

Brief for GSDR 2015

Environmental Solutions via Buoyant Flake Fertilization

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An opportunity exists to combine three sustainable or waste materials, and to deploy the resulting product in such a way that it: increases sustainable fish stocks; reduces surface ocean acidity; sequesters carbon; and cools the globe profitably, effectively, quickly, and by means closely matching how Nature has done this safely for millennia.

Introduction

Sustainable Development can come from solutions that replace fossil fuel consumption with sustainable resources, or from solutions that address environmental threats. Some solutions do both. One such prospective solution combines natural and waste materials to form ultra-slow release, buoyant flakes that provide the essential nutrients necessary to make the nutrient-deficient half of ocean surface waters productive. In food production terms, this is nearly the equivalent of having another Earth, such is the productivity of nutrient-rich waters. At the same time, the flakes deliver four other key benefits: the dark blue of the less-productive high seas is replaced with the milky-green hue of productive seas, thereby cooling the world by reflecting more solar energy back into space; chemicals released by the additional microscopic phytoplankton contribute to marine cloud brightening, thereby also increasing global albedo (reflectiveness) fairly evenly and hence reducing diverse regional effects; the additional photosynthetic phytoplankton offset ocean acidification by converting the carbon dioxide dissolved in the ocean surface waters (carbonic acid) into neutral biomass and oxygen; and part of this biomass sequesters carbon in the cold ocean depths and sediments when it sinks, leaving the surface waters able to take up more atmospheric carbon dioxide.

Scientific debate

Several international studies (Boyd et al. 2012, Lampitt et al. 2008, Williamson et al. 2012, Mills et al. 2004) have shown that fertilising ocean areas deficient in iron, silica or phosphate can produce additional phytoplankton in similar fashion to what dust storms and volcanic ash blown out to sea have been doing safely and effectively for millennia. Experiments show that the ocean surface lightens for several weeks after such fertilization. Some experiments demonstrated that the carbon flux to the deep sea was increased. However, it has since been ascertained that none of these experiments were monitored for a sufficient duration to measure the full flux effect. Nor do they appear to allow for the effects of mobile marine species evading their sediment traps. Other such experiments have recorded an increase in the cloud-nucleating chemical, dimethyl sulphide, (DMS), that results from the degradation of a chemical that plankton emit.

The probable effects resulting from one rogue experiment indicated that salmon stocks were massively increased in the two years following ocean fertilization. However, all these experiments utilised a deficient and unsustainable method: the minerals used were fossil fuel-intensive. Moreover, they were non-buoyant and hence disappeared from the productive surface waters within a few weeks, thereby losing probably well over 90% of their nutritive value. Worse still, the human-initiated experiments used fast-release minerals that caused unbalanced ecologies to develop and tended to cause a harmful boom-bust cycle, eutrophication and possibly the development of toxic species able to survive in low-oxygen conditions. All these bad effects are avoidable with the use of durable, low-cost buoyant flakes made from rice husks coated in ultra-slow-release mineral nutrients that are adhered to the silica-rich husks by sustainable

lignin glue made from plants. The nutrient minerals will typically be a mix of already finely-ground, iron-rich red mud tailings from alumina refining or plentiful laterites, from phosphatic clay wastes, and other low-grade sources of the nutrients that are selected to remedy the deficiencies of a particular ocean region. The lignin 'hot-melt glue' dust can be made from straw or woodchips from which the cellulosic sugars have been gently extracted for other purposes.

The tiny flakes are designed to last for approximately a year on the ocean surface before disintegrating, whereupon their residual lignocellulosic and mineral content sinks to the seabed. Within a few weeks of being broadcast pneumatically from a ship, the flakes become colonised as ideal habitat by phytoplankton and their tiny predators. The phytoplankton have special means, acquisitive ligand functional groups in their cell walls, by which to extract even notionally-insoluble nutrients from the coating minerals and husks. These ligands prevent most of the valuable nutrients from being wasted. They also mean that excessive concentrations of dissolved nutrients are not present to harm coral reefs or seagrass meadows, should the flakes ever be carried that far from the high sea sites of their typical dissemination. Buoyant, nitrogen-fixing blue-green algae (cyanobacteria), facilitated by the presence of iron in the flakes, somewhat make up for the absence of nitrogenous fertiliser that is otherwise traditionally derived using fossil fuels.

Some maintain that ocean fertilization will cause hypoxic (low oxygen) conditions in the deep sea that are friendly only to a minority of life-forms. This may well be the case in some areas. However, hypoxic conditions also help to keep biomass locked in stable forms, thereby assisting in the long-term biosequestration of carbon. The trade-off seems fair.

In cryogenic or polar regions, yet another benefit may be provided by buoyant flakes, this time using a different fertiliser mix. Polar regions,

especially those with methane clathrates (slurpies of methane and ice) lying on and within the ocean sediments and frozen tundra, are beginning to emit methane at presently dangerous and increasingly catastrophic rates because of global warming. Now, methanotrophs (methane eating microorganisms) can convert methane into biomass. However, to do this they require special enzymes. These enzymes are formed around transition metal atoms of tungsten or molybdenum, and are complemented by copper, nickel, iron and cobalt (Light et al. 2014), all of which are virtually absent from most polar water columns. These necessary metals can be provided from low-grade minerals coated onto buoyant flakes disseminated over the water or permafrost surface. As the nutrients from these are slowly released, they permeate the water column, methane vents and sediments. The nutrients are then available to make more methanotrophs and thus comprise a biological control mechanism that transforms methane into biomass. This biomass is reformed up the food chain until we might harvest much of it for a hungry world. Note, that it is only the hazardous, emitted gaseous methane and the dissolved methane that are so transformed, the benign, frozen clathrate methane is unaffected.

Triple bottom line aspects

As may be seen from the attachments at <https://groups.google.com/forum/#!msg/geoengineering/FUC2yTLyszE/6S8fW5MnAm8J>, buoyant flake dissemination is likely to be favourable to both humanity and the environment. Flakes might be produced and disseminated for as little as USD\$84 /tonne. Whilst they would notionally sequester carbon for as little as \$1.08/tonne C, a conservative estimate might lie within an order of magnitude around \$10/tonne C. Similarly, and allowing 80% for losses, a tonne of iron in buoyant flake fertiliser should produce some 6,000 tonnes of dry-weight fish catch for us. Now, providing that international law (Wilson 2014, Abate & Greenlee 2010) is created so that reasonable revenue streams are available to agencies that facilitate the additional food production and/or carbon sequestration, the

costs of flake production, dissemination and monitoring would probably be borne willingly by industry for profit. Policy-making action and funds are required only to provide the initial risk-reducing R&D, to establish the governance arrangements and social licence.

Issues for further consideration

Whilst the concept is founded upon scientific principles, individual aspects require validation. These include:

- Earth Systems modelling to establish the likely effects
- Determination of the optimal flake buoyancy recipe
- Refinement of the tailored mineral mixes
- Mesocosm trials
- Governance

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