Research Paper

Volume : 5 | Issue : 4 | April 2016 • ISSN No 2277 - 8179 | IF : 3.508 | IC Value : 69.48

A Review on The Removal of Pharmaceuticals And Personal Care Products From Wastewater

Engineering

KEYWORDS : Contaminant, Emerging, Pharmaceutical, Personal care products, Biosolids, Ozonation, Advanced oxidation process, Wastewater.

*** Rifath Sharmin** — Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, Sylhet-3100, Bangladesh. * Corresponding Author

Dr Saidur Rahman Chowdhury — Department of Civil and Environmental Engineering, Western Ontario University, London ON, Canada.

ABSTRACT

Pharmaceuticals and personal care products (PPCPs) are widespread contaminants in the environment. PPCPs are used in households, healthcare, and animal husbandry worldwide. PPCPs comprise a diverse collection of thousands of chemical substances. The regulation of these compounds is now being explored in many jurisdictions to control their release and potential impacts in the environment. Activated carbon adsorption, ozonation or advanced oxidation, and membrane separation are all promising advanced treatment processes that are capable of removing many of the PPCPs commonly found in wastewater. Among all treatment methods, advanced oxidation processes (AOPs) have been demonstrated to be more efficient. This manuscript reviewed the current information on the occurrence of PPCPs in water and wastewater environment, as well as also discussed the treatment of PPCPs in wastewater that could reduce the concentrations of PPCPs before introduction to the environment. It could contribute innovative information to the treatment industry.

1. Introduction

Over the last 15 years, research has focused on a number of "emerging" contaminants. One class of "emerging" contaminants is a diverse group of biologically active compounds commonly referred to as pharmaceuticals and active agents in personal care products (PPCPs) (Daughton and Ternes, 1999). According to Barceló and Petrović(2007),this large group consists of non-prescription drugs, prescription drugs, veterinary medicines, diagnostic agents, cosmetics, sunscreen agents, masks and disinfectants used in industry, households and agricultural practices. Even though these compounds have only in recent times been recognized as environmental contaminants, they have gained the attention of the public and the scientific community. Concerns have been raised about their continuous release into the environment at low concentrations and the possible subtle effects of these compounds may have on non-target organisms over an extended period (Barceló and Petrović, 2007). Limited attention has been given to the possible impacts of these compounds on ecosystem health (O'Brien and Dietrich, 2004).The regulation of these compounds is now being explored in many jurisdictions to control their release and potential impacts in the environment (EMEA 2006b).

Pharmaceuticals and personal care products (PPCPs) are widespread contaminants in the environment, and have been detected in groundwater, surface water and drinking water as well as in agricultural soils subject to land application of digested municipal sewage sludge or biosolids (Heberer et al. 2002, Kolpin et al. 2002; Parent et al. 1996).

Drugs enter the wastewater via excretion of urine and feces containing parent drugs and their conjugates as well as other metabolites, or from the disposal of unwanted or expired medications (Halling-Sorensen et al. 1998). In the same way, chemical constituents of personal care products may be directly disposed of in domestic wastewater.

Pomati et al. (2006) demonstrated that a mixture of pharmaceuticals at typical environmental concentrations (ng/L range) can lead to physiological and morphological effects on human embryonic cells. Pharmaceuticals released in the environment may impose toxicity virtually on any level of the biological hierarchy, i.e. cells, organs, organisms, population, ecosystems, or the ecosphere.

Conventional drinking water and wastewater treatment processes are not designed to remove PPCPs from water. However, many of the conventional treatment processes do reduce the concentrations of PPCPs in water to some extent. Literature has shown that nanogram to microgram per liter concentrations of many PPCPs are commonly found in effluent, which indicates inadequate removal of those contaminants using present wastewater treatment technologies (Miao et al. 2002). During wastewater treatment process, some PPCPs tend to partition into biosolids or sludge because of their high affinity for organic-matter rich biosolids. (Parent et al. 1996).Treated sewage sludge, which is termed "biosolids", meets regulations for pathogens, nutrients, and metals only. Pharmaceuticals are designed to have a physiological effect on humans and animals in trace concentrations. Persistence against biological degradation and their biological activity are key properties of these contaminants. They retain their chemical structure long enough to perform their therapeutic function and, because of their continuous input, they could remain in the environment for a long time. Their presence is considered dangerous in both low and high concentrations (Klavarioti et al.2009).

2. Literature Review

PPCPs are present in water at very low concentrations and therefore are normally referred to as micropollutants. Many PPCPs are also endocrine disrupting chemicals (EDCs), which are compounds that can disrupt an organism's endocrine system often resulting in a change to hormonal balance.

Main sources of EDCs/PPCPs in rivers are from sewage effluent and agricultural runoffs. Wastewater effluent can contain EDCs/PPCPs at concentrations that pose a potential risk to drinking water sources, and that are biologically active enough to be bioavailable to aquatic organisms. The significance of the addition of chemicals to the environment by humans has largely been overlooked.

2.1 Entry into the Environment

Pharmaceuticals have been found in raw and treated wastewater, soil, biosolids, sediment, groundwater, surface water and drinking water supplies in North America and Europe. The concentrations found have been comparatively low, with concentrations in the μg/L range for wastewater samples.

Pharmaceuticals and personal care products (PPCPs) are used in households, healthcare, and animal husbandry worldwide (Enserink, 2006). The global pharmaceutical market in 2005 was $606 billion U.S. dollars, with more than 268 billion located in North America. An American survey of more than 100 compounds in a drinking water treatment plant, found 22 persisted in treated water.

2.2 Effects on environment

Large amounts of pharmaceuticals and personal care products (PPCPs) are in common use for treatment and personal care of humans and animals, which may end up in wastewater effluents and surface water. Land application can lead to rapid breakdown of organic compounds but some persistent organic compounds may accumulate, depending on loadings and environmental conditions. The organic compounds are designed to be biologically active; a certain risk can be anticipated for organisms exposed to environmental PPCPs even when the concentrations of PPCPs in the environment are low. Several PPCPs are known to be endocrine disrupting chemicals (EDCs). The risk to humans from exposure to PPCPs in environmental waters is more disputed than the ecological risks of PPCP exposure. Although the presence of pharmaceuticals at the parts-per-trillion levels in the drinking water does not currently appear to pose a direct adverse risk to humans, indirect impacts from some pharmaceuticals are documented and need to be considered. Indirect impacts of other PPCPs on human health are more difficult to determine. Limited toxicology studies of chronic exposures exist to assess low level, long term exposures to anticonvulsants, antidepressants, antihypertensives, or cytostatics pharmaceuticals. Pharmaceutical, personal care and veterinary products, which have been found in wastewater, biosolids and surface water, are likely to contaminate the aquatic environment, including groundwater. Aquatic sentinel species that bioaccumulate some of these drugs remain to be identified, but studies with mussels and plants have shown that some antibiotics significantly accumulate in tissues. Laboratory tests have been conducted with some success on several aquatic species, including bacteria, plants, invertebrates and fish, with commonly found drugs both individually and in mixtures. These toxicity tests generally indicate that acute lethal effects are not likely to occur in the environment but that chronic or long-term effects are possible. (Thomas,2009)

The primary driver for the issue of PPCPs in the environment is the concern that long-term exposure to low levels of PPCPs residues could have adverse effects on aquatic and terrestrial ecosystems and human health. A recent study by Pomati et al. (2006) demonstrated that a mixture of pharmaceuticals at typical environmental levels (ng/L range) can lead to physiological and morphological effects on human embryonic cells.

PPCPs can adopt a pseudo persistent exposure nature given their continuous introduction from waste water treatment plant (WWTP) effluent thus providing a continuous exposure scenario for organisms residing in these aquatic systems over their entire life cycle. WWTPs do not eliminate all compounds completely (Herber,2002). As a result, exposure, and consequently tissue accumulation, would be expectedly higher in organisms residing in water resources receiving discharge from WWTPs.

2.3 Removal

Municipal wastewater treatment plants are mainly designed to remove pathogens and organic and inorganic suspended and flocculated matter. Two processes such as adsorption onto sludge and biodegradation are often responsible for the aqueous removal of PPCPs in a treatment plant. Typical wastewater treatment plants are able to achieve high removal efficiency for a limited number of emerging contaminants in present conventional biological treatment plants. Some compounds show remarkable persistent behavior which are unable to be removed through neither sorption nor biotransformation. As a result, most of the present treatment plants can not remove these compounds, so the compounds are continuously discharged in the environment.

2.4 Different types of treatment

Activated carbon adsorption, ozonation or advanced oxidation, and membrane separation are all promising advanced treatment processes that are capable of removing many of the PPCPs commonly found in wastewater. The main disadvantage of ozonation is that in general the target compounds are not fully mineralized, but merely transformed, and so even more harmful substances can be produced as a result. Membrane processes, such as microfiltration and ultrafiltration, are generally not fully effective in removing organic contaminants though both nanofiltration and reverse osmosis treatment show potential as an efficient method for removing pharmaceuticals from the wastewater, the disposal of the sludge, which could contain the pollutant in a more concentrated form, remains a problem(Deegan et al. 2011).

Advanced oxidation processes (AOPs) have been demonstrated to be promising technologies for the treatment of wastewaters containing pharmaceuticals and personal care products (Kinney et al., 2008). Among the AOPs, the most investigated method for destroying PPCPs and EDCs in water is photocatalysis with titanium dioxide. For the advanced treatment of water that structurally alters the organic compounds in situ, chemical transformation of the pollutants into readily biodegradable products is an important factor to be considered in the design and operation of the chosen advanced oxidation technologies.

3. Conclusions

It is concluded that the presence of residual pharmaceuticals in the environment and in aquatic systems, in particular, poses a serious environmental problem as these compounds (a) are resistant to biological degradation processes and generally escape intact from conventional treatment plants, (b) may impose serious toxic and other effects to humans and other living organisms, and (c) are present at small concentrations, thus requiring more sophisticated tools for their accurate determination. This manuscript could contribute innovative information to the treatment industry.

It is likely that with increased urbanization and further degradation of water supplies, the contamination of source waters with PPCPs will only increase; so, in anticipation of relevant toxicology data, it is very important that the water treatment industry investigate the removal of PPCPs for which standards may be established in the future. In recent decades, very severe regulations have impelled on researchers to develop and evaluate novel technologies to accomplish higher mineralization rate with lower amount of detectable contaminants.

References

1. Barceló, D., and Petrović, M. (2007). Pharmaceuticals and personal care products (PPCPs) in the environment. Analytical and Bioanalytical Chemistry, 387, 1141-1142.
2. Daughton, C. G., and Ternes, T. A. (1999). Pharmaceuticals and personal care products in the environment: agents of subtle change? Environmental Health Perspectives, 107, 906-938.
3. Deegan, A. M., Shaik, B., Nolan, K.K., Urell, M., Oelgemöller, J., and Tobin, A.(2011).Treatment options for wastewater effluents from pharmaceutical companies .Int. J. Environ. Sci. Tech, 8, 3, 649-666.
4. Enserink, M. (2006). WHO panel weighs radical ideas. Science 314, 1373.
5. European Agency for the Evaluation of Medical Products (EMEA). (2006b). Guideline on the environmental impact assessment for veterinary medicinal products (CVMP/ERA/418282 /2005-Consultation), 1-59.
6. Halling-Sørensen, B., and Nielsen, S. N. (1998). Occurrence, fate and effects of pharmaceutical substances in the environment - a review. Chemosphere, 36, 357-393.
7. Heberer, T., and Reddersen, K. (2002). From municipal sewage to drinking wa-

ter: fate and removal of pharmaceutical residues in the aquatic environment in urban areas. Water Science and Technology, 46, 81-88.

8. Klavariotia, M.,Mantzavinos, D., and Kassinos,D.(2009).Removal of residual pharmaceuticals from aqueous systems by advanced oxidation processes.Environment International, 35, 402–417.
9. Kinney, C.A., Furlong, E.T., Kolpin, D.W., Burkhardt, M.R., Zaugg, S.D., Werner, S.L., Bossio, J.P., and Benotti, M.J.(2008). Bioaccumulation of pharmaceuticals and other anthropogenic waste indicators in earthworms from agricultural soil amended with biosolid or swine manure. Environmental Science & Technology, 42, 1863–1870.
10. Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., and Buxton, H.T. (2002). Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999–2000: a national reconnaissance. Environmental Science & Technology, 36, 1202–1211.
11. Miao, X-S., and Koenig, B. G. (2002). Analysis of acidic drugs in the effluents of sewage treatment plants using liquid chromatography-electrospray ionization tandem mass spectrometry. Journal of Chromatography A, 952, 139-147.
12. O'Brien, E., and D. R. Dietrich. (2004). Hindsight rather than foresight: reality versus the EU draft guideline on pharmaceuticals in the environment. Trends in Biotechnology, 22, 326-330.
13. Parent, Y., Blake, D., Magrini-Bair, K., Lyons, C.,Turchi,C., Watt, A.,E. Wolfrum,E., and Prairie,M. (1996). Solar photocatalytic processes for the purification of water: State of development and barriers to commercialization. Solar Energy, 56, 429-437.
14. Pomati, F. S. ,Castiglioni, E., Zuccato, R., Fanelli, D., Vigetti, C., Rossetti, D., and Calamari,D.(2006). Effects of a Complex Mixture of Therapeutic Drugs at Environmental Levels on Human Embryonic Cells. Environmental Science and Technology, 40, 2442-2447.
15. Thomas, S. M., Bodour, A. A., Murray K. E., and Inniss, E. C. (2009). Sorption behavior of a synthetic antioxidant, polycyclic musk, and an organophosphate insecticide in wastewaterSludge. Water Science & Technology, 60,1.