Brief for GSDR – 2016 Update

Emerging Contaminants in urban stormwater: challenges and perspectives for sustainable water use

Erick R. Bandala[1] and Ashantha Goonetilleke[2*]

[1]Division of Hydrologic Sciences. Desert Research Institute (DRI), USA, [2]Queensland University of Technology (QUT), Australia

Introduction

Emerging contaminants (ECs) are chemical compounds commonly present in water. It is only recently that this family of compounds is being recognized as significant water pollutants (Czech and Ribinowska, 2013). ECs include a wide variety of chemicals such as pharmaceutical and personal care products (PPCPs), pesticides, hydrocarbons and hormones, among others, that once released into the environment exert adverse impacts on the human and wildlife endocrine system (Rosen et al., 2010). As result, many of them are now included within the Endocrine Disrupting Chemicals (EDCs) group. Natural attenuation and conventional treatment processes are not capable of removing these micro-pollutants detected in wastewater influent and effluent and surface and drinking water (Bustos et al., 2015; Rosen et al., 2010).

Stormwater has gained significant interest as a potential source of water for urban areas which lack adequate resources. Furthermore, with increasing detrimental impacts of climate change leading to changes to rainfall patterns and compounded by limited opportunities for further expansion of conventional water sources, stormwater has emerged as a reliable alternative to enhance urban water supply (Page et al., 2014).

Stormwater runoff is the main supply source to urban water bodies (Pal et al., 2014; Rosen et al., 2010) and the presence of pollutants suggest low quality in the waterway and poor viability for reuse (Leiker et al., 2009). Consequently, successful stormwater harvesting should not only be related to the catchment characteristics, but also the appropriate treatment and storage is essential in order to reduce demand on conventional sources during extended dry periods. Though in-depth scientific investigations have been undertaken in relation to stormwater pollutants such as nutrients, hydrocarbons and heavy metals, only a very limited number of systematic studies have reported in the past on the presence of ECs in stormwater and even fewer studies are promoted/encouraged by local water authorities. Furthermore, the proper treatment to this potential water source is an ongoing challenge in the context of its sustainable use in urban areas in the medium to long term.

It is imperative that before climate change-related impacts force communities to reuse stormwater without adequate safeguards, scientifically robust policies and good practices are developed and implemented to mitigate potential human and ecosystem health risk. Inability to appropriately manage the presence of ECs in stormwater entail the risk of squandering the opportunity to gainfully using the last standing available water resource in many urban areas.

Challenges posed by the presence of ECs in stormwater

The main challenges related with presence of ECs in stormwater in the context of reuse

are: a) Development of suitable laboratory test methodologies and protocols for ECs identification and quantification b) Identification of the sources of ECs in the urban environment; c) Understanding their impacts on human and/or ecosystem health; and d). Development of cost-effective removal technologies which are appropriate for large as well as small-scale application. All of the above challenges are of broad research interest to the scientific community.

Perspectives for sustainable development

Mitigation of the negative impacts of anthropogenic activities in the environment fall into two main categories. One category focuses on designing and implementing cleaner industrial processes to decrease or eliminate waste generation. The second includes site restoration using novel state-of-the-art technologies to remove waste's impact (Bandala and Raichle, 2013). Many technological approaches for improving water, air and soil quality have been developed over the last few decades. With an increasing emphasis placed on sustainability, technological solutions are evaluated not only for their cost-effectiveness, but also by their ability to withdraw pollutants from the environment without generating by-products and, preferably, by their use of renewable sources of energy.

ECs importantly affect conventional water treatment processes. Their ability to react with chlorine, for example, may not only decrease the water disinfection process, but also generate toxic by-products (Rivera et al., 2013). A variety of conventional and non-conventional water treatment processes have been investigated in relation to the removal ECs in water. Adsorption using activated carbon is a broadly reported technology for ECs removal from water (Ocampo-Perez et al., 2012). However, it involves phase change processes that represent the main barrier for its sustainable use (Carabineiro et al., 2011). Emerging Water Treatment processes (EWTs, i.e. ozone, permanganate, Fenton reaction) have recently emerged as potentially suitable alternatives for water treatment. Success tests at the laboratory scale, of direct EWT applications or coupled with other processes for pesticide degradation and textile dye and surfactants removal, and other ECs have been reported in research literature (Bandala et al., 2008a; Bandala et al., 2008b; Bustos et al., 2015; Bandala and Raichle, 2013).

Further research and pending tasks

Assessing the feasibility of application of EWTs for the removal of ECs in stormwater should be the next step in order to avoid the presence of compounds with such undesirable characteristics in stormwater runoff and to encourage stormwater reuse. To the best of our knowledge, there is a paucity of knowledge focused on this topic.

Due to the chemical characteristics of many of the compounds included within the ECs group, various advanced water processes, may not necessarily possess the required efficiency in the degradation of the chemical components or are not feasible due to the generation of residual effluent needing further treatment. One interesting alternative is the design of coupled-sequential water treatment processes where EWTs may be used as a pre-treatment step capable of degrading highly toxic ECs before biological treatment or as a post-treatment stage in membrane processes, for removing the ECs in the rejected effluent.

Solar radiation has been successfully used to promote some photo-chemical EWTs (Bandala and Raichle, 2013). The possibility of using a widely distributed, cheap and readily available non-conventional energy source as the sun, provides additional impetus for the use of these technologies. The removal of ECs in water, which can be undertaken using solar-driven EWTs is

extensive and well documented in research literature (eg. Hernandez and Medina, 2015). However, this work has been undertaken only at the laboratory scale and not proven to work at the field scale. This alternative approach provides a whole new perspective for the sustainable treatment of ECs in stormwater that has not been explored in-depth to-date.

Concluding remarks

Pollution of stormwater may prevent deriving the full potential benefits of its reuse in water deficient areas, particularly urban areas. The presence of ECs can constitute an intractable problem. Very limited investigations have been undertaken in relation to the fate, transport, health impacts and the removal of ECs in stormwater. In order to overcome the this issue, the support of all stakeholders including water authorities, researchers, regulatory authorities and the public should be strongly encouraged.

References

Bandala, E.R., Velasco Y., Torres, and L.G. (2008a). Decontamination of soil washing wastewater using solar driven advanced oxidation processes. *Journal of Hazardous Materials*, 160, 402–407.

Bandala, E.R., Peláez, M.A., García-López, A.J., Salgado, M.J., and Moeller, G. (2008b). Photocatalytic decolourization of synthetic and real textile wastewater containing benzidine-based azo dyes. *Chemical Engineering and Processing*, 47, 169–176.

Bandala, E.R., Raichle, B. (2013). Solar driven advanced oxidation processes for water decontamination and disinfection. In: Enteria N., Akbarzadeh A. (Eds.) *Solar Energy Sciences and Engineering Applications*. CRC Press.

Bustos, Y.A., Rangel-Peraza, J.G., Rojas-Valencia, M.N., Bandala, E.R., Álvarez-Gallegos, A., and Vargas-Estrada, L. (2015). Treatment of industrial effluents by electrochemical generation of H_2O_2 using an RVC cathode in a parallel plate reactor. *Environmental Technology*, 1-13.

Carabineiro, S.A.C., Thavorn-Amornsri, T., Pereira, M.F.R., and Figueiredo, J.L. (2011). Adsorption of ciprofloxacin on surface-modified carbon materials. *Water Research*, 45, 4583–4591

Czech, B., and K. Rubinowska. (2013). TiO_2-assisted photocatalytic degradation of diclofenac, metoprolol, estrone and chloramphenicol as endocrine disruptors in water. *Adsorption,* 19, 619–630.

Hernandez A., and Medina, I. (2015). *Photocatalytic semiconductors: Synthesis, Characterization and Environmental Applications*. Springer, New York.

Leiker, T.J., Abney, S.R., Goodbred, S.L., and Rosen, M.R. (2009). Identification of methyl triclosan and halogenated analogues in both male common carp (*Cyprinus carpio*) from Las Vegas Bay and Semipermeable Membrane Devices from Las Vegas Wash, Nevada. *Science of the Total Environment,* 407, 2102–2114.

Ocampo-Pérez, R., Rivera-Utrilla, J., Gómez-Pacheco, C., Sánchez-Polo, M., and López-Peñalver, J.J. (2012). Kinetic study of tetracycline adsorption on sludge-derived adsorbents in aqueous phase. *Chemical Engineering Journal*, 213, 88–96

Page, D., Miotlinski, K., Gonzalez, D., Barry, K., Dillon, P., and Gallen, C. (2014). Environmental monitoring of selected pesticides and organic chemicals in urban stormwater recycling systems using passive sampling techniques. *Journal of Contaminant Hydrology*, 158, 65-77.

Pal, A., He, Y., Jekel, M., Reinhard, M. and Gin, K.Y.H. (2014). Emerging contaminants of public health significance as water quality indicator compounds in the urban water cycle. *Environment International*, 71, 46-62.

Rivera, J., Sánchez-Polo, M., Ferro-García, M.Á., Prados-Joya, G. and Ocampo-Pérez, R. (2013). Pharmaceuticals as emerging contaminants and their removal from water: A review. *Chemosphere*, 93(7), 1268-1287.

Rosen, M., Alvarez, D.A., Goodbred, S.L., Leiker, T.J., and Patino, R. (2010). Sources and distribution of organic compounds using passive samplers in Lake Mead national recreation area, Nevada and Arizona, and their implications for potential effects on aquatic biota. *Journal of Environmental Quality,* 39, 1161-1172.