Sources of Pollution / Fate and Transport (Focus on Pharmaceuticals)

Group 1 Subtopic: Watershed case studies – from effluents to the tap

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Pharmaceuticals are generally used to treat symptoms but rarely to "cure" a disease. They have, of course, added to the quality of life through use of prescription or over the counter drugs, personal care products, or herbal remedies and enhanced lifetime expectancy but beginning in the 1970's their residues (initially from heart medications and pain relievers) began to show up in streams receiving discharges from wastewater treatment plants. As analytical methods became more refined in the subsequent decades, oral birth control medications were detected in natural waters and subsequently linked to reproductive impairments in fish. By the dawn of the new century, it became apparent that pharmaceutical products were present in all conventionally treated wastewaters raising concerns about the potential for a source of biologically active environmental contamination in our natural waters. Among the products routinely found in these wastewaters are x-ray contrasting agents, anti-epileptics, antibiotics, analgesics, anxiety and heart drugs, and illicit drugs. However, we should also compare and contrast the low µg/L levels of individual chemicals in wastewater with anecdotal evidence that nearly 80% of all $1 bills in Chicago have been found to be contaminated with up to 1mg of cocaine per bill. In the United Kingdom, over £15 million of currency is destroyed each year due to contamination with drugs including paracetamol, procaine, ephedrine, caffeine, ketamine, and diazepam.

The factors impacting the occurrence of pharmaceutically active compounds (PhACs) in natural waters include quantity, frequency and location of usage, the type of treatment used and retention time in wastewater unit processes, microbiological and macrobiological metabolism, environmental photo- and biological degradation, and transport processes downstream which can involve dilution, hydrolysis, and adsorption to sediments. When it comes to evaluating their occurrence in environmental waters, there are limitations associated with monitoring. Currently, we have analytical methods for well over 100 PhACs but at best a single method might measure 10-15 analytes and each method is laborious, time-consuming, requires expert skill and is, consequently, very expensive. As methods become more sensitive, we have the tools to look for needles in haystacks but without toxicological data, it is difficult for managers of wastewater and drinking water treatment plants to understand the relevance of occurrence data let alone be willing to commit limited public funds to expensive monitoring studies. As an example of this dilemma, a recent study of the occurrence of antibiotics in a watershed case study tracked sulfamethoxazole at a level of 1000-1500 ng/L in wastewater effluent moving 6 miles downstream to a reservoir where it was found at 60-240 ng/L and at the intake of a drinking water treatment plant using the reservoir as its source water at 50-100 ng/L. The levels in the finished drinking water from that plant were at or just below the limit of detection of 20 ng/L. In other drinking water treatment plants, levels of some of the antibiotics were 2-3 times higher in the water just prior to chlorination compared to after that treatment. While it is unlikely that chlorination caused the complete mineralization of the compound, declaring the finished water devoid of any pharmaceutical activity would be premature since the analytical methods target the parent compound and not the chlorinated derivative. We are also probably missing a number of environmental metabolites of the chemicals and, thereby, underestimating the degree of pharmaceutical activity in the water. With some of these concerns in mind and with a projected increased dependence on reuse of wastewater in which trace contaminants could potentially become concentrated, California's draft regulations for indirect potable reuse states, "Each year, the planned groundwater recharge reuse project shall monitor the recycled water for specified endocrine disrupting chemicals and pharmaceuticals based on the affected groundwater basin(s). These chemical include steroids (ethinyl estradiol, 17β-estradiol, & estrone) and the following PhACs: acetaminophen, amoxicillin, azithromycin, caffeine, carbamazepine, ciprofloxacin, gemfibrozil, ibuprofen, iodinated contrast media, methadone, morphine, salicylic acid, & triclosan".

It is, of course, very difficult to measure trace concentrations of ubiquitous chemicals because there is a high occurrence of low levels of PhACs even in blanks and since food, air, and water are all possible routes of exposure is it reasonable to single out only one of these medium for scrutiny?

Some of the questions this session might wish to address can be evolved from the above comments but could include:

(1) Is the low ng/L occurrence of multiple residues of pharmaceutically active chemicals a health priority in the absence of toxicological data?

(2) Even if advanced drinking water treatments might be capable of removing 70-90% of many of these chemicals, what should be the target maximum contaminant level for an individual chemical in a mixture for which we have no current indications of synergism?

(3) Should we be concerned about the possible build-up of residues in sediments downstream of wastewater treatment plants and the possible disruption to natural biological processes that concentrates of these chemical species might pose?

(4) Since we are likely missing the complete picture describing the fate of PhACs, should we looking for a measure of pharmaceutical activity in water rather than simply targeting individual compounds?

(5) Although carbonaceous soils are quite effective in slowing the migration of drugs originating from septic systems, can the presence of surfactants and other chemicals alter this process and ultimately impact groundwater quality and soil ecology?