and ILO, while the Intergovernmental Forum on Chemical Safety was founded by UNEP, WHO and ILO. UNEP and UNDP created the Partnership Initiative for the Integration of Sound Management of Chemicals into Development Planning Processes. UNDP and UNEP have jointly created the UNDP/UNEP Poverty Environment Initiative, while UNEP and the World Health Organization have also partnered to develop the Health and Environment Linkages Initiative.⁷⁴

Recognizing the need for cross country regional cooperation on chemicals has spurred the MEAs to promote regional forums such as the Basel Convention's Regional Centers (e.g., the Regional Center for Arab States in Cairo and similar regional centres in Dakar and Pretoria). The Stockholm Convention has also begun to establish similar regional centres. Such centres can support and encourage regional cooperation among proximate nations. In promoting sustainable development, the United Nations has supported "South-South" regional cooperation that has linked together groups of countries in Africa, Asia, Latin America or the Caribbean to help countries protect natural resources, share water

resources, meet climate change commitments, strengthen environmental laws or achieve other regional objectives. Focal points such as the Non-Aligned Movement Center for South-South Technical Cooperation have played an important role in these collaborations. These joint programmes promote efficiencies while enhancing cooperative learning and cross national programme integration, and could be models for South-South cooperation on chemicals management.⁷⁵

SAICM was designed to promote international coordination on chemicals management through its overarching global strategy. Recognizing the need for better coordination among the MEA secretariats has driven efforts to promote “synergies” among them. Administrative, logistical and programme integration has been advanced through discussions at UNEP’s Environmental Management Group and the Simultaneous Extraordinary Conferences of the Parties for the Basel, Rotterdam and Stockholm Conventions and has resulted in the appointment of an executive secretary to strengthen cross secretariat integration and coordination. The efforts on-going to develop joint activities, joint managerial functions, joint services, joint audits, and the synchronization of budget cycles extend and enhance the broader United Nations “Delivering as One” initiative.

However, the laudable efforts to better coordinate the activities and functions of the United Nations agencies responsible for chemicals remain insufficient in integrating sound chemicals management into the international organizations charged with social and economic development. The overarching coordinating initiative that links UNEP, WHO, UNDP, ILO, FAO, UNIDO, UNITAR and the World Bank, envisioned by the Inter-Organization for Sound Management of Chemicals (IOMC) in promoting SAICM, may need also to include UNESCO, the WTO, the multi-lateral development banks and the International Monetary Fund to truly integrate chemicals management into international and global social and economic development. This is a task that may need to be addressed by the UN Chief Executives Board for Coordination or the United Nations Development Group that is responsible for achieving the Millennium Development Goals. A comprehensive approach to the sound management of chemicals does not require a single strategy, but it does require that agency approaches be integrated and mutually reinforcing.

The success of SAICM can be measured by its endorsement by all relevant intergovernmental and non-governmental stakeholders, the “shared ownership” of chemicals management by government, business and civil society organizations, the solid financing of the SAICM Trust Fund, and the number of successful Quick Start projects. The IOMC has promoted coordination among SAICM initiatives and a host of countries have established internal coordination among the appropriate ministries. The second International Conference on Chemicals Management (ICCM2) commitment to four emerging policy areas - lead in paints, nanotechnology, information on chemicals in products and electronic wastes - has set international priorities for some of the most concerning international chemicals management problems.

However, limited operational financing and the absence of any legally binding authority have slowed the capacity of SAICM to reach the WSSD goals. Progress on the commitment to integrate chemicals into international economic development planning has been slow. The absence of a process for follow up planning for the period after 2020, and the possibility that funding for the Trust Fund will be discontinued after 2012, clouds the potential long-term success of SAICM.

6.3 Generating International Financial Assistance

Developing countries and countries in economic transition may be able to generate some funding for chemicals management through government appropriations and cost recovery instruments. However, with the rapid pace of the chemical intensification of economies, most of these countries need immediate assistance to develop and strengthen existing capacities and, in many cases, such assistance may be required for some time to come. While the amount of funding must be sufficient to meet institutional needs, its predictability is of equal importance, because stability over time allows for the personnel retention and programme follow through that leads to substantive capacity development.

International organizations, national development aid programmes and multi-lateral and bi-lateral banks could be a direct source of such financing. International organizations such as the World Bank, the African Development Fund, the Arab Fund for Economic and Social Development, the Asian Development Bank plus a host of national development aid programmes provide economic development and poverty reduction assistance. The challenge is to convince such institutions that funding sound chemicals management is critical to economic development and is cost effective. The World Bank has taken significant steps to promote sound chemicals management in its investment and co-lending programmes. In 2007 the bank laid out a strategy for linking chemicals management with poverty elimination, sustainable development and reaching the Millennium Development Goals.⁷⁶

The Global Environmental Facility and the Montreal Protocol's Multilateral Fund provide project-based funding tailored to MEAs that can be used to initiate sound chemical management initiatives. Since its founding in 1991, the GEF has allocated US\$ 9.5 billion, supplemented by over US\$ 42 billion in co-financing, for more than 2700 projects in 165 developing countries and countries with economies in transition.⁷⁷ The Multilateral Fund, also founded in 1991, has provided some US\$ 2.6 billion in similar project oriented funds.⁷⁸ However, funding from these sources is project oriented and not conducive to longer term commitments. While funding under the Multilateral Fund is linked to compliance and funding under the GEF is tied to "global environmental benefits," a third model of financing, the mainstreaming model, ties funding for chemicals and wastes into economic development as a whole.

Mainstreaming at the international level provides an opportunity to integrate chemicals management into bilateral and multilateral economic development and poverty reduction assistance. The Poverty Reduction Strategy Papers (PRSPs) that are necessary for proposals to the International Monetary Fund and the World Bank offer an important focus for integrating chemicals policy into development assistance programmes. While the UNDP/UNEP Partnership Initiative demonstrates that successful mainstreaming is a key to attracting economic development funding for chemicals management, there is a need for more such country initiatives.

In order to facilitate this mainstreaming strategy, it may be useful to "repackage" the concept of sound chemicals management. The term and the current vision rings well for its many proponents, but it may sound too foreign and distant to those with other primary concerns. The phrase "chemicals management" may not capture the urgency of protecting people and ecosystems from chemical hazards. It may be more effective to argue for poison reduction in agricultural communities, children's protection in public health settings, chemical entrepreneurship in business forums, accident prevention in local communities and bio-security and strategic resource protection in national legislatures. Finding new language and new metaphors more likely to fit into other points of reference may improve the chances that chemicals management gets serious attention.

In 2009, UNEP initiated a consultative process to explore the financial and support needs of developing countries and countries in economic transition in managing chemicals and wastes. A working group on the consultative process has met five times and currently is preparing a strategy document focused on four options to improve funding for sound chemicals management, including the mainstreaming of chemicals management into economic development assistance, public-private partnerships, a new trust fund similar to the Multilateral Fund, and the establishment of a new or expanded GEF focus on chemicals and waste management.⁷⁹ Private sector financing might be an important part of this. For instance, the Mitchell Kapor Foundation has made persistent organic pollutants (POPs) the focus of its grant-making, and the Ford Foundation made a US\$ 2.2 million grant to Vietnam in 2006 to bring critical health services to people living with dioxin-caused long-term disabilities.

6.4 Reducing the Illegal Traffic in Chemicals

While the problems associated with the illegal traffic in chemicals is directly felt at the national level, much of the solutions lie in improvements at the international level. In 2006 UNEP convened a symposium regarding illegal international traffic in hazardous chemicals in order to share information, evaluate impacts on human health and the environment and evaluate existing strategies for preventing international illegal traffic. Symposium participants identified a range of possible actions to be taken, including: harmonization and implementation of the MEAs and regional/bilateral agreements into national legislation; establishment of an administrative framework for efficient information exchange among enforcement officers; training of inspectors including development of guidance documents; and raising awareness within industry and civil society on legal restrictions.⁸⁰

Addressing the illegal traffic in chemicals at the national level requires strengthening governance and building institutional capacity. Customs officers and other enforcement officials are particularly vulnerable where they are poorly trained and their jobs are insecure and insufficiently compensated. Over the last decade, a number of programmes have been initiated in developing countries to provide training and strengthen the capacity of these officials to help them improve information sharing, and recognize and prevent illegal traffic. Some of the key programmes include:

The Green Customs Initiative is a multi-agency initiative organized to fight illegal chemical trade. Participants include the secretariats of the relevant MEAs, International Criminal Police Organization (Interpol), UNEP, the World Customs Organization and the Organization for the Prohibition of Chemical Weapons. The Green Customs Initiative has developed training materials and conducted training for customs officers and border officials around the world to build awareness and increase capacity to detect and take action against international traffic in illegal chemicals.⁸¹

UNEP's OzonAction is a programme that supports developing countries and countries in economic transition in their efforts to phase out ozone depleting substances (ODS) to meet the requirements of the Montreal Protocol. The programme has organized joint workshops of customs and ozone officers training some 2,000 customs officers from 70 countries.⁸² In 2006, OzonAction and customs administrations initiated "Project Sky Hole Patching," a joint operation that created a monitoring and notification system to track suspicious shipments of ODS and hazardous waste. That same year, OzonAction launched a programme to develop regional and integrated cooperation between countries in North-East, South, and Southeast Asia to help gain better control over chemical imports and exports.⁸³

The International Network for Environmental Compliance and Enforcement (INECE) Seaport Environmental Security Network (SESN) is a network of government, civil society and academic organizations working to monitor trans-boundary movement of hazardous waste through seaports and improve environmental compliance and enforcement from the local to global level. This group is working to raise awareness and build capacity to better detect and control illegal shipments. INECE SESN facilitated an inspection of international hazardous waste in 2010 and found that of 74 inspections, 53 per cent were non-compliant and found substantial shipments of hazardous waste, including e-waste, illegal under the Basel Convention.⁸⁴

With some chemicals and wastes the focus needs to be on developed countries. In the European Union, where strong legislation is in place for the recycling of electronic waste, there is still a need for improved controls on and auditing of products that have entered the recycling waste stream. For instance, the Environmental Investigation Agency (EIA), an NGO that investigates environmental crimes internationally, found significant amounts of illegal shipments of wastes from the United Kingdom and recommended that the British government review service operators to ensure that they have the infrastructure and capabilities for recycling.⁸⁵

Methods often used to hide illegal chemicals include false declarations, mislabeling of containers, and concealing materials through double layering in containers.⁸⁶ To address this problem, product and chemical labeling and

transport licenses provide important tools. However, because of the ease of falsifying labels, a universal labeling system for ozone depleting substances is not seen as valuable, except perhaps for used substances. Customs codes that identify substances are seen as a preferable means of fighting illegal transport. Improvements in the control of import and export licenses may provide the strongest means to reduce illegal trade in ozone depleting substances. Licensing is most effective when the system is quite visible to the user, for example, a license application that includes a declaration certifying accuracy that must be signed by the importer or exporter.⁸⁷

Preventing illegal international traffic in chemicals will remain difficult as long as banned or severely restricted chemicals continue to be produced. Chemicals banned for use and trade under the Montreal Protocol, Stockholm Convention and many national laws continue to be manufactured. Therefore, stronger enforcement of international and national chemical control laws is also critical to reducing illegal trade in chemicals.

The efforts to strengthen enforcement of chemical control laws and build capacity through training, information sharing and international partnerships need to continue. A recent SAICM update report on the illegal chemical traffic in Africa found the activities undertaken to date fall short of solving the problem as they are implemented in a piecemeal fashion. There is still a lack of education, and awareness and cooperation established at the international level is not well implemented at the national and regional levels.⁸⁸

The most recent report from the SAICM Africa Core Group sums up the needs:

....addressing illegal traffic effectively.....will depend on a variety of factors including information exchange and communication, awareness-raising and education, capacity building, financial and technical assistance, research and training, developing and implementing control measures and the transfer of technology. A holistic and integrated approach is needed; training of customs and law enforcement officials to detect, control and prevent illegal traffic will be insufficient, if there are no strong and established policies and legislation, good governance, adequate infrastructure, accessible financial resources, effective cooperation and coordination for combating illegal traffic and sound management of chemicals.⁸⁹

7. Advancing the Sound Management of Chemicals

Reaching the WSSD goal will require a more concerted effort by international agencies, national and local governments, businesses and civil society organizations. In many cases the needs are well recognized, the directions are clear and what is missing is financial resources and political will. In many countries with developing and transitional economies this will require technical assistance, technology transfer, institutional capacity building and training on the new methods and tools being used today by leading corporations and developed countries to improve chemicals management. In some cases, this may involve new statutes and new institutional frameworks and the development of new legal, economic, technical and voluntary programmes. At the international level, this will require better coordination, cooperation, integration and mainstreaming of organizational policies and programmes.

Five general themes emerge from this consideration of the instruments and approaches that are needed to promote the sound management of chemicals worldwide and specifically in developing countries and countries with economies in transition. These include:

1. Develop comprehensive, broad-spectrum and preventive chemicals management strategies. The European Union's REACH Regulation sets the gold standard, but many developed countries need to reform their current approaches to keep pace. For developing countries and countries in economic transition the challenge is to "leapfrog" beyond the conventional approaches and adopt policies, instruments and approaches that are comprehensive, coordinated across government agencies, anticipatory and proactive, and designed first to prevent, rather than control or remediate risks.

2. Mainstream chemicals management into national public health and social and economic development programmes. Recognizing the fundamental role that chemicals now play in all economic sectors and all aspects of daily life, chemicals management should be a commonly accepted element in all health promoting programmes and a central feature of national and international social and economic development planning and programmes.
3. Regulate and reduce chemicals of highest concern and substitute them with safer alternatives. Today, there is sufficient scientific literature and government initiatives to identify those chemicals of highest concern to human health and the environment, such that governments and businesses can move with confidence to reduce or restrict their production and use. In so doing it is important that the alternatives selected be safer across their life cycles and, where this is not possible today, that the public and private sectors be encouraged to research and develop safer alternatives.
4. Integrate and coordinate international and intergovernmental programmes to increase synergies and effectiveness. The broad array of international agreements and bodies now established to address chemicals in all modes of production, use and disposal requires strengthened authorities and improved programme and administrative coordination to promote efficiency and effectiveness in a mutually reinforcing campaign to achieve the sound management of chemicals by the WSSD goal.
5. Develop new national and international approaches to financing sound chemicals management. Recognizing the significant burdens of disease and injury resulting from the poor management of chemicals, the substantial economic costs of inaction and the potentially large economic benefits of action on chemicals management in developing countries and countries in economic transition, it is critical that new sources of financing for capacity building, professional development, and technology adoption be developed.

In order to more specifically consider the needs that lie ahead, it is useful to return to the five objectives laid out in the SAICM Overarching Policy Strategy - Risk Reduction, Knowledge and Information, Governance, Capacity Building and Technical Cooperation and Illegal International Traffic in Chemicals.

7.1 Risk Reduction

Measures to reduce the risks of chemicals based on solid science and informed by social and economic considerations is a central part of the WSSD goal. The government instruments and approaches and the various tools and methods developed by businesses, governments and civil society organizations provide an ample menu of devices for advancing the goal. Countries with developing and transitional economies need to develop broad spectrum plans that strategically select appropriate instruments, methods and tools that can be effectively implemented and develop the necessary capacities among institutional authorities.

- a. **Promote the adoption of chemical management instruments and approaches that link chemicals management with social and economic development.**

A comprehensive baseline assessment and a good national chemicals profile have proven to be effective tools for developing countries and countries in economic transition for identifying policy gaps and inconsistencies and can also be useful for identifying the most appropriate instruments and approaches that could be adopted to integrate chemicals management into national development planning. Experience in developed countries has demonstrated the importance of focusing policies on the point where chemicals first enter the market and the value of locating

the primary responsibility for chemical safety on those firms that manufacturer or use chemicals. Where possible, developing countries and countries in economic transition should consider regional approaches to chemicals management and adopt and adapt existing tools, methods and programmes (e.g., databases, lists, laboratory analyses, risk and alternatives assessments) from developed countries so as to reduce costs and harmonize mechanisms. Careful attention should be given to instruments that raise revenue or internalize costs.

b. Promote national and international agreements on reducing the use of priority hazardous chemicals and increasing the substitution of safer alternatives.

Whereas SAICM professes a comprehensive and broad-spectrum approach to all chemicals across their life cycles, it is important to approach chemical hazards as a systems problem with a strategy for incrementally controlling and substituting chemicals of concern in a progressive march towards safer alternatives. Developing countries and countries in economic transition could develop classification frameworks that organize chemicals in each nation's economy by degree of concern and set priorities for management. Lead, cadmium, mercury and the priority chemicals of international agreements provide a good starting list. In promoting restrictions on the use of these chemicals it is important that alternatives be analysed and compared, so that substitutes are indeed safer. In this transition to sound chemicals management, developing countries and countries in economic transition need to be viewed as partners with developed counties, each with its own specific role such that banned chemicals, obsolete technologies and hazardous wastes unwelcome in one country do not become burdens in another.

c. Promote the adoption of safer alternatives to chemicals of high concern including non-chemical and lower concern chemical alternatives.

Corporate programmes to avoid substances on restricted substance lists and government-sponsored cleaner production and toxic use reduction programmes demonstrate the many opportunities that exist currently for substituting safer chemicals and non-chemical alternatives to hazardous chemicals. The European Union's REACH regulation and large front runner corporations and retailers will drive the global market on some chemical substitutes. However, developing countries and countries in economic transition will need assistance in selecting appropriate tools and methods for evaluating and selecting safer alternatives. Large corporations need to provide leadership, but effective government and civil society technical assistance programmes are also needed to move small and medium-sized enterprises

d. Assist in the development and adoption of risk reduction programmes in the cleaning up of chemical wastes and the management of hazardous chemical stockpiles.

The African Stockpiles Programme (ASP) and the US Superfund Program present important models for the management of chemical wastes and the remediation of waste sites. Capacity building in developing countries and countries in economic transition is critical as the technical, legal and financial issues of legacy chemicals are complex. While developing countries and countries in economic transition work to better manage existing wastes, it is important that international efforts be made to stem the international transfer of hazardous wastes, particularly electronic wastes. Because such wastes have often raised significant local concerns, it is important that civil society organizations participate in the programmes, public information is provided and public involvement is encouraged.

7.2 Knowledge and Information

The transition towards sound chemical management requires a significantly expanded base of chemical information not only on the health and environmental effects of chemicals, but also on the production, use, transport and disposal of chemicals. Information is needed through-out the life cycle of products. The burden for this information must fall on those companies that manufacture and use chemicals; however, governments, along with companies and civil society organizations, must make it available, accessible and understandable to the public.

- e. **Provide opportunities for the international sharing of information on chemicals of high concern and chemicals of unknown concern such as nano-scaled substances.**

The ICCA HPV programme provided an important international challenge to chemical manufacturers to provide basic screening data on the highest production volume chemicals. Similar efforts are needed to provide screening information on moderate and lower production volume chemicals. Further effort is needed to conduct research and disseminate health and environmental effects information on the novel chemicals of nanotechnology and synthetic biology. While corporations should bear the primary responsibility here, government authority should be available to back up such voluntary programmes with regulatory defaults similar to the REACH “No data; No market” principle.

- f. **Promote systems for tracking the production, transport, use and disposal of chemicals of high concern.**

The OECD chemical testing standards, the Rotterdam Convention notifications and the Globally Harmonized System for Classification and Labelling of Chemicals (GHS) demonstrate both the value and success of creating international standards for generating and characterizing chemical information. A similar international chemical tracking system is needed to provide common criteria, guidance and requirements for reporting on the production, transport, use and disposal of chemicals. Such a system might start first with internationally recognized chemicals of concern such as those identified as Severely Hazardous Pesticide Formulations under the Rotterdam Convention and the Substances of Very High Concern under REACH.

- g. **Promote the adoption of tools and methods that improve the flow of chemical information, the screening of chemicals of concern and the evaluation of safer alternatives.**

Product manufacturers and retailers in consumer-oriented economies are being pressed to provide customers with safer products and this requires gathering information from suppliers on the chemical constituents of mixtures and components used in product manufacture. The European Union’s REACH regulation is generating some of this information and its requirements that chemical manufacturers inform downstream users and could help firms in developing countries and countries in economic transition. International businesses need to work with their supply chains in these countries to use the new decision support methods and tools to screen chemicals and develop both restricted substance lists (black lists) and lists of preferred substances (green lists). Businesses, civil society organizations and governments need to work together to create product ingredient disclosure protocols, comparative chemical screening tools and alternatives assessments.

- h. **Develop central focal points and local service programmes for international communication and information sharing on sound chemicals management.**

The OECD e-Chem Portal and various national, searchable chemical information databases organized by the European Union and various developed countries provide a wealth of information from authoritative bodies on the hazards of chemicals. These information sources need to be expanded

and strengthened. To be effective, such information must be received in forms appropriate to use (language, media, technology), particularly in developing countries and countries in economic transition. UNEP's Chemical Information Exchange Network provides a good model for professional training and network building. There is an important opportunity here for business associations, local governments and civil society organizations to provide similar assistance, training and support for small and medium-sized enterprises.

- i. Promote instruments for sharing and making public chemical information and information on chemicals in products and articles throughout their life cycles.**

The Swedish Chemicals Agency has recently released a strategy for managing chemicals in products in which access to information about hazardous chemical constituents in products through-out the life cycle of products is one of the central tenets.⁹⁰ This will require new legislation and will also create new responsibilities for chemical manufacturers to provide chemical information to downstream users, product manufacturers to obtain such information from suppliers, and provide it to product distributors, waste recyclers and disposers, and product retailers, in order to provide this information to customers. A small number of businesses now provide full public access to the ingredients in their products, but this is not true for the large majority of product manufacturers. Through product labeling, product declarations, accessible databases, or Web sites, firms should strive to provide the public with all but the most business sensitive chemical information so that governments and civil society organizations can develop programmes to interpret and widely disperse such information.

7.3 Governance

The development of effective approaches and the adoption of appropriate instruments for the sound management of chemicals are central to the creation of effective governance infrastructures in developing countries and countries in economic transition. Such initiatives at the national level need to be supported by similar efforts to improve and better integrate and coordinate governance systems at the international level.

- j. Develop and strengthen national chemical management authorities that can integrate sound chemicals management into sustainable development planning.**

The creation of National Chemical Profiles and the development of National Implementation Plans under the Stockholm Convention demonstrate the capacity of developing countries and countries in economic transition in providing a foundation for national chemicals planning. Such planning can bring together the differing ministries and agencies (health, environment, labour, agriculture, mining, customs) responsible for chemicals with those responsible for social and economic development. Technical and financial resources need to be made available under international and bilateral economic development assistance programmes. Already, some US\$ 10 million of SAICM Quick Start funding has been spent by recipients in integrating chemicals management into national planning.⁹¹ While there are international surveys of some instruments (PRTRs, laboratories) for sound chemical management, a broad, international survey on the status of adoption of instruments, approaches, methods and tools by governments and corporations is needed.

k. Promote coordination and information sharing among all stakeholders in advancing the sound management of chemicals.

SAICM itself represents a bold commitment to international coordination on chemicals management; however, overcoming differing institutional cultures and jurisdictional frictions, even where commitments are strong, is not easy. Recent efforts to find “synergies” bode well. Such efforts should include the many international agencies responsible for global economic development, human health promotion, ecosystem management and poverty reduction, as well as business and civil society organizations. The SAICM secretariat needs more funding and authority, and a plan for further integration after 2020 would help to spur current coordination efforts. In addition, the efforts to coordinate the programmes of the MEAs through regional collaborations and regional offices could be encouraged.

7.4 Capacity Building and Technical Cooperation

The widening gap between developed countries and developing countries and countries in economic transition encourages some of the most serious chemical risks to fall on those least prepared and hinders international developments at redress. While there is clear need locally for the preparation of qualified personnel and the strengthening of existing government institutions and civil society organizations, these improvements cannot occur without strong support from developed countries and international organizations.

l. Promote professional training, technical assistance and increased financial resources in building chemical management capacity.

The IOMC strategy provides a solid framework for organizing capacity building initiatives in developing countries and countries in economic transition. Implementing this strategy requires that on-going training and technical assistance programmes on chemicals management need to be expanded and strengthened. While local training and technical assistance can provide well-tailored content, there is also a need for regional approaches that reach wider audiences and lay the foundation for cross-national modeling and mentoring. New regional organizations such as the African Union’s New Partnership for African Development and the Latin America and Caribbean Economic Association, provide important initiatives for capacity building that could include chemicals management.

m. Promote economic instruments that generate revenues through cost-recovery mechanisms on chemical importation, transportation, use or disposal.

Developing institutional capacity and qualified professionals in developing countries and countries in economic transition requires financial resources. While exogenous sources such as bilateral aid and the Quick Start Programme can provide immediate funds, the challenge is to develop internal revenue sources such as taxes and service fees that promote sound chemicals management and generate a continuing source of revenue. While UNEP has begun to catalogue and evaluate these economic instruments, more work could be done to identify “best practices” in the use of economic instruments to promote sound chemicals management.

n. Integrate financing for the sound management of chemicals into bilateral and international economic development programmes.

Financing for chemicals management could be expanded if economic and social development assistance and poverty reduction programmes included chemicals management as a sustainable development priority. The challenge is to convince such institutions that funding sound chemicals

management is critical to economic development and is cost effective. This requires a “repackaging” of sound chemicals management and a coordinated “mainstreaming” campaign involving UN agencies, national governments, businesses and civil society organizations at both the international levels and focal point within countries. Strong economic arguments that document the economic burden of disease and the financial benefits of action on chemicals must be central to such campaigns. In addition, support needs to be built for the UNEP consultative process options on new international financial arrangements and instruments.

7.5 Illegal International Traffic

Illegal trade in banned and severely restricted chemicals will continue as long as markets for them thrive and the prospects of being apprehended are low. Illegal traffic in hazardous chemicals at the national and regional levels can be reduced by strong local enforcement, but international trade requires international agreements and strong national border controls.

o. Develop and strengthen national authorities capable of monitoring, interdicting and restricting illegal traffic in chemicals and wastes.

Although the Basel and Bamako, Wiagami and Izmir agreements create a framework for regulating international trade in hazardous wastes (including electronic wastes), much more needs to be done to manage the flow of banned chemicals and restricted wastes. Amendments to the Basel Convention will tighten loopholes and additional resources and national ratifications would help. The Rotterdam Convention could be expanded with additions to its list of regulated chemicals. However, there are also important needs at the national level where government agency personnel, particularly customs agents, need to be trained, secure, sufficiently compensated and given adequate authority to inspect and interdict such wastes. The Green Customs programme provides a good model for such training.

p. Strengthen national and international authorities in curbing the production and marketing of banned and severely restricted chemicals.

As the Montreal Protocol, the Stockholm Convention and the national governments of many developed countries employ their authority to prohibit the legal production and use of a select number of chemicals of high concern, they set the conditions for illegal markets. It is important that these efforts to phase out chemicals are coordinated with clear, implementable and well-funded programmes to enforce the bans and address the resulting stockpiles of legacy chemicals. The OzoneAction Teams and the Quick Start capacity building projects focused on illegal chemical trade provide a good start, but need follow up and additional resources.

8. Charting the Way Forward

Achieving the sound management of chemicals requires a global commitment. As the chemical intensification of all economies increases, significant responsibilities must be taken by national governments, intergovernmental organizations, corporations and civil society organizations. However, the capacity to share this commitment is not equally distributed. The growing presence of chemical manufacturing in developing countries and countries in economic transition, and the increasing chemical intensification of their economies, increase the risks to workers, communities and the environment, while these countries often lack the institutional capacity and resources for effective risk management.

Even though there are large challenges in coordinating chemical management programmes at the national level, national initiatives are not enough. To be effective and to be sufficiently funded and sustainably maintained, sound chemicals management must be internationally coordinated and comprehensively “mainstreamed” into national social and economic planning. Chemicals management must become a national and international environmental, public health and business development priority. This requires a broad and ambitious effort at coordination among a host of national agencies and ministries and intergovernmental and international organizations.

8.1 Addressing Rio+20

Reaching the WSSD goal by 2020 for the sound management of chemicals will require a comprehensive strategy that encourages policy instruments and approaches appropriate to specific economic conditions and rapid increases in the government, technical and resource capacities of developing countries and countries in economic transition. The United Nations Conference on Sustainable Development (“Rio + 20”) has provided an important venue for promoting this broadened approach to comprehensive chemicals policy. The sound management of chemicals fits well into the two themes of the Rio + 20 Conference, which were a global Green Economy and an institutional framework for sustainable development.⁹²

Global governance or an international framework for sustainable development requires a renewed institutional commitment by all intergovernmental agencies and international organizations to the goals of sustainable development. It is both a call for integration of efforts and a commitment to accountability and focus. There is today a significant amount of energy and resources committed to international sustainable development work, but effectiveness is eroded by the lack of coordination and integration.

The vision put forward here of a comprehensive chemicals strategy focused on achieving the WSSD goal of sound chemicals management parallels and fits this broader search for international coordination and integration. Recognizing that the most effective and possibly, only successful, approach to reducing the risks of dangerous chemicals and promoting the development of safer and more sustainable chemicals lies in integrating chemicals policy into environmental, public health and economic development policy is congruent with and supportive of the Rio + 20 theme of global governance.

A green economy as defined by UNEP results in “improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.”⁹³ Green technologies are seen as vital to the transition to a green economy. The United Nation’s 2011 World Economic and Social Survey describes the need for a “great green technological transformation.” The report notes that many green technologies such as solar, wind, biofuels, energy efficiency and techniques for sustainable agriculture and forestry already exist, but must be scaled up and made more accessible to developing countries. It describes how the next three to four decades will be critical for achieving this transformation and that government engagement and international cooperation will be essential because of the short time frame available to make these needed changes.⁹⁴

UNEP has outlined a range of strategies for supporting the transition to a green economy. These include investing in natural capital in the realm of agriculture, fisheries, forests, and water and investing in energy and resource efficiency in manufacturing, waste management, buildings and urban design, tourism and transportation.⁹⁵ Sound chemicals management is a vital element that underpins each aspect of a green economy and if packaged strategically could be integrated into these focus areas. Indeed, integrating sound chemical management into the various aspects of a green economy provides a useful exercise in repackaging the concepts of chemical management into ideas and language that are relevant to these sectors. For example:

- *Agriculture:* With increasing global demand for food, a new approach to food security must include green technologies that reduce hazardous chemical inputs including pesticides and fertilizers.⁹⁶
- *Water:* Water scarcity is determined by many factors, including the polluting of water supplies by toxic chemicals. Nearly 1 billion people do not have access to clean water. In a green economy, water will need to be used more efficiently, available to all at a reasonable cost and free from harmful chemical pollutants.⁹⁷
- *Manufacturing:* In a green economy, eco-design of products and closed loop manufacturing will become the norm rather than the exception. This involves investing in cleaner technologies, greening of supply chains, and reducing the use of hazardous chemicals.
- *Waste management:* In situations where waste cannot be avoided, materials and energy in a green economy will be recovered for recycling and remanufacturing. Sound chemicals management is critical to the safe recycling of waste products as the chemical hazards in these products must be reduced or carefully controlled through the redesign of products and packaging.
- *Building:* The development of green buildings including improvements in energy and water efficiency and reductions in toxic chemical use is an essential component of a green economy. These design parameters have proven to result in improvements in health and safety and increased worker productivity.
- *Transportation:* In a green economy, vehicles and transportation systems will be designed to be more efficient and use cleaner fuels such that carbon emissions will be greatly reduced as will air emissions of hazardous chemicals that threaten public health.
- *Tourism:* In a green economy, green-oriented tourism will flourish, including improved systems for energy and water efficiency and responsible chemicals and waste management.

There are many strategies for integrating sound chemicals management into the follow up to the Rio + 20 Conference, but these approaches will take effort and persistence. There are many deserving issues to consider as contributors to global governance and the green economy. Rather than one central chemicals campaign, it may be better to identify significant “points of entry” in the resulting conference agreements and programmes. Certainly, the announcement of a new UN Office of Sustainability focused on research and training provides a promising opportunity for advancing the sound management of chemicals.

8.2 Long Term Goals

It is important to think beyond the Rio + 20 Conference, indeed beyond 2020, and the possible reorganization or conclusion of SAICM. Chemicals, even if soundly managed, will remain a global issue. In a dynamic and ever evolving global economy, it will be important to be vigilant for the possibility of backsliding on firmly ratified international agreements and attentive to emerging issues of concern that can only now be vaguely anticipated. The depletion of oil reserves, the build-up of synthetic chemical residues in every organism on the planet, the prospects of food or water scarcity, new threats to global security, and, even, the achievement of a globally sustainable economy will all have significant implications for chemicals management.

The years ahead will see increased chemical intensification of economies with chemical production and the use of chemical intensive products ever more widely dispersed. International efforts to increase resource productivity and reduce emissions and wastes will improve if for no other reason than the rising costs of energy and materials. However, large volumes of today's chemicals will continue to be produced and used and scientific advances will continue to generate novel chemistries and materials. If sound chemicals management succeeds, the development and use of these chemicals will be managed with respect for human health, ecosystem management and social and economic well-being. However, this may require a larger and more ambitious global framework. Moving from a chemical-by-chemical approach at the national level towards more comprehensive approaches that address all chemicals in terms of social and economic development could be a model for a similar transition at the international level. This suggests re-opening discussion of a new global Sustainable Chemicals Convention, although recent attempts to promote such an initiative have proven to be challenging.

Suggestions have surfaced on the formation of a Chemicals Senior Advisory Group or the creation of an independent United Nations Panel on Chemicals that might parallel the scientific purposes of the International Panel on Climate Change.⁹⁸ Such proposals plus other suggestions for a United Nations Environment Organization provide a lofty vision and might do well to spur coordination and integration of the current diverse bodies. However, big paradigmatic reorganizations alone will not solve the problems of fragmentation and coherency. Such visions must be tied to smaller and more incremental changes that create new efficiencies and effectiveness both as a prelude to and an enabler of major transformations.

The sound management of chemicals is not an end. Achieving the WSSD goal by 2020 is a goal, but it is also a benchmark in a continuing and ever challenging journey. There will surely be more work after 2020. However, building the legal, economic and institutional infrastructure today, particularly in developing countries and countries in economic transition, is a critical determinant not only of meeting the WSSD 2020 goal, but also of managing the mission thereafter.

Endnotes

- ¹ Organisation for Economic Cooperation and Development (2008). *OECD Environmental Outlook to 2030*. Chapter 18: Chemicals. Available from http://www.oecd.org/document/20/0,3746,en_2649_37465_39676628_1_1_1_37465,00.html
- ² United Nations Environment Programme and World Health Organization (2007, March). Strategic Approach to International Chemicals Management. Available from http://www.saicm.org/documents/saicm%20texts/SAICM_publication_ENG.pdf.
- ³ United Nations Environment Programme and World Health Organization (2007, March). Strategic Approach to International Chemicals Management. Available from http://www.saicm.org/documents/saicm%20texts/SAICM_publication_ENG.pdf.
- ⁴ For such policy considerations see Mulhall, D. (2002). *Our Molecular Future: How Nanotechnology, Robotics, Genetics and Artificial Intelligence Will Transform our World*. New York: Prometheus; and Garfield, M.S., & Epstein, G.L. (2007, October). *Synthetic Geonomics: Options for Governance*. J. Craig Venter Institute, Center for Strategic and International Studies and the Massachusetts Institute of Technology. Available from <http://www.jcvi.org/cms/fileadmin/site/research/projects/synthetic-geonomics-report/synthetic-geonomics-report.pdf>.
- ⁵ United Nations Environment Programme (2005). *UNEP's Action to Meet the Challenge of Illegal Trade in Chemicals*. Available from <http://www.uneptie.org/Ozonaction/information/mmcfiles/4488-e-Illegal-Trade.pdf>.
- ⁶ Environmental Investigation Agency (2011). *System Failure: The UK's Harmful Trade in Electronic Waste*. Available from http://ewasteguide.info/files/EIA_2011_UK.pdf.
- ⁷ United Nations Environment Programme, Chemicals Branch (2011). *An Analysis of Economic Instruments in Sound Chemical Management of Chemicals*. Unpublished Draft.
- ⁸ Krarup, S. (2001) Can Voluntary Programs Ever be Efficient? *Journal of Cleaner Production*, 9, 135-144; Brouhe, K., Griffiths, C., and Wolverton, A. (2009). Evaluating the Role of EPA Policy Levers: An Examination of a Voluntary Program and Regulatory Threat in the Metal Finishing Industry. *Journal of Environmental Economics and Management*, 57, 166-181.
- ⁹ International Programme on Chemical Safety. *International Chemical Safety Cards (INCHEM)*. Available from <http://www.inchem.org/pages/icsc.html>.
- ¹⁰ Uganda National Environmental Management Authority (2002, November). *National Profile to Assess the Chemicals Management Infrastructure in Uganda*. Available from http://www2.unitar.org/cwm/publications/cw/np/np_pdf/Uganda_National_Profile.pdf.
- ¹¹ American Chemistry Council. (2007). Responsible Care, Product Stewardship. Available from www.americanchemistry.com/s_responsiblecare; see also www.icca-chem.org/en/Home/ICCA-initiatives/global-product-strategy/.
- ¹² International Council on Minerals and Mining. Available from <http://www.icmm.com/>.
- ¹³ Croplife International, Available from <http://www.croplife.org/>.
- ¹⁴ United Nations Global Compact. Available from <http://www.unglobalcompact.org/>.
- ¹⁵ Principles for Responsible Investment. Available from <http://www.unpri.org/principles/>
- ¹⁶ Global Reporting Initiative. Available from <http://www.globalreporting.org/Home>.
- ¹⁷ World Business Council for Sustainable Development. Available from <http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?type=p&MenuId=MQ&doOpen=1&ClickMenu=LeftMenu>.
- ¹⁸ Freyman, J. (2011). A Rapidly Changing Landscape. *Environmental Health and Safety Today*, 54-60.

- ¹⁹ Global Automotive Declarable Substances List (GADSL). Available from <http://www.mdssystem.com/magnoliaPublic/en/public/list/GADSL.html>.
- ²⁰ American Apparel and Footwear Association. Available from <http://www.apparelandfootwear.org/Resources/restrictedsubstances.asp>
- ²¹ Becker, M. Considered Chemistry at Nike: Creating Safer Products through Evaluation and Restriction of Hazardous Chemicals. Available from www.greenchemistryandcommercecouncil.org.
- ²² BootsUK. Available from http://www.boots-uk.com/Corporate_Social_Responsibility.aspx.
- ²³ Sony. Available from www.sony.net/SonyInfo/csr/environment/chemical/index.html.
- ²⁴ S.C. Johnson Greenlist™. Available from <http://www.scjohnson.com/en/commitment/focus-on/greener-products/greenlist.aspx>.
- ²⁵ GreenWERCS. Available from www.greenwercs.com.
- ²⁶ International Organization for Standardization. Available from <http://www.iso.org/iso/home.htm>
- ²⁷ ASTM International. Standardization News. Toy Safety. Available from <http://www.astm.org/standardization-news/update/toy-safety-jf12.html>; and European Committee for Standardization. Happy Children with Safer Toys. Available from <http://www.cen.eu/cen/News/PressReleases/Pages/HappyChildrenwithSaferToys.aspx>
- ²⁸ Jakl, T., and Schwager, P., (eds.). (2008). *Chemical Leasing Goes Global: Selling Services Instead of Barrels*. New York: Springer Wien; and www.chemicalstrategies.org.
- ²⁹ International Chemical Secretariat. Available from <http://www.chemsec.org/list/sin-database>.
- ³⁰ European Trade Union Confederation - Trade Union Priority List. Available from <http://www.etuc.org/a/6023>.
- ³¹ RISCTOX. Available from <http://www.istas.net/risctox/>.
- ³² Clean Production Action. The GreenScreen™ for Safer chemicals. Available from <http://www.cleanproduction.org/Greenscreen.php>.
- ³³ CleanGredients®. Available from <http://www.cleangredients.org/home>.
- ³⁴ Big Room and World Resources Institute (2010). Global Ecolabel Monitor 2010. Available from <http://www.wri.org/publication/global-ecolabel-monitor>.
- ³⁵ UL Environment. Available from <http://www.ulenvironment.com/ulenvironment/eng/pages/offerings/services/organizational/ule880/>.
- ³⁶ GoodGuide.com. Available from <http://www.goodguide.com/>.
- ³⁷ SAICM. (2009, May 11-15). *Implementation of the Strategic Approach to International Chemicals Management: financial and technical resources for implementation. Regional discussions on financial considerations*. Available from <http://www.saicm.org/documents/iccm/ICCM2/meeting%20documents/ICCM2%20INF14%20finance%20regions.pdf>
- ³⁸ United Nations Development Programme (2010). *Integrating the Sound Management of Chemicals into MDG-Based development Planning*. Available from <http://www.undp.org/chemicals/integrating-chemicals-management-into-development.shtml>.

- ³⁹ United Nations Development Programme (2009, May). *Managing Chemicals for Sustainable Development*. Available from <http://www.beta.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/chemicals-management/managing-chemicals-for-sustainable-development/Managing%20Chemicals%20for%20Sustainable%20Development.pdf>
- ⁴⁰ United Nations Environment Programme (2007). *Elements of Good Practices in Legal Frameworks for the Implementation of the Stockholm Convention on Persistent Organic Pollutants in Latin America*. Prepared by the Center for International Environmental Law. Available from <http://www.chem.unep.ch/Legal/Stockholm%20Good%20Practice%20Final.pdf>.
- ⁴¹ SAICM Secretariat. Open Ended Working Group of the International Conference on Chemicals Management (2011). *Draft Baseline Estimate Report (2006-2008): Progress in Implementing the Strategic Approach to International Chemicals Management*. Available from http://www.saicm.org/documents/OEWG/Meeting%20documents/OEWG1%20INF1_Baseline%20report.pdf; and SAICM Secretariat. Open Ended Working Group of the International Conference on Chemicals Management. (2011). *First Progress Report on Implementation of Progress in Implementation of the Strategic Approach to International Chemicals Management*. Available from http://www.saicm.org/documents/OEWG/Meeting%20documents/OEWG1%20INF%202020_first%20progress%20report-final.pdf.
- ⁴² UNEP Chemicals Branch (2011). *Guidance on the Development of Legal and Institutional Infrastructures and Measures for Recovering Costs of National Administration*. Available from [http://www.chem.unep.ch/unepaicm/mainstreaming/Documents/GCO_SteerComm4/LIRA%20Guidance_March%202011%20\(Final\).pdf](http://www.chem.unep.ch/unepaicm/mainstreaming/Documents/GCO_SteerComm4/LIRA%20Guidance_March%202011%20(Final).pdf)
- ⁴³ UNITAR (2007, April). *Developing a Capacity Assessment for the Sound Management of Chemicals and National SAICM Implementation*. Available from http://www.who.int/iomc/saicm/capacity_assessment_en.pdf.
- ⁴⁴ United Nations Development Programme (2010). *Integrating the Sound Management of Chemicals in MDG-Based Development Planning*. Available from http://www.beta.undp.org/undp/en/home/librarypage/environment-energy/chemicals_management/integrating-sound-management-of-chemicals-into-mdg-based-development-planning.htm.
- ⁴⁵ KEMI - Swedish Chemicals Agency (2010). *Capacity Building for the Sound Management of Chemicals: Organization, Responsibilities and Tasks of Governmental Institutions and Enterprises*. Available from http://www.kemi.se/upload/Trycksaker/Pdf/PM/PM1_10.pdf.
- ⁴⁶ United Nations Environment Programme (2007). *Elements of Good Practices in Legal Frameworks for the Implementation of the Stockholm Convention on Persistent Organic Pollutants in Latin America*. Prepared by the Center for International Environmental Law. Available from <http://www.chem.unep.ch/Legal/Stockholm%20Good%20Practice%20Final.pdf>.
- ⁴⁷ KEMI - Swedish Chemicals Agency (2010). *Capacity Building for the Sound Management of Chemicals: Organization, Responsibilities and Tasks of Governmental Institutions and Enterprises*. Available from http://www.kemi.se/upload/Trycksaker/Pdf/PM/PM1_10.pdf.
- ⁴⁸ Lowell Center for Sustainable Production. (2009). *State Leadership in Formulating and Reforming Chemicals Policy*. Available from <http://www.chemicalspolicy.org/downloads/StateLeadership.pdf>.
- ⁴⁹ World Health Organization (2009). *WHO Classification of Pesticides by Hazard*. Available from http://www.who.int/ipcs/publications/pesticides_hazard_2009.pdf.
- ⁵⁰ Swedish Chemicals Agency. *Prio: A Tool for Risk Reduction of Chemicals*. Available from http://www.kemi.se/templates/PRIEngframes___4144.aspx; Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung. *The Column Model: An Aid to Substitute Assessment*. Available from <http://www.dguv.de/ifa/en/pra/spalte/spaltmod.pdf>.
- ⁵¹ United Nations Economic and Social Council. Economic Commission for Africa (2009). *Africa Review Report on Chemicals (Summary)*. Available from http://www.un.org/esa/dsd/csd/csd_pdfs/csd-18/rims/AfricanReviewReport-on-ChemicalsSummary.pdf.

- ⁵² United Nations Environment Programme. Chemical Information Exchange Network. Available from <http://www.estis.net/communities/cien/>.
- ⁵³ Organisation for Economic Cooperation and Development (OECD). *OECD Survey on the Implementation of ECE Recommendation*. C (96)41/Final on PRTR.
- ⁵⁴ UNITAR. *Pollutant Release and Transfer Registries*. Available from <http://www.unitar.org/cwm/prtr#pops-prtr>.
- ⁵⁵ United Nations Environment Programme (2007). *Elements of Good Practices in Legal Frameworks for the Implementation of the Stockholm Convention on Persistent Organic Pollutants in Latin America*. Prepared by the Center for International Environmental Law. Available from <http://www.chem.unep.ch/Legal/Stockholm%20Good%20Practice%20Final.pdf>.
- ⁵⁶ UNEP/UNDP/DUTCH Joint Project on Environmental Law and Institutions in Africa (1999). *Report on the Development and Harmonization of Laws on Toxic and Hazardous Substances*. Available from [http://www.unep.org/padelia/publications/Prelims_\(Vol_4\).pdf](http://www.unep.org/padelia/publications/Prelims_(Vol_4).pdf).
- ⁵⁷ United Nations Industrial Development Organization and United Nations Environment Programme (2010). *Taking Stock and Moving Forward: The UNIDO-UNEP National Cleaner Production Centers*. Available from http://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Contacts/Contacts/Taking%20stock%20and%20moving%20forward-November2010.pdf.
- ⁵⁸ For a fundamental text on green chemistry see Anastas, P., and Warner, J. (1998). *Green Chemistry: Theory and Practice*. New York: Oxford University Press.
- ⁵⁹ Kenmore, P.E. (2002). Integrated Pest Management. *International Journal of Occupational and Environmental Health*, 8, 173-174.
- ⁶⁰ Inter-Organization Programme for the Sound Management of Chemicals (2011). *IOMC Strategy for Strengthening National Chemicals Management Capacity*. Available from http://www.who.int/iomc/publications/strategy_english.pdf.
- ⁶¹ Carvalho, S.M., Conway, T., Madsen, K., and Quiblier, P. (2009, May). The UNEP/UNDP Partnership Initiative for the Integration of Sound Management of Chemicals into Development Planning Processes: Maximizing Return on Investment. Available from <http://www.chem.unep.ch/unepsaicm/mainstreaming/SupportingDocuments.htm>.
- ⁶² United Nations Environment Programme and World Health Organization (2008). *Libreville Declaration on Health and Environment in Africa*. Available from http://www.unep.org/roa/hesa/Portals/66/HESA/Docs/SANA_docs/decLibrevilleDeclaration.pdf.
- ⁶³ United Nations Environment Programme (2004). *Bali Strategic Plan for Technology Support and Capacity building*. Available from <http://www.unep.org/GC/GC23/documents/GC23-6-add-1.pdf>. A.
- ⁶⁴ United Nations Environment Programme (2011). *Enhancing the Role of Industry in Financing Chemicals and Wastes*. Fourth Meeting of the Consultative Process on Financing Options for Chemicals and Wastes, New York. Available from <http://www.unep.org/dec/docs/industryRoleOfIndclean.pdf>.
- ⁶⁵ SAICM. (2006). International Conference on Chemicals Management. Draft Overarching Policy Strategy, paragraph 19. Available from http://www.chem.unep.ch/ICCM/meeting_docs/iccm1_3/3%20OPS%20E.pdf.
- ⁶⁶ United Nations Environment Programme (2011). *An Analysis of Economic Instruments in the Sound Management of Chemicals*, Unpublished Draft.
- ⁶⁷ Andersson, I. (2009, October). Swedish Chemicals Agency, personal communication.

- ⁶⁸ Massey, R. (2005, September). Building a Healthy Economy: Chemicals Risk Management as a Driver of Development. Swedish Chemicals Inspectorate [KemI] Report No. 2/0. Available from http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Rapport2_05.pdf.
- ⁶⁹ United Nations Environment Programme (2011). *Enhancing the Role of Industry in Financing Chemicals and Wastes*, Fourth Meeting of the Consultative Process on Financing Options for Chemicals and Wastes. Available from <http://www.unep.org/dec/docs/industryRoleOfIndclean.pdf>.
- ⁷⁰ United Nations Environment Programme. *Proceedings of the Governing Council/Global Ministerial Environment Forum at its Twenty-Sixth Session*. Pg. 31. Available from http://www.unep.org/gc/gc26/docs/Proceedings/K1170817_E-GC26-19_Proceedings.pdf.
- ⁷¹ Halpaap, A. (2011). International Chemical Management within Global Environmental Governance Context. In Wexler, P., van der Kolk, J., Mohapatra, A. and Agarwal, R., eds. *Chemicals, Environment, Health: A Global Management Perspective*. (pp. 301-310). New York: CRC Press.
- ⁷² The International Labour Organization adopted a convention on the use of white lead in paints in 1921. For the long history see Buccini, J. (2004, February). The Global Pursuit of the Sound Management of Chemicals. Available from <http://siteresources.worldbank.org/INTPOPS/Publications/20486416/GlobalPursuitOfSoundManagementOfChemicals2004Pages1To67.pdf>.
- ⁷³ United Nations Economic and Social Council, Economic Commission for Africa (2009, October). *Africa Review Report on Chemicals*. Available from <http://www.uneca.org/csd/csd6/AfricanReviewReport-on-ChemicalsMainReport.pdf>.
- ⁷⁴ Carvalho, S.M., Conway, T., Madsen, K., and Quiblier, P. (May 2009). The UNEP/UNDP Partnership Initiative for the Integration of Sound Management of Chemicals into Development Planning Processes: Maximizing Return on Investment. Available from <http://www.chem.unep.ch/unepsaicm/mainstreaming/SupportingDocuments.htm>.
- ⁷⁵ United Nations Environment Programme (2010). *South-South Cooperation in Achieving Sustainable Development*. Available from www.unep.org.
- ⁷⁶ World Bank. *Linking Sound Chemical Management to the Development Agenda*. Available from <http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTPOPS/0,,contentMDK:21348048~pagePK:210058~piPK:210062~theSitePK:408121,00.html>.
- ⁷⁷ United Nations Environment Programme. Division of Law and Conventions. Available from <http://www.unep.org/dec/docs/Annex4.pdf>.
- ⁷⁸ United Nations Environment Programme. Division of Law and Conventions. Available from <http://www.unep.org/dec/docs/Annex5.pdf>.
- ⁷⁹ United Nations Environment Programme (2011). *Outcome Document on the Consultative Process on Financing Options for Chemicals and Wastes*. Available from <http://www.unep.org/dec/docs/ConsultativeProcessOutcomeDocumentbangkokmeeting.pdf>.
- ⁸⁰ United Nations Environment Programme (2006). *Symposium on Illegal International Traffic in Hazardous Chemicals. Prague, Czech Republic -Draft Report*. Available from http://www.chem.unep.ch/unepsaicm/prague_nov06/meeting_docs/Symposium-report%20final.pdf.
- ⁸¹ Green Customs Initiative. Available from <http://www.greencustoms.org>.
- ⁸² United Nations Environment Programme (2005). *UNEP's Action to Meet the Challenge of Illegal Trade in Chemicals*. Available from <http://www.uneptie.org/Ozonaction/information/mmcfiles/4488-e-Illegal-Trade.pdf>.

- ⁸³ United Nations Environment Programme (2008). *Progress report on the Implementation of Governing Council Decision 24/4 on the Prevention of Illegal International Trade*. Available from http://www.unep.org/civil_society/GCSF9/pdfs/progress-report-Illegal-traffic-for-CPR.pdf.
- ⁸⁴ INECE Seaport Environment Security Network (2010). *International Hazardous Waste Inspection Project at Seaports: Results and Recommendations*. Available from http://www.inece.org/seaport/exercise/INECE_SeaportInspectionProjectOutcomes_22dec.pdf.
- ⁸⁵ Environmental Investigation Agency (2011). *System Failure: The UK's Harmful Trade in Electronic Waste*. Available from http://ewasteguide.info/files/EIA_2011_UK.pdf.
- ⁸⁶ Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. Available from <http://basel.int/legalmatters/illegaltraffic/index.html>.
- ⁸⁷ United Nations Environment Programme (2002). *OEWG Study of Monitoring the International Trade in Ozone Depleting Substances, Mixtures and Products Containing Ozone-depleting Substances*. Available from http://ozone.unep.org/Meeting_Documents/oewg/22oewg/22oewg-4.e.pdf.
- ⁸⁸ SAICM (2011). *Fourth African Regional Meeting on the Strategic Approach to International Chemicals Management. Update on the Secretariat Work on Illegal Traffic*. Available from <http://www.saicm.org/documents/meeting/afreg/Nairobi%202011/Meeting%20documents/Afr%204%20INF9%20Illegal%20traffic%20updates.pdf>.
- ⁸⁹ United Nations Environment Programme (2005). *UNEP's Action to Meet the Challenge of Illegal Trade in Chemicals*. Available from <http://www.uneptie.org/Ozonaction/information/mmcfiles/4488-e-Illegal-Trade.pdf>.
- ⁹⁰ Swedish Chemicals Agency, KemI (2011). *Kemikalier i Varor: Strategier och Styrmedel for att Minska Riserna med Farfiga amnen i Vardagen*, Report Nr 311.
- ⁹¹ SAICM, *Quick Start Projects, Approved Projects*, see. www.saicm.org/documents/_menu_items/QSP%trust%20fund%20approved%20projects%Dec%2009.pdf.
- ⁹² United Nations Commission on Sustainable Development. Available from <http://www.uncsd2012.org/>.
- ⁹³ UNEP. 2011. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. Available from www.unep.org/greeneconomy.
- ⁹⁴ United Nations (2011). *World Economic and Social Survey -The Great Green Technological Transformation*. Available from http://www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf/.
- ⁹⁵ United Nations Environment Programme (2011). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. Available from www.unep.org/greeneconomy.
- ⁹⁶ United Nations (2011). *World Economic and Social Survey -The Great Green Technological Transformation*. Available from http://www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf/.
- ⁹⁷ United Nations Environment Programme (2011). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. Available from www.unep.org/greeneconomy.
- ⁹⁸ Wallstrom Opens ECHA's Conference Center and Calls for a UN Chemicals Panel. (April 6, 2009). News Release. European Chemicals Agency. ECHA/PR/09/04. Available from www.echa.europa.eu/doc/press/pr_09_04_inauuration_conf_centre_20090406.pdf.

APPENDIX

Progress among Developing Countries in Meeting the SAICM Objectives, 2010			
	Indicator	Dimensions	Number of Developing Countries
Risk reduction	1. Number of countries (and organizations) implementing agreed chemicals management tools	Use of guidance tools and materials published by participating organizations of the IOMC	<p><i>At least one:</i> 36</p> <p><i>Top three:</i> 26 FAO Code of Conduct 25 WHO drinking water 21 WHO pesticides classification</p>
		New tools or guidance materials published to implement risk reduction in selected subject area	<p><i>At least one:</i> 28</p> <p><i>Top three:</i> 18 Chemicals pollution and waste 16 Obsolete chemicals 14 Chemicals in use; Management of pesticides' risks</p>
	2. Number of countries (and organizations) with mechanisms to address key categories of chemicals	Categories of chemicals prioritized for risk management	<p><i>At least one:</i> 38</p> <p><i>Top three:</i> 35 Pesticides 30 POPs 29 Mercury or mercury containing sources</p>
	3. Number of countries (and organizations) with hazardous waste management arrangements	Parts of waste management cycle covered by legislation	<p><i>At least one:</i> 35</p> <p><i>Top three:</i> 30 Collection and interim storage 29 Prevention/ reduction in generation 29 Disposal of hazardous waste</p>
		Waste streams addressed through legislation or permits	<p><i>At least one:</i> 36</p> <p><i>Top three:</i> 28 Biomedical & healthcare waste 25 Lead-acid batteries 23 Pesticides contaminated wastes</p>
	4. Number of countries (and organizations) engaged in activities that result in monitoring data on selected environmental and human health priority substances	Types of monitoring covered by established arrangements	<p><i>At least one:</i> 39</p> <p><i>Top three:</i> 30 Environmental monitoring 22 Human poisoning 18 Chemical incidents</p>
	5. Number of countries (and organizations) having mechanisms in place for setting priorities for risk reduction	Types of exposures taken into account through a science-based assessment before chemicals are placed on the market	<p><i>At least one:</i> 36</p> <p><i>Top three:</i> 32 Pesticides 18 Food additives; Environmental risks; Consumer or public health risks 17 Biocides</p>

Knowledge and information		Scientific committee, body or institutes involved in setting priorities for risk reduction before chemicals are placed on the market	Yes: 22 <i>In development:</i> 2
		Programmes for management of priority risks	<i>At least one:</i> 22 <i>Top three:</i> 25 Pesticides 21 Air pollutants 18 Drinking water
	6. Number of countries (and organizations) providing information according to internationally harmonized standards	Standards and requirements for labeling hazards and risks at different stages in a chemical's lifecycle	<i>At least one:</i> 34 <i>Top three:</i> 26 Transport 24 Occupational use 22 Production
		Conformity with the Globally Harmonized System for the Classification and Labeling of Chemicals - the GHS	<i>At least one:</i> 20 <i>Top three:</i> 13 Pesticides; Industrial chemicals 11 Dangerous goods 9 OHS/ workplace use
	7. Number of countries (and organizations) that have specific strategies in place for communicating information on the risks associated with chemicals to vulnerable groups	Activities to communicate chemical safety issues to vulnerable groups	<i>At least one:</i> 31 <i>Top three:</i> 19 The general public 17 Women; Children; Highly exposed groups 6 The elderly; Workers not speaking official national languages; Others
	8. Number of countries (and organizations) with research programmes	Commissioned or funded research during 2009-2010 on chemical safety	<i>At least one:</i> 27 <i>Top three:</i> 18 Cleaner production technologies 15 Human health effects or exposure 14 Environmental effects or exposure
9. Number of countries (and organizations) with websites that provide information to stakeholders	Publicly available information on selected topics	<i>At least one:</i> 33 <i>Top three:</i> 18 Safety laws 13 Chemicals in use; hazards and risks 11 Pollution release	
10. Number of countries (and organizations) that have committed themselves to implementation of the Strategic Approach	Demonstrated expressions of commitment	<i>At least one:</i> 39 <i>Top three:</i> 26 Establishment of a SAICM coordination committee 19 Ministerial statements; new SAICM focal point 18 Inclusion of progress information in annual report	

Governance	11. Number of countries (and organizations) with multi-stakeholder coordinating mechanism	Composition of committee	<p><i>At least one:</i> 40</p> <p><i>Top three:</i> 33 Environment 32 Agriculture; Health 28 Customs authorities; Industry</p>
		Participation of NGOs in national committee or advisory group	<p><i>At least one:</i> 31</p>
	12. Number of countries (and organizations) with mechanisms to implement key international chemicals priorities	Instruments of the ILO	<p><i>At least one:</i> 22</p> <p><i>Top three:</i> 15 ILO 170 12 ILO 148 11 ILO 162; ILO 174</p>
		Instruments of the IMO	<p><i>At least one:</i> 25</p> <p><i>Top three:</i> 18 Prevention of pollution from Ships; Oil pollution preparedness, response & cooperation 7 Preparedness, Response and Cooperation to Pollution Incidents by Hazardous and Noxious Substances; Control of harmful anti-fouling systems on ships 5 Others</p>
		Instruments of UNEP	<p><i>At least one:</i> 40</p> <p><i>Top three:</i> 38 Stockholm Convention; Montreal Protocol 35 Basel Convention 14 Other UNEP Conventions</p>
		Rotterdam Convention	<p><i>Yes:</i> 31</p> <p><i>In development:</i> 4</p>
		Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and their Destruction	<p><i>Yes:</i> 23</p> <p><i>In development:</i> 2</p>
		International Health Regulations	<p><i>Yes:</i> 20</p> <p><i>In development:</i> 5</p>
		Instruments of the UNECE	<p><i>At least one:</i> 12</p> <p><i>Top three:</i> 9 Aarhus Convention 6 PRTR Protocol; LRTAP 2 Others</p>

Capacity-building and technical cooperation	13. Number of countries (and organizations) providing resources (financial and in kind) to assist capacity-building and technical cooperation with other countries	Financial resources	2	
		In-kind resources	3	
	14. Number of countries (and organizations) that have identified and prioritized their capacitybuilding needs for the sound management of chemicals	Types of plans completed or updated in 2009 or 2010	At least one:	30
			Top three:	23 National Chemicals Profile 18 NIP Stockholm 13 SAICM implementation plan
	15. Number of countries (and organizations) engaged in regional cooperation on issues relating to the sound management of chemicals	Regional cooperation agreements	At least one:	23
			Top three:	15 Knowledge and information 11 Governance; Capacity-building and technical cooperation 10 Risk reduction
16. Number of countries where development assistance programs include the sound management of chemicals	National development plans for 2009 and 2011 that address priority needs for chemicals		18	
17. Number of countries (and organizations) with projects supported by the Strategic Approach's Quick Start Programme Trust Fund			40	
Illegal international traffic	19. Number of countries having mechanisms to prevent illegal traffic in toxic, hazardous and severely restricted chemicals individually	Activities in place in 2009 and 2010	At least one: 32 Top three: 23 Communication 21 Legislation; Training border agents 10 Public awareness; Monitoring of trade	
		Measures taken for specific individual hazardous substances	Yes: 18 In development: 4	
	20. Number of countries having mechanisms to prevent illegal traffic in hazardous waste	Activities in place in 2009 and 2010	At least one: 31 Top three: 24 Implementation of national legislation preventing illegal traffic of hazardous waste 19 Communication of information on movements of hazardous waste out of the country to neighboring countries 15 Specific training of border control agents	

Source: Table prepared by Armand Racine, UNEP Chemicals, based on SAICM, *First progress report on implementation of progress in implementation of the Strategic Approach: Results of preliminary data collection for 2009 and 2010*, SAICM/OEWG.1/INF/2, November 2011 ; and SAICM (November 2011), *First progress report on implementation of progress in implementation of the Strategic Approach: Detailed results for the data collection for 2009 and 2010*, SAICM/OEWG.1/INF/2/Add1, November, 2011.

Global Chemicals Outlook

Conclusion Recommendations

CONCLUSION

Achieving the Johannesburg Plan of Implementation goal that, by 2020, chemicals will be produced and used in ways that minimize significant adverse impacts on the environment and human health will require a more concerted effort by international agencies, national and local governments, business and civil society organizations. Corporations will need to assume more responsibility for safe chemical production and sound management all along the value chain. Governments will need to adopt and more effectively implement instruments and approaches, define responsibilities and improve administrative and strategic coordination. This also requires providing developing countries and countries with economies in transition with technical assistance, technology transfer, institutional capacity building and training on the new methods and tools that are being used today by developed countries, private sector and civil society.

The absence of effective chemical management by governments, corporations and international bodies leads to market uncertainties in developing countries and countries with economies in transition. It inhibits risk aware financial institutions in the investment and banking sectors from making investment that support strong economic development. Additional financing for chemical management may come from economic instruments for cost integration and recovery within countries. Such funding has to be triggered and complemented by international financing from national and international development assistance programmes. To be effective and sufficiently funded and sustainably maintained, sound chemicals management must be comprehensively mainstreamed into national, social and economic planning and be coordinated internationally.

Sound chemicals management is a vital element that underpins each aspect of a Green Economy and should be integrated not only by investments in natural capital in the realm of agriculture, fisheries, forest and water, but also in the investment in energy and resource efficiency, manufacturing, waste management, building and urban design, tourism and transportation. Sound chemicals management must become a national and international environmental, public health and economic and business development priority.

RECOMMENDATIONS

The following recommendations are made with a view to raise the awareness and attention of policy-makers and key stakeholders in order to strengthen the implementation of SAICM and of the chemicals related conventions and accelerate the achievement of the Johannesburg Plan of Implementation goal that, by 2020, chemicals will be produced and used in ways that minimize significant adverse impacts on the environment and human health.

Two sets of recommendations emanate from the key findings and conclusions of the report. The first set provides general recommendations on institutional, economic and development policy related issues. The second set focuses on more specific, technical and managerial types of recommendations to address the main challenges raised in this report related to trends and indicators, economic implications and instruments and approaches.



General recommendations

1. Develop and implement comprehensive, multi-stakeholder and prevention-oriented chemical management strategies tailored to the economic and development needs of the developing countries and countries with economies in transition.
2. Mainstream sound chemicals management into national public health, labour, social and economic development programmes.
3. Regulate and reduce the use of chemicals of highest concern and substitute with safer alternatives.
4. Integrate and coordinate regional, international and intergovernmental chemical management programmes to promote synergies and increase effectiveness.
5. Develop and implement national, regional and international approaches to financing adequate capacity and resources to support sound chemicals management.

Specific recommendations on responses to address identified challenges include:

Trends and indicators

1. Develop coherent approaches for monitoring of chemical exposures and environmental and health effects that allow spatial assessments and establishment of time trends.
2. Include as baseline information on chemicals not only data on chemical exposure and health and environment effects but also on chemicals throughout their lifecycle.
3. Develop and strengthen global, regional and national integrated health and environment monitoring and surveillance system for chemicals to make timely and evidence-based decisions for effective information management of environmental risks to human health.

Economic implications

4. Further analyse the economic cost of chemical effects.
5. Increase the capacities of health and environment agencies to use economic analysis in the development of sound chemicals management policies.
6. Integrate sound chemicals management in social and economic development processes through greater use of decision-making economic tools and methodologies.

Instruments and approaches

a) National and regional level

7. Build capacity at national level for mainstreaming sound chemicals management into national development plans and processes.
8. Adopt and implement legal instruments that define the responsibilities of the public and private sector for chemical control and improve administrative coordination for compliance and enforcement.
9. Adopt a full policy chain of instruments and approaches that stretch across the lifecycle from the entry of chemicals onto the market to the management of chemicals at their disposal.
10. Use regional approaches to increase the efficient use of resources for risk assessment and management of chemicals and to prevent illegal trafficking.
11. Strengthen national capacity to facilitate the appropriate use of economic instruments to internalize the cost of chemical management and create financial incentives to improve chemical management strategies and promote safer alternatives.
12. Strengthen or develop a single national coordinating chemical management entity.

b) Corporate level and civil society

13. Foster the incorporation of sound management of chemicals in corporate policies and practices.
14. Involve small and medium-sized enterprises (SMEs) in the sound management of chemicals and encourage industry to cooperate with governments to fairly share the responsibility and costs for social and economic development.
15. Industry should generate and make public an appropriate baseline set of health and environmental effects for chemicals in commerce.
16. Further develop and improve chemical management programmes throughout the value chain including communication about chemical hazards and risks, both for chemicals as such and chemicals in articles.
17. Encourage industry to provide the public with all health and safety information and all but the most business sensitive chemical information to effectively reduce the related risks.

18. The financial sector should evaluate more thoroughly the chemical risks inherent in the activities and corporations which it finances, and work with other stakeholders to reduce them.
19. Encourage civil society organizations to participate in government policymaking and to develop activities to access, assess and widely communicate chemical information on chemical safety to the public.
20. Civil society organizations should participate actively and meaningfully in decision-making processes on chemical safety at all levels.
21. Civil society organizations should actively participate in the implementation, and monitoring, of chemicals and wastes regulatory policies including national, regional, and global agreements and facilitate their enforcement.

c) International level

22. Further promote synergies among Multilateral Environmental Agreements (MEAs) in terms of administrative, logistical and programmes integration.
23. Strengthen international and national chemical control activities including legislation to address gaps in current chemicals related MEAs.
24. Mainstream sound chemicals management into multilateral and bilateral economic assistance programmes.
25. Facilitate the assessment of the efficacy and value of corporate and civil society organizations' methods and tools, compare them in terms of potential goals and identify strategies where some or a combination of these might be most effective.
26. Foster public private partnerships to promote the implementation of sound chemical management policies and strategies as a contribution to economic development plans and processes.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

- > sustainable consumption and production,
- > the efficient use of renewable energy,
- > adequate management of chemicals,
- > the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

- > The International Environmental Technology Centre - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- > Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- > Chemicals (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- > Energy (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- > OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- > Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

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