Concern of Pharmaceuticals in Drinking Water

By Kelly A. Reynolds, MSPH, Ph.D.

The topic of pharmaceuticals in drinking water is not new and was even addressed in a previous issue of *On Tap* (June 2003). In fact, as long as pharmaceuticals have been in use, they and their metabolites have contaminated the environment. Increased public awareness combined with increased monitoring and the fear of unknown health effects keeps the topic of pharmaceuticals in the drinking water supply in the headlines.

An *Associated Press* investigative report released in March 2008 confirms that at least 41 million Americans in 24 major metropolitan areas receive drinking water that is tainted by a variety of pharmaceuticals including: mood stabilizers, antibiotics, anti-convulsants, hormone therapies and more. The report was the result of a five-month survey of hundreds of scientific reports, federal drinking water databases, expert interviews and site visits of wastewater treatment plants and drinking water utilities in 50 of the largest US cities. There are many reports identifying the hazard, but much less information on what should be done about the problem.

Evidence of drinking water contamination

More than 20 years ago, surveys in the US and Europe identified the presence of caffeine, aspirin, nicotine and compounds from personal care products (i.e., shampoos, lotions, cosmetics) in wastewater discharges impacting environmental rivers. Around this same time, the US Department of Agriculture (USDA) documented cholesterol-lowering medication being found in groundwater infiltration basins (sites where groundwater was being recharged with treated sewage effluent—a common practice in the US, particularly in the arid west). Expanded monitoring over the next 20 years proved there was no shortage of pharmaceuticals, endocrine disrupting compounds (EDCs) and personal care products in drinking water sources.

Pharmaceuticals in the environment originate from industrial, agricultural, medical and common household practices (i.e., cosmetics, detergents and toiletries). Pain killers, tranquilizers, anti-depressants, antibiotics, birth control pills, estrogen replacement therapies, chemotherapy agents, anti-seizure medications, etc. are just some examples of everyday contaminants finding their way into the environment via human and animal excreta, from disposal into the sewage system (i.e., flushing unused medication down the toilet) and from landfill leachate that may impact drinking water supplies. Agricultural practices are a major source, where 40 percent of antibiotics manufactured are fed to livestock as growth enhancers. Manure, containing traces of pharmaceuticals, is often spread on land as fertilizer, from which it can leach into local streams and rivers. Based on sales, the US uses about half of all pharmaceuticals in production.

During 1999-2000, the US Geological Survey (USGS) conducted the first nationwide investigation of the occurrence of pharmaceuticals, hormones and other organic contaminants in 139 streams from 30 states. A total of 95 contaminants were targeted, including antibiotics, prescription and nonprescription drugs, steroids and hormones, 82 of which were found in at least one sample. Although the researchers caution that sites were chosen based on their increased susceptibility to contamination from urban or agricultural activities, a surprising 80 percent of streams sampled were positive for one or more contaminants. Furthermore, 75 percent of the streams contained two or more contaminants, 54 percent had greater than five, while 34 percent had more than 10 and a whopping 13 percent tested positive for more than 20 targeted contaminants.[1]

Possible health impacts

The levels of pharmaceuticals found in the environment are six to seven orders of magnitude lower than therapeutic doses, in spite of the fact that up to 90 percent of an oral drug can be excreted in human waste. Low, yet consistent exposures would not likely produce acute, notable effects, but rather subtle impacts, such as behavioral or reproductive disorders that are difficult to detect and could very well go unnoticed. Low-level exposures (i.e., far below the recommended prescription dose) have not shown measurable effects in humans, but have been found to affect aquatic ecosystems. Evidence of hormone disruption in fish due to exposure to pharmaceutical estrogens and the rise of bacterial pathogens resistant to conventional antibiotic treatment, due, in part, to their exposure to sub-lethal levels of antibiotics in their environment, provide evidence of potential adversity resulting from widespread environmental contamination. Antibiotics and estrogens are only two of many pharmaceuticals suspected to persist in the environment either due to their inability to biodegrade naturally or to their constant use keeping them ever-present. Other studies have shown antidepressants trigger premature spawning in shellfish, while drugs designed to treat heart ailments block the ability of fish to repair damaged fins.

How the dose-response relationship in fish and bacteria might be extrapo-

lated to human exposures to low doses of pharmaceuticals is not known. Equally unknown are the risks of exposure in developing fetuses or persons with drug allergies. In addition, few studies with animals focus on the complex exposure scenarios of mixed-drug interactions. Studies are now underway evaluating the effect of low levels of individual and combined drugs on human cells and their growth or functions. Various studies have shown pharmaceuticals commonly found in water can increase or decrease the development or function of kidney cells, blood cells and breast cancer cells.

Treatment options

Pharmaceutical compounds can be isolated from soil, water and treated sewage effluent. Conventional wastewater treatment is not effective to eliminate the majority of pharmaceutical compounds. Many of these compounds do not biodegrade and are known to persist for years in groundwater.

A study of selected pharmaceuticals in 1) treated effluent discharged upstream from drinking water intakes; 2) in raw drinking water and 3) in finished drinking water from a watershed in metropolitan Atlanta, Ga. determined that the number of drugs detected decreased from 16 to 10 to three, respectively.[2] The drugs found in finished water were all nonprescription varieties (caffeine, nicotine and acetaminophen).

Advanced water treatment technologies have been evaluated for their efficacy in removing the most common pharmaceuticals from drinking water. Oxidation of pharmaceuticals during conventional ozonation has proven effective where relatively low doses of ozone were capable of complete transformation of the select pharmaceuticals tested.[3] Chlorine, the most popular drinking water disinfectant used in the US, was found to be much less effective than ozone. Some highly prevalent pharmaceutical compounds are effectively removed by additional, advanced oxidation practices (i.e., ozone and UV or ozone and hydrogen peroxide); however, toxic metabolites may be created following oxidation procedures. Membrane filtration and filtration with granular activated carbon (common processes in advanced POU treatment devices) are also shown to be highly effective. Nanofiltration and RO eliminated all drugs tested.[4]

Conclusions

The amount of pharmaceuticals and personal care products released into the environment each year is reported to be tantamount to the amount of pesticides used each year. Little is known about the occurrence, transport, fate, synergistic, accumulative and/or long-term effects of pharmaceuticals and other personal care products following their end use. Currently, there is no national coordinated effort requiring the monitoring or focused treatment of waters and wastes for the presence of pharmaceuticals.

Trends of increased testicular cancer, reproductive abnormalities, breast cancer, early puberty and decreased sperm count have all been suggested as problems possibly related to low-level exposure to chemicals (pharmaceuticals and EDCs) in the environment. The use of prescription medications is also on an upward trend, an increase expected to continue. POU water treatment offers some targeted control over individual exposures to these unknown risk factors.

Footnoted references

1. Kolpin, D.E. et al., 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance. *Environmental Science & Technology*, v. 36, no. 6, p. 1202-1211. (Also available at www.usgs.gov).

2. Frick, E.A., et al., 2001. *Presence of pharmaceuticals in wastewater effluent and drinking water, metropolitan Atlanta, Georgia, July-September 1999*. Proceedings of the 2001 Georgia Water Resources Conference. Athens, Ga. March 26-27, 2001. (Also available at http://ga.water.usgs.gov/nawqa/pharm_final.pdf).

3. Huber, M.M. et al., 2003. Oxidation of pharmaceuticals during ozonation and advanced oxidation processes. *Environmental Science & Technology*, v. 36, no. 6, p. 1202-1211.

4. Drewes, J.E. et al., 2002. Fate of pharmaceuticals during indirect potable reuse. *Environmental Science & Technology*, v. 46, no. 3, p. 73-80.

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