AwwaRF Featured Topic: EDCs, PhACs, and PCPs Posted May 26, 2005

Three major, related groups of potential contaminants have gained attention in recent years, with acronyms familiar to most everyone in the drinking water industry: EDCs, PhACs, and PCPs. These acronyms stand for endocrine-disrupting compounds (EDCs), pharmaceutically active compounds (PhACs), and personal care products (PCPs), respectively.

Endocrine disrupting compounds, by definition, are chemicals that interfere with the synthesis, transport, and/or action of natural hormones responsible for the reproduction, development, and/or behavior of an organism. EDCs also are contained in anthropogenic substances such as detergent, pesticides (a category that includes herbicides, insecticides, and fungicides), plasticizers, natural and synthetic hormones, among many other substances. Potential EDCs are contained in natural agricultural products such as soybeans, alfalfa, and natural hormones in animals.

The term pharmaceutically active compounds (PhACs) encompasses some of the hormone-based compounds already noted as EDCs, and includes antibiotics, anti-epileptic medications, heart medications, pain medications, and cancer medications generally used to treat symptoms rather than underlying disease. This category also covers veterinarian drugs and feed additives used for livestock.

Personal care products (PCPs) refer to common, anthropogenic products such as shampoos, fragrances, over-the-counter medications, and herbal remedies. The United States Environmental Protection Agency (USEPA) and other entities have also begun referring to the latter two categories as PPCPs – pharmaceuticals and personal care products.

All three categories contain compounds with specific, discreet attributes, yet due to their nature a number of these compounds belong in both categories. EDCs, PhACs, and PCPs come from many different classes of chemicals. The United States Environmental Protection Agency (USEPA) has estimated that approximately 87,000 compounds may need to be evaluated.

Occurrence surveys reflect that these substances are entering public water supplies in trace quantities via natural processes, non-point source pollution such as agricultural runoff, and wastewater treatment effluent. Because some of these compounds have been suspected in developmental and reproductive changes in fish and amphibians, and there is evidence that mammals may be sensitive to extremely low concentrations of hormones, EDCs, PhACs, and PCPs are under study for possible health effects by USEPA. To date, however, there is no firm evidence for a causal association between low-level exposure to EDCs and adverse human health outcomes.

According to the USEPA's Web site, "there simply is not sufficient evidence to warrant regulation [at this time]; certain representative PPCPs, however, might prove appropriate to eventually add to the USEPA Office of Water's Drinking Water Contaminant Candidate List." (See the question-and-answer below on regulatory issues.)

In AwwaRF's own research effort, initiated in 1999 with an expert workshop on research issues, the Foundation has surveyed the literature, gathered and analyzed occurrence data, and assessed analytical methods and

treatment options. AwwaRF has issued a number of reports and in 2005 has at least a half-dozen studies currently underway.

Specifically, AwwaRF's research is focused on

- providing drinking water utilities with the guidance and tools utility managers need to assess EDCs, PhACs, and PCPs in their own water supplies ("methods development"),
- evaluate treatment options,
- understand these compounds' potential toxicological implications, and
- how utilities can communicate effectively with the public on the topic.

The world-wide occurrence of EDCs in water supplies led the Global Water Research Coalition (GWRC) – a coalition of 14 international research organizations, of which AwwaRF is a founding member – to select EDCs as its first "priority issue" in 2002 for its collaborative research program. **The GWRC has issued a half-dozen reports on its findings since 2003, available here to AwwaRF subscribers.**

AwwaRF Mission: Provide research into understanding the sources, occurrence, nature, fate, possible health effects, and treatment options for EDCs, PhACs, and PCPs.

Q: What are the common EDCs, PhACs, and PCPs and why are they an issue?

A: Endocrine disrupting compounds, by definition, are chemicals that interfere with the synthesis, transport, and/or action of natural hormones responsible for the reproduction, development, and/or behavior of an organism. Potential EDCs are contained in natural products such as soybeans, alfalfa, and natural hormones in animals, and in anthropogenic substances such as soy products, detergent, pesticides (a category that includes herbicides, insecticides, and fungicides), plasticizers, oral contraceptives, and hormone-replacement treatments.

Many chemicals have yet to be investigated for possible endocrine-disrupting activity. After human excretion into wastewater, and wastewater treatment, these compounds reach surface waters drawn on by drinking water utilities. Occurrence surveys from various countries reflect that EDCs, PhACs, and PCPs are a global issue, although the types and concentrations of these compounds vary, country to country, even watershed to watershed.

The term pharmaceutically active compounds (PhACs) encompasses some of the hormone-based compounds already noted as EDCs, and includes antibiotics, anti-epileptic medications, heart medications, pain medications, and cancer medications generally used to treat symptoms rather than underlying disease. This category also covers veterinarian drugs and feed additives used for livestock.

These compounds enter public water supplies – both in groundwater and surface water – primarily after human therapeutic use, or in ranching and farming operations, as reflected by their widespread distribution in municipal wastewater treatment plants. These compounds are used and excreted by humans or animals into wastewater or soil, or improperly disposed of, ending up in surface and/or groundwaters drawn on by drinking water utilities. Only limited data exists for the occurrence of pharmaceuticals in drinking water, less data is available on personal care products.

Personal care products (PCPs) such as shampoos, fragrances, sunscreen ingredients, insect repellant, and herbal remedies also are entering public drinking water supplies.

A more thorough list of EDCs and PhACs, by their category of use and specific chemical names.

These compounds are variously identified according to their use or chemical class. Many compounds found in wastewater influent and effluent, and in soil, have not yet been studied for possible biological effects.

Without definitive knowledge of how EDCs, PhACs, PCPs and a host of unexamined compounds – even in trace concentrations – may affect human health, and given these compounds' ubiquity, their observed effect on fish, amphibians, and birds, and their continued presence of some compounds after wastewater treatment processes, the consensus in the drinking water community is that they deserve close study and, possibly, mitigation efforts.

Q: Which specific compounds are the most common and likely to be a concern for drinking water utilities?

A: The most common EDCs include pesticides, steroids, and industrial chemicals. Frequently occurring PhACs include antibiotics, painkillers, antidepressants, x-ray contrast media. Common PCPs include synthetic musks, detergents, sunscreens, and antimicrobials. These contaminants and their concentrations vary from urban to rural settings, watershed to watershed, nation to nation.

An expert workshop convened by AwwaRF in 2004 to develop research goals included a strategy for cutting the monitoring task down to size for this massive category of potential contaminants: develop a short list of pharmaceuticals for monitoring, focus on compounds with suspected risks, and regard pharmaceuticals as tracers for wastewater-derived contaminants.

Drinking water sources of concern include surface waters impacted by wastewater treatment plant effluent, aquifers recharged with effluent (SAT), and water from advanced treatment systems.

According to AwwaRF's *Occurrence Survey of Pharmaceutically Active Compounds* (order # 91051), in a United States survey, PhACs are present at detectable concentrations in the effluent of wastewater treatment plants. Compounds detected at the highest concentrations were gemfibrozil, naproxen, sulfamethoxazole, and trimethoprim – all ranked among the top 30 drugs with respect to predicted concentrations in wastewater. The main source of PhACs is municipal wastewater, although some PhACs are successfully removed during wastewater treatment.

Q: How do you monitor and measure the presence of these various chemicals and compounds in drinking water?

A: In AwwaRF's study *Occurrence Survey of Pharmaceutically Active Compounds* (order # 91051) it was determined that although a large number of PhACs are used in the United States, a relatively limited number of compounds can be detected frequently with existing analytical methods. The concentrations of PhACs detected in the aquatic environment typically are less than 100 ng/L (i.e., < 0.1 µg/L). Because it is difficult to measure trace concentrations of PhACs, it is difficult to detect PhACs in most water supplies.

PhACs can be monitored by gas chromatography/tandem mass spectrometry (GC/MS) and high performance liquid chromatography/mass spectrometry (HPLC/MS). These methods require careful attention to detail and rigorous quality assurance/quality control (QA/QC) measures.

If it is necessary to monitor PhACs in drinking water sources, the analytical methods described in *Occurrence Survey...* can be used. It is important, however, that the laboratory analyze control samples and matrix recovery samples before beginning a monitoring program.

Direct measurement in nanograms per liter is difficult, sometimes not specific enough, and can be expensive. The following list of processes has proven useful in detecting and measuring concentrations of EDCs, PhACs, and PCPs in water samples:

- bioassays and immunoassays that determine biological activity
- GC/MS (gas chromatography/tandem mass spectrometry)
- LC/MS (mass spectrometers)
- mass spectrometers

AwwaRF research suggests that in the absence of specific regulatory requirements on EDCs, PhACs, and PCPs, drinking water utilities should consider first answering a list of questions to clarify their purpose in monitoring for these compounds:

- Specifically, which compounds are you attempting to monitor?
- At what level?
- For what reason?
- Are wastewater treatment plants located upstream in surface water sources?
- Are you attempting to address regulations?
- What is your budget for monitoring and measuring?
- How do you intend to use the data you gather?

Q: What are the most effective methods for removing these compounds?

A: An AwwaRF study titled "Evaluation of Conventional and Advanced Treatment Processes to Remove Endocrine Disruptors and Pharmaceutically Active Compounds" (project # 2758) found that among conventional processes, coagulation, flocculation, and sedimentation are ineffective for removing the majority of target EDCs, PhACs, and PCPs. Free chlorine disinfection can remove many target compounds, depending on the structure of the contaminant. Chloramines are less effective than free chlorine at removing EDCs, PhACs, and PCPs.

Among advanced processes, ozone is much more effective than chlorine, and is able to significantly remove the majority of target analytes. Ultraviolet (UV) irradiation at disinfection doses is ineffective for removing most EDCs, PhACs, and PCPs. High energy UV at oxidative doses, however, can be highly effective. Advanced oxidation processes (AOPs) – e.g., ozone/peroxide and UV/peroxide – are highly effective at removing the majority of the contaminants evaluated in project # 2758.

Activated carbon is highly effective for removal of target analytes, though exhausted activated carbon is ineffective. Magnetic ion-exchange is ineffective for the removal of most EDCs and PPCPs. Reverse osmosis and

nanofiltration are highly effective for removing EDCs and PPCPs, while ultrafiltration and microfiltration are largely ineffective. Biological removal and sorption processes can reduce the concentrations of many target analytes during riverbank filtration, biological filtration, and soil aquifer treatment.

Treatment trains combining various advanced processes – e.g., reverse osmosis, ozone, AOPs, activated carbon – are the most effective for removing trace concentrations of EDCs, PhACs, and PCPs, according to project # 2758, which is due for publication in fall 2005.

AwwaRF's *Occurrence Survey of Pharmaceutically Active Compounds* (order # 91051) analyzed samples from three full-scale advanced wastewater treatment plants and found that concentrations of PhACs decrease during advanced treatment. Trace concentrations of certain PhACs, however, still were detected in effluent from advanced treatment plants.

Soil aquifer treatment (SAT) also resulted in decreased concentrations of PhACs, particularly acidic drugs, beta-blockers, and antibiotics, although low concentrations of certain PhACs still can be detected after SAT. Little removal of PhACs occurred in the two engineered-treatment wetlands under study, even at hydraulic residence times of up to one week.

Q: What is the current regulatory status of EDCs, PhACs, and PCPs in the United States ?

A: In the United States , the U.S. Environmental Protection Agency has regulatory authority over EDCs through five programs:

- Safe Drinking Water Act (SDWA)
- Endocrine Disruptors Screening and Testing Program (EDSTP)
- Food Quality Protection Act (FQPA)
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- Toxic Substances Control Act (TSCA)

Under the SDWA, the USEPA is required to publish every five years a Contaminant Candidate List (CCL) of contaminants known or anticipated to occur in public water supplies. The EDSTP issued a final report in 1998 outlining a multi-tiered approach of screening, testing, and assessment for the evaluation of some 87,000 compounds – a reflection of the potentially wide-ranging nature of the EDC issue.

The EDSTP report calls for the USEPA to prioritize potential contaminants, then validate public health concerns for selected compounds through screening and testing, identify any adverse effects, and establish a dose-response relationship for hazard assessment. Those efforts are currently ongoing.

In an article on the regulation of EDCs, "Endocrine Disruptors as a New Regulatory Endpoint," Alan Roberson, director of security and regulatory affairs for AWWA, concludes that it remains unclear how USEPA's efforts to implement the Endocrine Disruptor Screening Program (EDSP) will impact drinking water regulations.

In Roberson's view, USEPA's assessment of endocrine disruptors could conceivably shift the focus of drinking water regulations from the long-term concept typical with carcinogens, to more frequent monitoring and shorter timeframe for compliance determination that may be appropriate for compounds such as EDCs. This is due to

EDCs' far shorter window of exposure risks and the nature of their health effects (developmental and reproductive).

In the case of atrazine, for instance – one of the first compounds to be assessed based on a reproductive and developmental endpoint – instead of compliance based on an annual average based on quarterly samples, compliance conceivably could become based on a 90-day average of bi-weekly or monthly samples, Roberson suggests. This would require drinking water utilities to use rapid, accurate, and cost-effective analytical methods that have yet to be developed.

Based on the large number of potential endocrine disruptors, new regulations could shift towards regulating compounds as a class based on a common mechanism for toxicity (e.g., endocrine disruption) or similar chemical structure rather than by individual compound. Another possible regulatory approach could require a specific treatment technology (e.g., granular activated carbon) for an array of chemicals, instead of setting standards for a class of chemicals or a proliferation of specific MCLs.

USEPA's presentation on its current regulatory stance on EDCs, PhACs, and PCPs.

Q: How should water utilities communicate with the public about EDCs, PhACs, and PCPs, which may be perceived by the public as emerging contaminants?

A: When drinking water utilities acknowledge and respond to stakeholder concerns, they demonstrate respect, help educate, and build trust with the public. Utilities can accomplish these goals with a systems-based risk communication program. That means implementing a senior management-supported, long-term effort on risk communication strategies – in advance of a specific issue – that adequately addresses the public's concerns on emerging contaminants.

This requires a well-grounded understanding of the science of the contaminants, their occurrence, how treatment affects them, and as well as the demographics of a utility's service area and the perceptions and communications needs of subgroups in the population. The AwwaRF report, *Risk Communication for Emerging Contaminants* (order # 91047F), offers utilities a diagnostic guide to aid utilities in assessing the need to communicate about specific emerging contaminant risks.

Q: What is the direction and nature of ongoing and future AwwaRF studies on EDCs?

A: Having initiated its own EDC-related research in 1999, AwwaRF has surveyed the literature, gathered and analyzed occurrence data, and assessed analytical methods and treatment options. Through its work with the Global Water Research Coalition (GWRC), AwwaRF has also participated in the publication of a half-dozen reports on a global research strategy, global occurrence, analysis, and treatment studies.

Ongoing efforts are examining conventional and advanced treatment for removing EDCs, PhACs, and PCPs, the toxicological relevance of these compounds in drinking water, and focusing in on specific, target contaminants such as triclosan.

Subscribers may be particularly interested in following "Toxicological Relevance of Endocrine Disrupting Chemicals and Pharmaceuticals in Drinking Water" (project # 3085), funded in 2004. This project will address the fundamental issue of potential human health impacts from trace concentrations of EDCs and pharmaceuticals

detected in drinking waters from across the United States by combining toxicological literature reviews and analytical monitoring results.

The study will also compare drinking water risks from these contaminants with risks from similar air- and food-borne chemicals. Further, a comparative risk assessment will be conducted to compare the risk of trace estrogens in drinking waters to the risks from natural estrogens in the human diet. Bioassay results from raw and finished waters will be compared to those from food items in order to develop comparisons that are comprehensible to the public. Ultimately, the study should contribute to the overall purpose of developing sensible treatment and analytical goals to inform utility operators and regulators.

New AwwaRF studies

"Removal and Fate of EDCs and Pharmaceuticals in Bank Filtration Systems" (project # 3136, partnership with Water Technology Center , funded in 2005, completion date TBD)

Ongoing AwwaRF studies

"Toxicological Relevance of Endocrine Disruptors and Pharmaceuticals in Drinking Water" (project # 3085, funded in 2004, completion due in 2007)

"Pharmaceuticals, Personal Care Products, and Endocrine Disruptors – Occurrence, Fate, and Transport in the Great Lakes Water Supplies and the Effect of Advanced Treatment Processes on Their Removal" (project # 3071, funded in 2004, completion due in 2007)

"Comprehensive Utility Guide for Endocrine Disruptors and Pharmaceuticals in Drinking Water" (project # 3033, funded in 2004, completion due in 2007)

"Research Strategy Workshop on Pharmaceuticals and Personal Care Products in the Water Cycle" (project # 2972)

"Evaluation of Triclosan Reactivity in Chlorinated and Monochloraminated Waters" (project # 2902, funded in 2002, completion due in 2005)

"Impact of UV and UV-Advanced Oxidation Processes on Toxicity of Endocrine-Disrupting Compounds in Water" (project # 2897, funded in 2002, completion due in 2006)

"Evaluation of Conventional and Advanced Treatment Processes to Remove Endocrine Disruptors and Pharmaceutically Active Compounds" (project # 2758, funded in 2001, completion due in 2005)

Published reports

"Research Strategy Workshop on Pharmaceuticals and Personal Care Products in the Water Cycle" (project # 2972) funded in 2003, partnership with CUWA, NWRI, USEPA, WERF, WRF, and GWRC, resulting in *Pharmaceuticals and Personal Care Products in the Water Cycle: Report of the GWRC Research Strategy Workshop* (London: GWRC, 2004)

"Pharmaceutically Active Chemicals Research" (project # 2785) funded in 2001, produced another study (project # 2617) and the report, *Occurrence Survey of Pharmaceutically Active Compounds* (order # 91051) partnership with WRF

Pharmaceuticals and Personal Care Products in the Water Cycle: Report of the GWRC Research Strategy Workshop (London: GWRC, 2004) AwwaRF participation

Pharmaceuticals and Personal Care Products in the Water Cycle: An International Review (London: GWRC, 2004) AwwaRF participation

Endocrine Disrupting Compounds: Priority List of EDCs (London: GWRC, 2003) AwwaRF participation

Endocrine Disrupting Compounds: An Overview of Sources and Biological Methods for Measuring EDC (London: GWRC, 2003) AwwaRF participation

Endocrine Disrupting Compounds: Occurrence of EDC in Water Systems (London: GWRC, 2003) AwwaRF participation

Endocrine Disrupting Compounds: Workshop on Knowledge Gaps and Research Needs of EDC in Water Systems (London: GWRC, 2003) AwwaRF participation

Risk Communication for Emerging Contaminants (order # 91047F)

Assessment of Waters for Estrogenic Activity (order # 90940F)

Endocrine Disruptors and Pharmaceuticals in Drinking Water (order # 90849), partnership with WERF and WRF