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Sludge as new sentinel for human health risks

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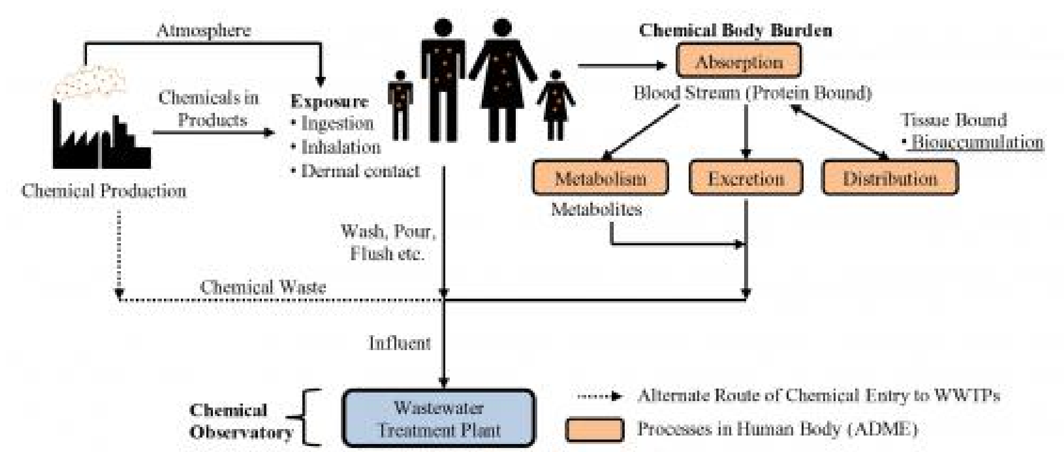

The schematic outlines the fate of anthropogenic chemicals from initial production through human exposure and wastewater treatment. Credit: Halden/Venkatesan

Thousands of chemicals serving a variety of human needs flood into sewage treatment plants once their use life has ended. Many belong to a class of chemicals known as CECs (for chemicals of emerging concern), which may pose risks to both human and environmental health.

Arjun Venkatesan, a recent doctorate and Rolf Halden, professor and director of the Center for Environmental Security at Arizona State University's Biodesign Institute, have carried out meticulous tracking of many of these chemicals.

In a study appearing today in the Nature Publishing Group journal *Scientific Reports*, both authors outline a new approach to the identification of potentially harmful, mass-produced chemicals, describing the accumulation in sludge of 123 distinct CECs.

Ten of the 11 chemicals found in greatest abundance in treated municipal sludge or biosolids were high-production volume chemicals, including flame-retardants, antimicrobials and surfactants.

The study shows a strong overlap between chemicals found in biological samples taken from the human population and those detected in municipal biosolids. These findings suggest that analysis of sludge may provide a useful surrogate for the assessment of human exposure and bioaccumulation of potentially hazardous substances.

According to Venkatesan, "presence of CECs in sewage suggests that consumers already may get exposed to these chemicals prior to their discharge into sewage, suggesting a need for human biomonitoring and risk assessment of these priority chemicals."

Prioritizing the thousands of CECs and predicting their behavior has been a daunting challenge. Evaluation is costly, tedious and time-consuming. Further, as the new study emphasizes, laboratory modeling of chemical behavior, including rates of environmental breakdown and potential for bioaccumulation often deviate significantly from real-world scenarios.

Conventional chemical screening evaluates the persistence, bioaccumulation and potential toxicity of various chemicals. The method however suffers from two shortcomings: the production rates of chemicals in current use are not incorporated into analysis and the detailed behavior of these chemicals in real-world biological systems—including the human body—is not assessed.

In the current study, a repository of samples from U.S. wastewater treatment plants, created and maintained by Halden at ASU's Biodesign Institute was used to conveniently identify CECs, as well as evaluate their potential for bioaccumulation and their ability to withstand degradation processes. The working hypothesis proposes that such treatment plants may act as reliable gauges for monitoring chemical prevalence and bioaccumulation potential relevant to human society and the environment.

Specifically, chemicals managing to survive primary and secondary treatment in municipal sewage systems display notable resistance to aerobic and anaerobic digestion processes and are therefore more likely to stubbornly persist in the environment upon their release.

As Halden notes, post-treatment sludge provides a sink for water-avoiding (hydrophobic) organic compounds. Such sludge is often applied to land, where the persisting hydrophobic chemicals (including polychlorinated biphenyls [PCBs], briominated flame retardants [BFRs] and various pharmaceutical and personal care products including antimicrobial agents) can accumulate in considerable quantity.

The analysis identified a total of 123 chemicals in biosolids. Of these, 17 brominated chemicals were detected in U.S. biosolids for the first time. The most abundant chemicals were surfactants, which occur commonly in detergents, emulsifiers, foaming agents and dispersants.

After surfactants, pharmaceutical and personal care products were most abundantly detected, followed by BFRs, which commonly occur in plastics, textiles, electronics, and household flame-retardants. BFRs often persist and bioaccumulate in the environment and under proper conditions are also capable of transforming into other hazardous chemicals, including brominated dioxins and furans. The study notes that the pathways by which BFRs enter wastewater treatment facilities remain speculative, requiring further investigation

The surfactant and antimicrobial chemicals identified fall into the category of high production volume (HPV) compounds, produced in annual quantities of over 450,000 kg (1 million pounds). The study notes that the abundance of some chemicals is traceable to specific societal events, for example the 2001 anthrax scare, which significantly boosted production and consumption of the antibiotic ciprofloxacin. Antibiotic accumulation in the environment is of particular concern, due to a tendency to cause heightened drug resistance in microbial pathogens.

Rolf Halden: Director The Biodesign Institute Center for Environmental Security; Professor, Ira A. Fulton Schools of Engineering, School of Sustainable Engineering and the Built Environment; Senior Sustainability Scientist, Global Institute of Sustainability

The study reveals that 91 percent of the 11 most abundant compounds detected in biosolid samples are HPV chemicals, reinforcing the strong link between the occurrence of hydrophobic chemicals in sludge and their production volume.

Hydrophobic compounds occurring in the range of parts per trillion are generally of low environmental occurrence or experience significant biodegradability, or both. On the other hand, those chemicals occurring in parts per million quantities are of potential concern, owing to low biodegradability, high usage and the tendency to accumulate in biosolids due to their hydrophobic nature.

When results of the current study were matched against a comprehensive exposure assessment of environmental chemicals conducted by the Center for Disease Control and Prevention, it was observed that roughly 70 percent of chemicals detected in biosolids were also detected in humans.

Chemical abundance in biosolids appears to be a reliable indicator of current rates of chemical usage, resistance to biodegradation and potential for bioaccumulation. Further, by using biosolids as a pre-screening step, researchers may reduce the thousands of potentially hazardous CEC chemicals in circulation to a manageable number of priority substances most in need of further evaluation. Such a list of chemicals could then be scrutinized with respect to their absorption, distribution, metabolism and excretion as well as their potential harmfulness to humans and ecosystems.

"With over 85,000 chemicals in daily use in the U.S., it is a daunting task to pinpoint those that need more monitoring, regulation or replacement with safer alternatives," Halden says. "It turns out that we can use existing infrastructure, our wastewater treatment plants, to take the chemical pulse of the nation, determine chemical inventories, and zero in on risky chemicals prone to harm people, prosperity and the planet."

Provided by Arizona State University

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