

# PHARMACEUTICALS AND PERSONAL CARE PRODUCTS IN DRINKING WATER

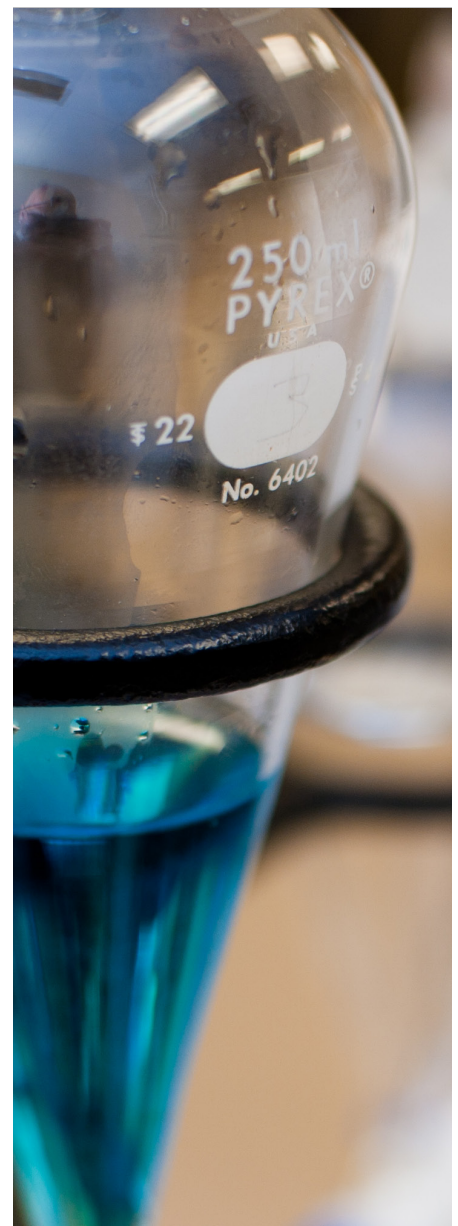


# Pharmaceuticals and Personal Care Products in Drinking Water

Scientific advances in pharmaceutical therapies and the growing availability of pharmaceutical drugs has done much to improve the overall health of the world's population. But the widespread use of pharmaceuticals and other personal care products has increased concerns about concentrations of these substances throughout the water cycle, including surface and ground waters, wastewater, and drinking water. Despite seemingly small concentrations, the presence of pharmaceuticals in drinking water has raised concerns about the potential risks to human health from exposure to water-borne pharmaceuticals.

In part, the increased detection of pharmaceuticals in drinking water is due to advances in analytical technology that support the measurement of concentrations to levels as low as the nanogram per liter range. However, the effects of prolonged exposure to even small concentrations of pharmaceuticals in water are not well understood. Further, since the use of pharmaceuticals and other personal care products is expected to increase, the risk from their introduction into the water system will also rise. As such, water supply stakeholders, including government officials, drinking water regulators, water suppliers and the general public, are focusing increased attention on pharmaceutical concentration levels in drinking water.

This UL white paper provides an overview of the issues related to the presence of pharmaceuticals and personal care products (PPCPs) in drinking water. The paper discusses the possible effects of PPCPs on humans and on the environment and summarizes recent research conducted by U.S. government agencies, UL and others on PPCP concentrations found in public drinking water supplies and wastewater facilities. The white paper also discusses available water treatment options for reducing PPCP concentrations and their relative effectiveness. The paper concludes with areas for further research and a preview of possible future regulatory actions.





### Types and Sources of PPCPs in Drinking Water

In general, the term PPCP refers to any product used for either personal health or cosmetic reasons as well as any product used in the agricultural industry to maintain the health or enhance the growth of livestock. Specifically, PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs for humans and animals, biopharmaceuticals, diagnostic agents, vitamins and other nutritional supplements, cosmetics and fragrances, and growth-enhancing chemicals used in livestock operations.<sup>1</sup>

PPCPs enter the water supply as a result of multiple industrial, commercial and agricultural activities and pharmaceutical manufacturing (although the latter is tightly regulated<sup>2</sup>). PPCPs also enter the water supply in the form of residue from hospitals and other healthcare facilities and as a byproduct of veterinary drug use, most notably antibiotics and steroids. Water-born PPCPs can also result from the surreptitious disposal of illegal drugs.

Individual consumers are also an important source, both intentionally and unintentionally, of PPCPs found in water. Consumers often dispose of unused prescription medications by including them with household refuse or flushing them through their home plumbing systems. But unintentional PPCP contamination of water by consumers also occurs through the simple elimination of waste material from the body, since drugs are not always fully metabolized by the body, and also

through bathing or showering, when soaps and cosmetic creams are washed from the body into the waste water system.

### The Impact of PPCPs in Drinking Water

While there are no confirmed adverse human health effects associated with PPCPs in drinking water, PPCP contamination remains a significant concern. For example, pharmaceuticals are designed to interact with cellular-level receptors at low concentrations to induce specific biological effects, and the side effects caused by interaction with nonreceptor targets are unpredictable and poorly understood. Further, certain strains of bacteria subject to prolonged exposure to antibiotics can develop resistance to those antibiotics, resulting in strains of drug-resistant bacteria.

Other PPCPs, such as steroid hormones like estrone, progesterone and testosterone and fragrance additives like galaxolide, have been identified as endocrine-disrupting compounds (EDCs). EDCs are synthetic chemicals that block or mimic natural hormones in the body, disrupting normal organ function. It is important to note that EDCs, even at extremely low concentrations, can have effects on the human endocrine system.<sup>3</sup>

Beyond potential effects on human health from exposure the PPCPs in water, there are also potential consequences for aquatic life, where the exposure risk is potentially much greater. Fish and aquatic organisms can experience continual exposure to PPCP concentrations, often at higher concentrations than found in

treated water. In addition, prolonged multi-generational exposure can lead to effects that accumulate over time.<sup>4</sup>

### Research on PPCPs in Water

Research on PPCPs in water has been ongoing for nearly 20 years, with the first Environmental Protection Agency (EPA) studies on conventional, nonconventional and toxic pollutants in water dating to 1982. The EPA web-site lists more than 100 separate research projects related to PPCPs in which the EPA has been or is currently involved,<sup>5</sup> and the agency maintains an extensive database of published literature on PPCPs as environmental contaminants.<sup>6</sup> Here is a brief summary of some of the key research that has been conducted concerning PPCPs in water.

#### National Reconnaissance of Pharmaceuticals, Hormones and Other Organic Wastewater Contaminants in Streams of the U.S., 1999-2000

This important field study<sup>7</sup> was conducted by researchers at the U.S. Geological Survey in 1999 and 2000 to provide baseline information on the occurrences of pharmaceuticals, hormones and other wastewater contaminants in water resources. Concentrations of 95 separate organic wastewater contaminants (OWCs) were measured in water samples taken from 139 streams in 30 states across the United States. Researchers found OWCs in 80% of the streams sampled, with coprostanol (a fecal steroid), cholesterol (a plant and animal steroid), tridosan (an antimicrobial disinfectant), 4-nonylphenol (a non-ionic detergent metabolite) and caffeine as the most frequently detected compounds.



According to the results of this field study, the measured concentrations of OWCs found were low - generally, less than one part per billion - and rarely in excess of drinking water guidelines or health advisories. However, researchers noted that concentration guidelines have been established for only 14 of the 95 identified compounds. The study's report recommended further research to "fully understand not only the fate and transport of OWCs in the hydrologic system but also their ultimate overall effect on human health and the environment."

### Study of Occurrence of Contaminants of Emerging Concern in Wastewater

This multi-stage study<sup>8</sup> was conducted by the U.S. Environmental Protection Agency (EPA) from 2005 through 2008 to identify contaminants of emerging concern (CECs) found in untreated and fully treated wastewater at publically owned water treatment facilities in the United States. The CECs evaluated in this study included PPCPs, steroids and hormones, bisphenol A (BPA), commercial flame retardants, and pesticides. A total of 72 different PPCPs were tested in both influent and effluent samples.

According to the final report issued in August 2009, detectable amounts of 44 different PPCPs were identified in at least one influent sample collected, and 27 different PPCPs were detected in 75% or more of the influent samples analyzed. For effluent samples, 33 separate PPCPs were detected in at least one sample, and 16 were detected in less than 25% of the effluent samples analyzed. Pharmaceutical antibiotics represented the category of PPCPs most frequently identified, accounting for half of the total PPCPs identified in both influent and effluent samples.

EPA researchers cautioned that the results of this study were not statistically representative of all public-owned treatment works. Further, although the study measured PPCP concentrations in both influent and effluent samples from water treatment facilities, researchers noted that the data were insufficient to draw any conclusions about the effectiveness of various treatment methods.

An important byproduct of this EPA study was the development of new analytical methods for detecting the occurrence of PPCPs and other contaminants in untreated and fully treated wastewater and sludge. These methods include "Method 1694: Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC/MS/MS,"<sup>9</sup> and "Method 1698: Steroids and Hormones in Water, Soil, Sediment, and Biosolids by HRGC/HRMS."<sup>10</sup> The methods cover over 100 separate chemicals, 74 PPCPs, and 27 steroids and hormones.

### "Pharmaceuticals in Drinking Water"

Published in June 2011 by the United Nation's World Health Organization (WHO), this technical report<sup>11</sup> is based on work conducted by a WHO working group that included experts in water quality and health, water treatment, drinking water regulation and policy, and water quality and health. The chief goal of the working group was to review and summarize available scientific knowledge about pharmaceuticals in drinking water, and recommend steps for managing the problem.





The WHO report determined that concentration levels of pharmaceuticals in drinking water fall outside the scope and sensitivity of the analytical methodologies that are prescribed for compliance analysis of drinking water. However, WHO experts acknowledged that there are “very few systematic monitoring programmes or comprehensive, systematic studies on the occurrence of pharmaceuticals in drinking-water.” Further, according to the report, the “limited occurrence data present one of the key challenges in assessing the potential risks associated with trace concentrations of pharmaceuticals in drinking-water.” The report concluded that “future research ... may be beneficial to better characterize potential health risks from long-term, low-level exposure to pharmaceuticals.”

### Research by the Associated Press

Research into the presence of pharmaceuticals and other personal care products in drinking water has not been limited to U.S. government agencies. A five-month long investigation in 2008 by the Associated Press (AP)<sup>12</sup> analyzed federal drinking water databases, reviewed hundreds of scientific reports, and interviewed more than 230 officials, scientists and academics. AP’s investigatory team also surveyed drinking water system providers in 50 of the largest cities in the United States as well as small community water providers in all 50 states.

AP’s investigation determined that a wide array of pharmaceuticals, including antibiotics, anti-convulsant drugs and mood stabilizers, were found in the drinking water supplies that serve at

least 41 million Americans. Specifically, pharmaceuticals were found in the drinking water supplies of 24 major U.S. metropolitan areas. The AP investigation also tested samples from the watersheds of 35 of the 62 major providers and found pharmaceutical concentrations in 28 of those watersheds.

### Research by UL

As noted in the WHO technical study discussed above, concentrations of pharmaceuticals in drinking water have often been below levels detectable with most analytical testing equipment. But most studies on PPCPs also concede that the effects of prolonged exposure to even small concentrations of pharmaceuticals in water are not well understood. Although the increased detection of PPCPs in drinking water in recent years is due, in part, to advances in analytical technology, continued technological advances along with routine monitoring are necessary to fully understand the occurrence of these contaminants and their relevance to human health and the environment.

UL has a long history of developing analytical technologies for emerging contaminants in drinking water. During the past decade UL has invested in advanced analytical equipment such as high performance liquid chromatograph with triple quadrupole mass spectrometer (HPLC/MS/MS). When coupled with various sample preparation techniques, this technology has enabled UL to develop several analytical methods to detect a wide range of emerging contaminants in the parts per trillion (ppt) concentration range. This level of detection represents a thousand-fold increase in measurement

sensitivity when compared with the parts per billion (ppb) concentration range available with standard analytical equipment and methods.

UL has leveraged these advanced analytical technologies to enable increased understanding of the occurrence of PPCPs and EDCs in drinking water. Table 1 lists the 10 most frequently detected PPCPs submitted to UL from various cities in 30 states between 2008 and 2009. A total of 57 different PPCPs and 17 different EDCs were detected.

While the concentrations of PPCPs found in drinking water supplies sampled by UL were millions of times lower than the concentrations prescribed for therapeutic effect, additional research by the EPA and others is underway to determine the potential health risk to humans and ecological systems of PPCPs at these concentration levels.

More recently, UL has continued its efforts to further develop its own testing methods for identifying PPCPs and other contaminants in water. In 2009 and 2010, UL developed a specific method for the analysis of PPCPs and EDCs based on prior proprietary testing methods. The new method, L222, focuses on the detection and analysis of almost 30 of the most frequently detected and studied PPCP and EDCs, including acetaminophen, bisphenol A, caffeine, DEET, estrone, nicotine, nonylphenol and triclosan. UL also created method S190, which streamlined the analysis of selected semi-volatile organic compounds, including sterols, phosphate flame retardants, fragrances, polyaromatic hydrocarbons (PAHs), phenols and pesticides.



NAME	(# OF SAMPLES)	USE	MEDIAN LEVEL DETECTED (PPT)
Carbamazapine	235	Mood stabilizer	10.3
Cotinine	221	Metabolite of nicotine	3.4
DEET	221	Insect repellent	15.2
Galaxolide	134	Synthetic fragrance used in cosmetics, cleaners & perfumes	61.5
Gemfibrozil	264	Cholesterol lowering drug	5.9
Nicotine	221	Tobacco products	15.6
Sulfamethoxazole	219	Antibiotic	34.9
Paraxanthine	219	Metabolite of caffeine	20.7
Acetaminophen	219	Analgesic	8.1
Caffeine	235	Coffee, tea, soda	104

Table 1: Top ten PPCPs found in drinking water samples tested at UL

### Treatment Methods for PPCPs in Drinking Water

Most conventional water treatment systems are not specifically engineered or equipped to remove PPCPs from drinking water. However, depending on the specific chemical class of the contaminant, there is a range of treatment methodologies that have proven effective for removing PPCPs or reducing their concentration.

Such methodologies include:

- Activated carbon
- Biologically activated carbon
- Ozone/advanced oxidation processes
- Ultraviolet (UV) treatments
- Nanofiltration
- Reverse osmosis

According to some researchers,<sup>13</sup> a number of individual water treatment methods have demonstrated high levels

of success in removing PPCPs in several classifications, as follows:

- More than 90% of steroids can be removed from drinking water using activated sludge, activated carbon, biologically activated carbon, ozone/advanced oxidation processes, UV treatments and reverse osmosis
- More than 90% of antibiotics, antidepressants and antimicrobials can be removed using activated carbon, biologically activated carbon, nanofiltration and reverse osmosis
- More than 90% of anti-inflammatories can be removed using activated carbon, biologically activated carbon, ozone/ advanced oxidation processes, UV treatments, nanofiltration and reverse osmosis

- More than 90% of lipid regulators can be removed using activated carbon, biologically activated carbon, ozone/advanced oxidation processes, nanofiltration and reverse osmosis
- Less than 40% of listed PPCPs can be removed through the use of coagulation/flocculation and softening/metal oxides

The EPA’s Office of Water maintains an inventory of scientific studies and literature on the treatment of CECs, which includes abstracts of over 400 documents available through the U.S. National Library of Medicine and other sources. The EPA’s 2010 report, “Treating Contaminants of Emerging Concern,”<sup>14</sup> offers a detailed review of the effectiveness of various types of treatment methodologies, based on compiled data from a subset of the EPA’s research document inventory.



## Areas for Future Research and Possible Regulation

As authorized under the U.S. Safe Drinking Water Act (SDWA), the EPA sets drinking water standards to control contaminants in the public drinking water supply, and currently has drinking water regulations for more than 90 separate contaminants. To determine whether a contaminant should be regulated, the EPA analyzes peer-reviewed science addressing a number of variables, including the occurrence levels of a contaminant in the environment, routes of human exposure and the health effects of exposure, particularly the effects on vulnerable subpopulations.

The fact that contaminants are detected in trace amounts does not alone imply risk to humans. Significant research is still

needed to understand both the scope of the problem and its implications for our public drinking water supply. The EPA has several research efforts currently underway to strengthen the science for understanding the behavior of PPCPs in drinking water, including research, methods development and occurrence studies. Data from this research will assist the agency in determining whether regulations regarding acceptable concentrations of PPCPs in drinking water and the testing of public drinking water systems should be considered, even in the absence of health-based standards.

As part of its ongoing research to determine the occurrence of contaminants of emerging concern, the EPA has recently proposed the Unregulated Contaminant Monitoring

Rule (UCMR 3). UCMR 3 will require all public water systems serving more than 10,000 people, as well as a representative sample of the 800 systems serving 10,000 or fewer people, to conduct assessment monitoring for the presence of 28 separate chemicals during a 12-month period. The rule will require public water systems (PWS) to conduct this occurrence monitoring from January 2013 through December 2015. Included in UCMR 3 are a number of hormones, including equilin and esteron (used in estrogen replacement therapies) and testosterone. Although these substances are not currently regulated by national primary drinking water regulations, the EPA will use the data from this and prior UCMR assessment phases to determine whether further regulations are in the interest of public health.<sup>15</sup>



### Conclusion

The presence of PPCPs and other emerging contaminants in drinking water is not a new issue, and significant research is still required to understand both the scope of the problem and its implications for the safety of the public drinking water supply. However, advancements in analytical technologies now make it possible to analyze a wider range of contaminants in drinking water with greater specificity and sensitivity than at any time in the past. Only a few laboratories, including UL, have developed methods to detect pharmaceuticals and other compounds at ultralow levels.

UL is a recognized leader in drinking water analysis and has analyzed over 2.5 million samples for thousands of water utilities, bottled water producers, engineering firms, and state and federal governments, including the U.S. EPA and the U.S. military. UL is one of only a few laboratories in the United States that can analyze a wide variety of emerging contaminants in drinking water, including PPCPs, estrogens and other hormones, phenolic endocrine disrupters, brominated and phosphate flame retardants, herbicide degradates, and perfluorochemicals. With advanced detection methodologies, UL can analyze drinking water for a broad range of contaminants using the most efficient methods available, thereby streamlining the testing process and reducing testing costs.

For more information about the “Pharmaceuticals and Personal Care Products in Drinking Water” white paper, please contact Laura Snell, marketing manager – Food & Water, at [Laura.J.Snell@ul.com](mailto:Laura.J.Snell@ul.com)

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- <sup>4</sup>"Frequent Questions: Pharmaceuticals and Personal Care Products (PPCPs)." *U.S. Environmental Protection Agency*. 4 Nov 2011. [www.epa.gov/ppcp/faq.html](http://www.epa.gov/ppcp/faq.html)
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- <sup>6</sup>"Published Literature Relevant to Issues Surrounding PPCPs as Environmental Contaminants." *U.S. Environmental Protection Agency*. Web. 7 Nov 2011. [www.epa.gov/ppcp/lit.html](http://www.epa.gov/ppcp/lit.html)
- <sup>7</sup> Kolpin, D., Furlong, E., Meyer, M., and others. "Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in U.S. Streams, 1999-2000: A National Reconnaissance." published in *Environmental Science & Technology*, 15 Mar 2002. Web. 7 Nov 2011. An abstract of the study report is available at <http://pubs.acs.org/doi/full/10.1021/es011055j>. Additional information about this study, as well as study data, is available at [http://toxics.usgs.gov/regional/emc\\_surfacewater.html](http://toxics.usgs.gov/regional/emc_surfacewater.html)
- <sup>8</sup>"Occurrence of Contaminants of Emerging Concern in Wastewater from Nine Publically Owned Treatment Works." *U.S. Environmental Protection Agency*, Aug. 2009. Web. 7 Nov 2011. <http://tiny.cc/wnzfr>
- <sup>9</sup>"Method 1694: Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC/MS/MS." *U.S. Environmental Protection Agency*. Dec. 2007. Web, 10 Nov 2011. [http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/2008\\_01\\_03\\_methods\\_method\\_1694.pdf](http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/2008_01_03_methods_method_1694.pdf)
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