WESTCAS Issue Paper
Research and Technology

CONTAMINANTS OF EMERGING CONCERN

Background

Contaminants of emerging concern, or CECs, can be broadly defined as chemicals that have been recently detected in the environment and that may pose public health or ecological risks. CECs encompass a wide variety of chemicals, including pharmaceuticals and household chemicals. Many CECs differ from conventional environmental contaminants such as pesticides, metals, polychlorinated biphenyls (PCBs), etc., in that they are used in household products. Some CECs include newer classes of compounds of environmental concern, such as nanomaterials and genetically modified food items.

CECs identified in wastewater discharges include household and industrial chemicals such as flame retardants, plasticizers, detergent compounds, pharmaceutical and personal care products (PPCPs), fragrances, and anti-microbial cleaning agents (Esposito, *et al.*, 2007).

These chemicals are “emerging” if in the public eye, brought to the attention of the United States Environmental Protection Agency (U.S. EPA) and “of concern” because of widespread exposure, persistence, bioaccumulation, or toxicity data (Hemmett, 2008).

As with any contaminant, a variety of physical, chemical, and biochemical processes, such as dilution, volatilization, sorption, hydrolysis, photolysis, and biotransformation, determine the partitioning and fate of CECs in the environment. These fate and transport processes are compound-specific. Initial studies of CEC occurrence in the environment focused on locations near sources, such as those downstream from wastewater treatment plants (WWTPs) and livestock facilities. However, recent research has indicated that some CECs may be present in relatively undeveloped areas or even a global scale (Kim *et al*., 2007).

Some CECs are known or suspected carcinogens, others may act as endocrine disrupting chemicals (EDCs), and still others are not fully understood. EDCs have the potential to affect hormone-driven processes, such as reproduction. Aquatic organisms are particularly susceptible to water-borne EDCs, because their entire life cycles occur in continuous contact with water. It has also been determined that thousands of compounds have the potential to interact with components of the endocrine system, altering the natural action of the hormone (Drewes *et al*, 2006).

Wastewater effluent is a pathway of CECs in the environment. However, human waste streams are not the only route of introduction of CECs to the environment. Chemicals such as antibiotics and insecticides are often used in concentrated animal feeding operations. As with biosolids from municipal wastewater, CECs in animal wastes, if not suitably contained, can seep into the soil and water bodies.

Regulatory Status

CECs are currently not included in routine monitoring programs for the United States, and may be candidates for future regulation, depending on research on their occurrence in various environmental matrices, toxicity, and public perception. There is currently no EPA-approved detection method for many of the listed CECs. It is challenging for the EPA to establish regulations when relatively little scientific information about the fate and transport of CECs as well as effects on wildlife and humans. Their approach is to encourage voluntary reduction while an Agency workgroup consisting of various program offices and regions gather data about specific chemicals, evaluate it to determine whether it is an "emerging chemical", and discuss approach for limiting presence in the environment (Hemmett, 2008).

While the Toxic Substances Control Act (TSCA) regulates the introduction of new and existing chemicals it grandfathered most existing chemicals. However, the European Union (EU) regulation for Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) addresses impacts of all chemical substances on the environment and human health. It is currently being phased in and will be in full force by 2018 and applies to all chemicals produced and imported into the EU.

Current Status of Technology

The great majority of WWTPs are designed to remove organic and inorganic materials, and pathogens, but are not designed to specifically destroy chemicals. One of the primary ways for CECs to enter the environment is from wastewater plants (Esposito, *et al*, 2007) where even after treatment low concentrations of contaminants, primarily human drug metabolites and animal steroid hormones and antibiotics, may still occur. CECs leave WWTP dissolved or suspended in the effluent or sorbed to biosolids. CECs in the effluent reach receiving water bodies and are further distributed in the sediment, ground water, and biota. Land applications of biosolids potentially allow the contaminants to leach into the soil, surface or ground water.

According to the USGS, contaminants have also been shown to occur in soil irrigated with reclaimed water (Kinney *et al*, 2006), accumulate in fish from wastewater treatment wetlands (Barber *et al*, 2006), and to disrupt cellular development and hormonal function in sheep reared on sewage-sludge treated pasture (Catriona *et al*, 2005). This is especially of concern for indirect potable reuse which is the planned incorporation of reclaimed water into a raw water supply. Although contaminants may be found in soil, other studies have shown that a range of CECs are removed by traveling significant distances through an unsaturated, aerobic, and moderately fine grained soil profile (Bruce, I will provide a good ref. - and perhaps additional elaboration - later - the "soil-aquifer treatment" concept is important in potential control of later human exposure by recharge through the vadose zone).

One focus of preventing CECs in the environment is through the wastewater treatment process. While additional, or tertiary, treatment is often required for CEC removal, some studies have looked at increasing hydraulic or solids retention time, optimizing activated sludge processes, and IFAS, or integrated films-activated sludge, systems. However, according to WERF, conventional treatment alone is capable of removing up to 90% of many of the most common compounds suspected of being EDCs that enter a treatment plant (Anderson, 2005). A complicating factor of wastewater treatment is, according to David Sedlack of University of California,-Berkeley, that chlorine or chloramines can convert contaminants into more problematic compounds (Ritter, 2006).

According to a WERF Technical Brief (Anderson, 2005), as of 2005 no studies in the United States have linked changes in fish population with wastewater treatment plant discharges. Additionally, according to the publication, low levels of EDCs in wastewater have not been shown to adversely affect humans.

Detection of ECs in drinking water is far less common than in surface water and wastewater, and the concentrations in drinking water are a hundred to a thousand times lower. Several studies in Europe and the U.S. have examined the concentrations of CECs in finished drinking water. Concentrations are generally less than 100 ng/L, with many of the compounds reported at levels less than 10 ng/L.

Recently, an American Water Works Association Research Foundation (AwwaRF) project (2007), led by Shane Snyder of the Southern Nevada Water Authority, investigated removal of EDCs and pharmaceuticals of less than 100 ng/L in typical drinking water treatment processes at bench, pilot, and full scales. They looked at spiked natural waters as well as raw and treated drinking water from drinking-water utilities as well as reuse plants. They found that conventional coagulation, flocculation, and filtration removed few of the target compounds when used at full scale. They also found that magnetic ion exchange also had little effect. Disinfection processes were the most effective. They found that chlorine disinfection removed roughly half of the compounds and that low ozone doses removed most of the compounds. Ultraviolet (UV) disinfection at typical drinking-water dosages was largely ineffective alone, but when UV was combined with hydrogen peroxide for advanced oxidation, it offered the same removal rates as ozone. Some filtration processes were also found to be effective. When regularly replaced or regenerated, granular activated carbon provided good removal. Reverse-osmosis membranes and nanofiltration membranes were most the effective by removing all of the target analytes with reporting limits of 1–10 ng/L. Lastly, they found that ultrafiltration and microfiltration membranes were not as effective.

Research Needs

There is a common misconception that CECs are chemicals that have only recently been *released* into the environment. However, most CECs have been present in the environment as long as they have been in use, but were previously undetected. Typically, presence in the environment and the potential for toxic effects may not be recognized until more sensitive analytical techniques and toxicity characterization methods become available. Therefore, there is a need for more research into the analytical methods for detection of these compounds.

Advances in analytical chemistry, instrumentation, and hydrology have greatly improved our ability to identify and study CECs in the environment. Over the last three decades detection and quantification limits of analytical techniques have generally improved from parts per thousand levels, to parts per trillion, and even parts per quadrillion. Our ability to detect and quantify CECs in the environment often exceeds our understanding of the risks that these chemicals pose to human health and ecosystems. There needs to be more understanding of risk and toxicity at the concentrations found in the environment.

Treatment goals may not be defined until toxicologically-based limits are defined for the chemicals. Environmental regulators, including the U.S. EPA, do not have the time or resources to characterize the chemical properties, biological activities, and environmental behavior of all the chemicals that are in use today in our society. Approximately 60,000 chemicals need to be assessed, and the list is growing. Synthesis of new chemicals or changes in use and disposal of existing chemicals create sources of new CECs thereby expanding the growing list of research needs. More research is needed to limit the compounds to a manageable number so that the effectiveness of treatment techniques can be investigated.

WESTCAS Focus

A fundamental goal of WESTCAS is to encourage and support research to meet the needs of member utilities. Emerging contaminants, their impact on the environment and treatment techniques for removing them are of to the arid states of the Southwest. WESTCAS can play an important part in helping water and wastewater agencies prepare for the impacts of emerging contaminants by focusing on the following activities.

- Support research in quantifying the presence of emerging contaminants and toxicity at concentrations that there are found in the environment.
- Support research into treatment techniques for removing contaminants of concern.
- Help member agencies understand the impacts of emerging contaminants on how they will operate their facilities.
- If these compounds should become regulated, provide input into the formulation of such regulations.

REFERENCES

Anderson, Paul D., 2005, Technical Brief: Endocrine Disrupting Compounds and Implications for Wastewater Treatment. Water Environment Research Foundation (WERF), 04-WEM-6.

Barber, L.B., Keefe, S.H., Antweiler, R.C., Taylor, H.E., and Wass, R.D., 2006. Accumulation of contaminants in fish from wastewater treatment wetlands: Environmental Science and Technology, 40(2), p. 603-611.

Catriona, P., Rhind, S.M., Kyle, C.E., Scott H., McKinnell C., and Sharpe, R.M., 2005, Cellular and hormonal disruption of fetal testis development in sheep reared on pasture treated with sewage sludge: Environmental Health Perspectives, 113(11), p. 1580-1587.

Drewes, J. E., Hemming, J., Schauer, J., and Sonzogni, W. 2006. Removal of Endocrine Disrputing Compounds in Water Reclamation Processes. Final Report 01-HHE-20T. Water Environment Research Foundation (WERF). Alexandria, Virginia.

Esposito, K., Tsuchiihashi, R., and Stinson, B. 2007, Contaminants of Emerging Concern: Considerations for Planned Indirect Potable Reuse: Water World. Accessed at http://ww.pennnet.com/ (10/10/08).

Hemmet, R., 2008. "Emerging Contaminants: Identification, Concerns, Actions", Presented at New Jersey Water Monitoring Council Meeting. Accessed at http://www.state.nj.us/dep/wms/Emerging%20%20Contaminants%20of%20Concern%20web%20-%20EPA.pdf (10/11/08).

Kim, S.D., J. Cho, I.S.. Kim, B.J. Vanderford, and S.A. Snyder, 2007, Occurrence and Removal of Pharmaceuticals and Endocrine Disruptors in South Korean Surface, Drinking, and Waste Waters. Water Research 41:1013-1021.

Kinney, C.A., Furlong, E.T., Werner, S.L., and Cahill, J.D., 2006, Presence and distribution of wastewater-derived pharmaceuticals in soil irrigated with reclaimed water: Environmental Toxicology and Chemistry, 25(2), p. 317-326.

Ritter, Stephen K., 2006. Detective work and expertise are used to evaluate environmental contaminants of emerging concern. Chemical & Engineering News, 84(5), p. 37-40.

Snyder, S. A., Wert, E. C., Hongxia, L., Westerhoff, P., and Yoon, Y. 2007. Removal of EDCs and pharmaceuticals in drinking and reuse treatment processes. American Water Works Association Research Foundation (AwwaRF).