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PHARMACEUTICALS AND EDCS
in the US Water Industry—An Update

Recent advances in analytical chemistry methods have allowed the detection of progressively smaller concentrations of some endocrine disrupting chemicals (EDCs) and pharmaceuticals in water. These emerging contaminants appear to be ubiquitous in municipal wastewater treatment plant (WWTP) effluents and in surface waters influenced by effluents, including source waters for drinking water treatment plants. EDCs are agents that interfere with the functioning of natural hormones in the body. Pharmaceuticals found in surface waters include prescription and nonprescription human and veterinary drugs.


Prescription and nonprescription pharmaceuticals or their metabolites recently have been reported to occur at very small concentrations in some finished drinking water samples in the United States.

SOURCES AND EXPOSURE

The US Environmental Protection Agency (USEPA) developed the Endocrine Disruptor Screening Program to identify screening methods and toxicity testing strategies that can be used to identify chemicals as EDCs. This process is incomplete, and toxicologists have not yet agreed on a testing strategy to definitively determine whether a chemical is an EDC. Many chemicals have not been tested by any method for potential endocrine activity. However, naturally occurring and synthetic chemicals widely considered to be EDCs include various pharmaceuticals, pesticides, industrial chemicals, combustion by-products, phytoestrogens, and hormones excreted by animals and humans.

Although EDCs and pharmaceuticals can potentially originate from numerous sources and enter the environment by many routes, municipal WWTP effluents have been identified as a major source of EDCs in surface waters (Lee et al, 2004; Daughton, 2001). Pharmaceuticals enter WWTPs when people taking medications excrete pharmaceuticals and associated metabolites, rinse them from their bodies during bathing, or flush unused medications into wastewater. EDCs entering WWTPs originate from many sources including plant material, paints, personal care products, plastics, flame-retardant materials, cleaning products and other household chemicals, pesticides, and hormones excreted by humans. Industrial discharges and stormwater runoff treated by WWTPs also may contain EDCs. Although wastewater treatment processes remove pharmaceuticals and EDCs to varying degrees, chemicals that resist treatment may remain in effluent discharged to surface water, where they may be subject to dilution or environmental degradation or may persist in the environment.

Certain endocrine disrupting chemicals have been measured in the effluents of some wastewater treatment plants at concentrations that have been demonstrated in laboratory studies to cause endocrine effects in fish.

Certain prescription and nonprescription pharmaceuticals or their metabolites recently have been reported to occur at very small concentrations in some finished drinking water samples in the United States. These include caffeine, analgesics/anti-inflammatories, anticonvulsants, anti-anxiety medications, x-ray contrast media, lipid regulators, antibiotics or their metabolites, and metabolites of nicotine and a hypertension medication (Snyder et al, 2004; Stackelberg et al, 2004; Frick et al, 2001). Known or suspected EDCs detected in US finished drinking water samples include a synthetic musk, a polycyclic aromatic hydrocarbon compound, a plant sterol, plastic components, an insecticide, certain degradation products of nonionic surfactants, a fixative used in perfumes and soaps, and a flame retardant (Lee et al, 2004).

HEALTH EFFECTS AND REGULATIONS

Effects on human health. The adverse effects of the estrogenic pharmaceutical diethylstilbestrol, a medication once prescribed to pregnant women, on children exposed to the drug during gestation have clearly shown that humans are susceptible to the effects of EDCs. Human and animal studies of the effects of long-term exposure to environmentally relevant doses are lacking for most known or potential EDCs, but results of some animal studies indicate that certain EDCs can produce effects at low doses. However, to date there is little evidence to support the hypothesis that environmental EDCs at levels encountered by the general population have produced adverse endocrine effects in humans.

Industrial chemicals, organochlorine pesticides, and naturally occurring chemicals have been implicated as potential causes for reported effects in humans, including reduced sperm counts, increased incidences of breast and reproductive tract cancers, and early breast development in girls. However, a chemical cause has not been established, and the existence of the effects has been disputed in some cases. Atypical dose–response relationships and potential additive toxicity or interactions among chemicals within mixtures to which people are commonly exposed (including mixtures occurring in drinking water) complicate toxicological risk assessments for EDCs.

Although a wealth of toxicological information may be available for pharmaceuticals, the effects of unintended chronic exposure to subtherapeutic doses that could occur via consumption of drinking water are often not known. Risk assessments conducted to date have not reported that the trace concentrations of pharmaceuticals detected in drinking water pose a health risk to consumers, and likewise, no evidence that EDCs in drinking water have produced adverse effects in humans exists. People are commonly exposed to pharmaceuticals and EDCs in greater amounts through medications and other sources and through routes other than drinking water including diet, inhalation of airborne chemicals, and dermal absorption (i.e., from topical medications or applicaiton of personal care products). Consequently, the contribution of drinking water to total exposure and its relative importance should be considered in risk assessments for these contaminants.

Effects on aquatic life. Certain EDCs have been measured in the effluents of some wastewater treatment plants at concentrations that have been demonstrated in laboratory studies to cause endocrine effects in fish. Estrogenic effects related to municipal WWTP effluents have been reported to be in fish in Europe, Canada, the United States, and elsewhere. Because WWTP effluents contain complex mixtures of potential EDCs, it has not been possible to determine the specific chemicals responsible. However, likely candidates include the animal sex steroid hormones 17β–estradiol and estrone, the pharmaceutical estrogen ethinylestradiol (EE2), and certain alkylphenolic degradation products of nonionic surfactants (e.g., nonylphenol, octylphenol). Results of most of the limited number of studies on the effects of pharmaceuticals other than EE2 on aquatic life suggest that concentrations required to pro-

duce adverse effects are greater than those expected to occur in the environment.

Regulations. The concentrations of pharmaceuticals (with the exception of fluoride added intentionally) and EDCs in drinking water are not regulated in the United States. Although certain contaminants that are regulated in drinking water may later be identified by USEPA as EDCs, they are not currently regulated on the basis of their potential endocrine disrupting effects. Increasing demands on water resources, particularly in the arid southwestern United States, are driving greater consideration of water reuse strategies, including indirect potable reuse applications such as recharging of depleted drinking water aquifers. The California Department of Health Services' Draft Groundwater Recharge Reuse Regulations include monitoring requirements for specified EDCs and pharmaceuticals but do not establish standards. To the best of the authors' knowledge, no regulatory limits have been established in the United States for EDCs or pharmaceuticals in municipal WWTP effluents. However, the US Food and Drug Administration requires environmental risk assessments for new pharmaceuticals with predicted environmental concentrations >1 µg/L.

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COURSES OF ACTION

The public and regulatory agencies are concerned about whether EDCs and pharmaceuticals that might be ingested in drinking water pose a risk to consumers' health. To address these concerns, it is necessary to characterize potential exposure to and effects of these chemicals. Occurrence data for trace concentrations of EDCs and pharmaceuticals in source water are sparse, and even fewer data are available for finished drinking water. A limited number of laboratories are capable of conducting these trace analyses, the costs can be substantial, and analytical methods have not been developed for all of the EDCs and pharmaceuticals that may occur in source water or drinking water.

Further development of analytical methods should be encouraged, but because the analytical costs and difficulty tend to increase substantially with decreasing detection limit requirements, the least expensive and simplest method that can quantitate concentrations below toxic thresholds (if these are known) for humans and aquatic life should be used. Because data on occurrence, routes of exposure, and low-dose toxicity are lacking for many of the potential contaminants of concern, selection of contaminants for monitoring and treatment is a challenge. Efforts are under way to identify the EDCs and pharmaceuticals in drinking water that are toxicologically most important or that might serve as surrogates or indicators for other contaminants in monitoring and treatment studies.

Water treatment. Recent research indicates that many EDCs are removed to varying degrees through conventional and advanced wastewater and drinking water treatment processes. Because EDCs and pharmaceuticals with widely varying properties might occur in the environment, a single treatment process is unlikely to be effective and feasible for all contaminants of potential concern. Each of the available treatment options has advantages and disadvantages in terms of effectiveness, feasibility, and cost. Little is known about the occurrence and potential toxicity of degradation products of EDCs and pharmaceuticals that might result from treatment processes such as oxidation that alter chemical structures rather than removing chemicals from water. Reverse osmosis is highly effective for removal of most of these contaminants, but it is very costly, some of the water is lost as brine, and disposal of the brine is a significant problem.

Source water protection. Advanced drinking water treatment processes are likely to substantially reduce exposure to EDCs and pharmaceuticals for humans but will provide no protection for aquatic life. Source water protection (SWP) measures to reduce the release of these contaminants to the environment should be considered, particularly when dealing with contaminants that are recalcitrant to environmental degradation and drinking water treatment processes. Detection and removal of contaminants may be less complicated at point sources, where they are likely to occur at elevated concentrations before becoming diluted in source waters. SWP might potentially provide ancillary benefits to the environment and particularly to aquatic organisms, which are likely to receive much greater exposure to EDCs and pharmaceuticals in water than humans, and which have demonstrated adverse effects attributable to EDCs in the environment. Although reports of endocrine disruption in fish exposed to WWTP effluents have generated public concern about the potential for similar effects on humans exposed to drinking water

from sources influenced by these effluents, exposures to and effects of EDCs and pharmaceuticals in fish cannot be readily equated to the same in humans. Additionally, efforts to prevent adverse effects in fish may or may not result in benefits for humans. SWP efforts should seek to identify sources of EDCs in the aquatic environment and to assess the relative importance of various sources to determine where expended effort and funds might produce the greatest benefits (e.g., improved wastewater treatment versus control of agricultural runoff).

Dealing with uncertainty. Utilities and their customers will have to decide whether to wait for more information that can be used to guide action or to take proactive measures despite limited information and uncertain benefits. Of particular concern are uncertainties related to the selection of contaminants for monitoring and treatment and uncertainties related to unknown risks and benefits for humans and aquatic life. Consideration should be given to

- the willingness of the public to pay for potentially costly mitigation efforts,
- the importance of pharmaceuticals and EDCs in surface waters and drinking water relative to other public health and environmental concerns, and
- potential losses or gains related to waiting for more information or taking action despite uncertainties.

Effective communication with the public is needed to address these issues.

ONGOING RESEARCH

Research is being conducted by the authors and others to address some of the issues and questions that are developing as more becomes known about EDCs and pharmaceuticals in water systems. Toxicological Relevance of Endocrine Disruptors and Pharmaceuticals in Drinking Water is the title of one such research project funded by the AWWA Research Foundation (AwwaRF) and the WateReuse Foundation. In addition to synthesizing current understanding of methods, occurrence, treatment, and health effects of endocrine disrupting chemicals and pharmaceuticals in drinking water, the study also will compare drinking water risks from these contaminants with risks from similar air- and foodborne chemicals. More information about this ongoing study and those working on it can be found at www.awwarf.org/research/topicsandprojects/projectSnapshot.aspx?pn=3085 and http://www.watereuse.org/pdf/wrf_projectsummary-0904.pdf.

The Comprehensive Utility Guide for Endocrine Disruptors and Pharmaceuticals in Drinking Water is another AwwaRF-funded project on which the authors are co-investigators. This study will synthesize the existing knowledge on endocrine disrupting chemicals and pharmaceuticals in drinking water supplies. The resulting report, developed for the water industry professional, will include what is known about health effects, analysis, occurrence, and behavior in drinking water treatment processes for this broad range of chemicals. Additional information about this research project and its co-investigators may be found at www.awwarf.org/research/TopicsAndProjects/projectSnapshot.aspx?pn=3033.

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