THE Water Research FOUNDATION

Compounds of Emerging Concern

THE CHALLENGE

As new methods and technologies allow us to more effectively detect chemicals and other substances at lower levels, we get a better picture of what's in our water—zeroing in on substances that were either previously not measurable or may be newly introduced. From medicine and personal care products to pesticides and flame retardants, everyday activities result in many compounds winding up in our wastewater systems and potentially making their way into our water sources. And because we are just beginning to recognize their presence, there is uncertainty about their short- and long-term health effects, as well as the best processes to reduce or remove them.

We already know that some of these substances, known as endocrine disrupting compounds (EDCs), can trigger developmental and reproductive effects in aquatic life. Additionally, many compounds may bioaccumulate and can be passed up the food chain. As more data becomes available and awareness increases regarding the potential presence of these compounds, regulations could follow suit—setting limits for these compounds that the water sector must comply with. Utilities are increasingly faced with finding new approaches for monitoring and treatment that account for these compounds, and must also be prepared to address new concerns that are not yet known.

THE RESEARCH

Since the late 1970s, WRF has built a body of research on compounds of emerging concern (CECs). Some of the first research involved volatile organic compounds (VOCs), a group of chemicals that are off-gassed from things like paint and pesticides. In the following years, WRF expanded this research, exploring pharmaceuticals and personal care products (PPCPs) and other chemical compounds including radionuclides, hexavalent chromium, perchlorate, and manganese. WRF research also investigates biological compounds, addressing long-standing issues with cyanotoxins, as well as the more recent interest in areas like antibiotic-resistant bacteria, microplastics, and per- and polyfluoroalkyl substances (PFAS).

With nearly 250 projects in this area, WRF research is building the scientific base to understand how these compounds behave in the environment—including wastewater, drinking water, and recycled water systems—and to assess the impacts to ecological and human health. The foundation's research helps develop the resources and guidance the water sector needs to identify, monitor, and treat these compounds, as well as to communicate with the public about any potential risks.

Because this topic has implications beyond the water sector, such as health, pharmaceuticals, and manufacturing, WRF has collaborated with strategic partners, connecting world-class experts to ensure that research is based on the best science. As a result, WRF took a key step in mapping a collaborative research plan by hosting the 2007 Workshop on Trace Organics (CEC1W06). The event provided a forum for a dozen research-funding organizations to share current and planned research efforts on CECs, identify potential partners, and develop a unified path forward.

Occurrence

CECs have likely been present in water for as long as humans have been using them; however, an increase in the number and volume of chemicals being manufactured and used, coupled with advances in technology, is raising interest in detecting their occurrence in the environment. WRF emerged as an early leader in this area, helping the water sector better understand the various compounds that are present and providing the tools and resources to more accurately detect and measure them in all water sources. A key step in this process was the 2002 project *Endocrine Disruptors and Pharmaceuticals in Drinking Water and Wastewater* (2598), which brought together water and health organizations, as well as utilities, to establish the state of the science on the presence of EDCs and PPCPs in water and to identify critical questions and research needs.

In 2005, WRF made another significant advancement with the release of *Occurrence Survey of Pharmaceutically Active Compounds* (2617). Based on early reports from Europe on the detection of pharmaceuticals in wastewater and surface water, this effort began investigating their presence in U.S. water. The results confirmed the presence of these drugs at detectable levels, but also shed light on the ability of advanced wastewater treatment to significantly lower concentrations. The research also led to the development of reliable analytical methods for tracing acidic drugs, beta-blockers, and antibiotics.

Building on this research, the 2015 WRF study *A Comprehensive Overview of EDCs and PPCPs in Water* (4387) provides one of the first overarching views of the specific compounds frequently found in the water environment. Based on samples from source water, wastewater influent and effluent, drinking water influent, finished drinking water, and distribution drinking water, the research breaks down the most prevalent compounds found in different sources—such as caffeine and DEET in drinking water and antibiotic compounds and herbicides found in surface water. This could help in the development of more effectively targeted treatment processes in the future.

More recently, WRF also turned its attention toward the presence of antibiotics. *Occurrence, Proliferation, and Persistence of Antibiotics and Antibiotic Resistance During Wastewater Treatment* (WERF1C15/4593) looks at several common antibiotics and examines the variables that affect their presence at wastewater plants—such as influent water quality and unit operations and conditions. The findings improve the industry's understanding of how unit processes and operational conditions impact antibiotic resistance—a key step in establishing frameworks for measuring public and environmental health risks.

Effects

Although the ability to detect CECs in water is a significant development, it does not necessarily mean that adverse health effects are likely. Many factors play a role in whether a compound will affect humans, animals, and the environment, including the dose and likelihood of exposure. WRF research is moving this science forward, helping to measure true impacts in order to assess risk, protect public health, and inform effective water quality guidelines and regulations.

Several studies published between 2008 and 2015 made important strides in understanding the effects of PPCPs and EDCs in drinking water. *Toxicological Relevance of EDCs and Pharmaceuticals in Drinking Water* (3085) takes a comprehensive look at 60 compounds of concern and, based on occurrence and a health risk evaluation, finds that none of the indicator pharmaceuticals or potential EDCs are relevant to human health at current levels in U.S. drinking water. Along the same line of research, *A Comprehensive Overview of EDCs and PPCPs in Water* (4387b) establishes acceptable daily intakes of exposure for humans and drinking water equivalent levels for nearly 400 PPCP ingredients and EDCs. These values were then used to calculate the number of glasses of water a person would have to drink per day to receive a dose that is equal to the calculated levels. Findings suggest CEC levels in drinking water are far below acceptable daily intakes. However, because people are regularly exposed to more than one chemical at a time and through multiple routes (air, food, etc.), the effects from these complex mixtures remains a subject of ongoing research.

WRF is also exploring the effects of other emerging compounds, such as microplastics. The 2017 study *Microplastics in Aquatic Systems* (CEC7R17) provides some of the first in-depth information on the effects of plastic particles in the environment and wastewater effluent, which are derived from sources like microbeads and foam packaging. Research indicates that microplastics have not been shown to cause adverse effects to aquatic wildlife, and while these particles do adsorb some toxic chemicals, they are not a significant exposure route for birds or aquatic organisms. Findings point to the possibility of macroplastics, as opposed to microplastics, as the major cause of physical harm to fish, fish-eating birds, and aquatic mammals and reptiles. However, the study also raises questions about whether existing aquatic toxicity tests effectively assess potential physical impacts, calling for improved microplastic exposure models for effluent discharges into receiving waters.

Treatment and Control

Once CECs enter a utility's water supply, no single treatment process can remove them all due to their wide range of properties. While both conventional and advanced water treatment systems have the capability to reduce concentrations, many utilities struggle with finding the right combination for their situation. WRF has conducted numerous research projects that investigate the most effective and affordable ways to control and remove these compounds, including wastewater and drinking water treatment processes and online monitoring, as well as strategies to prevent them from initially being introduced into our water systems.

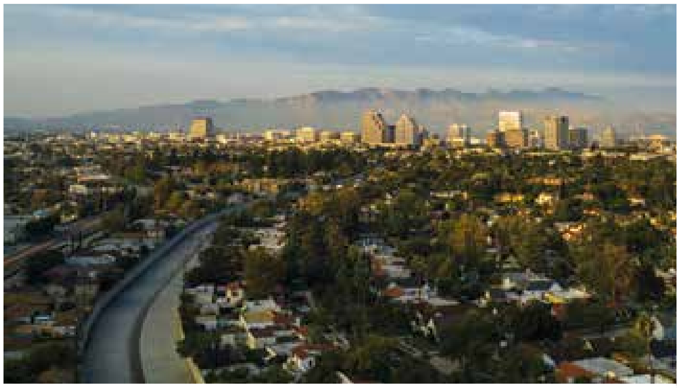
One 2014 WRF study explores the role wetlands can play in reducing these compounds. *Constructed Wetlands for Treatment of Organic and Engineered Nanomaterial Contaminants of Emerging Concern* (4334) offers insight into design criteria for wetlands to effectively remove different types of CECs, such as PPCPs, EDCs, disinfection byproducts, and engineered nanomaterials. Findings demonstrate that by controlling hydraulic flow and the amount of plant growth, wetlands upstream of drinking water intakes can efficiently remove nitrates and other pollutants, while simultaneously removing CECs.

Another WRF study released that same year made progress in the removal of hexavalent chromium, or Cr(VI). *Impact of Water Quality on Hexavalent Chromium Removal Efficiency and Cost* (4450) analyzes the pros and cons of three of the most promising treatment options for Cr(VI), helping utilities determine the most appropriate treatment solution for their situation based on unique aspects of water quality and treatment site characteristics. The report also features a companion cost estimating tool to help project a range of potential costs for Cr(VI) removal.

Between 2014 and 2015, WRF teamed up with EPA to release a series of reports on treatment processes for carcinogenic VOCs (cVOCs). *Removal of Volatile Organic Contaminants via Low-Profile Aeration Technology* (4439) and *Removal of Volatile Organic Contaminants from Drinking Water via Granular Activated Carbon Treatment* (INFR1SG09/4440), look at some of the most common and widely used VOC-treatment technologies—air stripping and granular activated carbon (GAC). Findings based on 12 VOCs of concern point to low-profile air strippers as a good treatment option due to their convenience, ease of use, and assembly, as well as their efficiency under wide range of conditions. The research also assesses the use of GAC to remove VOCs down to sub-ppb levels using the rapid small-scale column test, which is designed to provide data equivalent to full-scale behavior.

WRF continued collaborating with EPA on the issue of CECs, looking beyond traditional treatment, and in 2017 published findings from *Enhanced Removal of Nutrients and Trace*

SOLUTIONS IN THE FIELD: Glendale Water and Power



In 2000, Glendale Water and Power was ready to take delivery of water from a Superfund cleanup project and integrate the treated water into their distribution system. However, the water had elevated levels of hexavalent chromium. Although well below drinking water standards, the recent release of the movie *Erin Brockovich* had brought attention to this chemical, causing public concern over any presence of chromium, regardless of speciation. In response, Glendale initiated a major research effort to identify technology to remove Cr(VI). Since standard regulated levels for this specific chromium species did not exist, the utility ambitiously targeted levels of 5 parts per billion (ppb)—significantly lower than the 100 ppb federal levels for total chromium.

The 15-year research effort involved over $10M in funding from diverse partners, and when it came time to pilot some of the technologies, Glendale turned to WRF. Through a series of projects, Glendale and WRF worked to test advancements in treatment technologies, including microfiltration in the reduction/coagulation/filtration process (4365), and to evaluate new resins and adsorptive media (4423). These efforts set the course for future refinements in treatment and residual management methods, demonstrating the feasibility of Cr(VI) removal from drinking water and paving the way for others to address groundwater contamination issues.

Organic Contaminants in Pilot-Scale Stormwater Treatment Systems (4567). The report offers guidance on the design and operation of systems for controlling trace organics released into surface waters. Through testing of different media combinations to capture and treat urban stormwater, results also highlight a highly effective process for removing trace organics with the use of woodchips and biochar.

Because cyanobacteria continue to be among the most problematic organisms in our freshwater systems—with nearly a third of the United States reporting blooms—research in this area also remains a top priority for WRF. Without clear guidance or consensus regulations in place, many utilities struggle with preventing these events. Since 1994, WRF has completed more than 30 research projects on these microscopic organisms and the cyanotoxins they produce, helping facilities detect, monitor, and manage these nuisance organisms.

Communication

Communicating about CECs can be a challenge for water utilities because the science informing the risks is still evolving. Because these compounds are also frequently the focus of media attention, the public often has preconceived ideas that might be driven by fear. To help encourage transparent and effective dialog, WRF has provided some of the water sector's first scientifically based guidance on communicating about CECs in water and the potential impacts.

In 2005, WRF released *Risk Communication for Emerging Contaminants* (2776), which features a diagnostic tool based on business management strategies to help utilities determine when to communicate about emerging contaminants. The research also highlights how experts and the public view these contaminants, identifying key factors that influence consumer judgment and perception.

Core Messages for Chromium, Medicines and Personal Care Products, NDMA, and VOCs (4457), released in 2015, generated a series of products to help the water community communicate with different audiences about the risks of several key CECs, taking into account consumer risk perceptions. An animated film, *Protecting Our Drinking Water*, provides an easy-to-understand overview of some of the most prevalent CECs, covering issues such as occurrence, treatment, and regulations and how they are all linked to clean, safe water. The project also produced question-and-answer articles and technical information sheets for these substances.

OTHER RESOURCES

For more information on WRF's efforts on various compounds that enter our water systems, see:

- **Microbes & Pathogens Factsheet**
- **Per- and Polyfluoroalkyl Substances Factsheet**
- **Cyanobacteria & Cyanotoxins Factsheet**

WHAT'S NEXT?

WRF continues to invest in research on CECs that are gaining increased interest, like PFAS, antibiotics, and microplastics. The ongoing WRF projects *Evaluation and Life-Cycle Comparison of Ex-Situ Treatment Technologies for Per-and Polyfluoroalkyl Substances (PFAS) in Groundwater* (5011) and *Investigation of Treatment Alternatives for Short-Chain Per- Polyfluoroalkyl Substances* (4913) are studying innovative treatment options as well as best management practices for PFAS to prevent entry into water supplies. Another project on the horizon, *Critical Evaluation and Assessment of Health and Environmental Risks from Antibiotic Resistance in Reuse and Wastewater Applications* (4813), is examining approaches to assess public health and environmental risks associated with antibiotic-resistant bacteria and antibiotic-resistance genes in reuse and wastewater applications. Additionally, WRF is collaborating with the National Academies of Science on *Determining the Fate and Major Removal Mechanisms of Microplastics in Water and Resource Recovery Facilities* (4936), which is exploring the occurrence of microplastics throughout the entire wastewater treatment process—including liquid discharge and biosolids.

As public and environmental safety continue to be top priorities, WRF will provide the tools needed to improve treatment of CECs in wastewater effluent, source water, drinking water, and water for reuse. Recently launched projects, such as *Evaluation of CEC Removal by Ozone/BAF Treatment in Potable Reuse Applications* (Reuse-17-04), are already taking the lead—helping to develop systems and operations guidelines for new treatment options for CECs in water reuse to facilitate broad implementation. WRF will also develop a technical brief on compounds of current and future interest, which will address human health and ecological impacts looking at the entire water system in the context of one water.