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# Re-Imagining drinking water safety based on 21st century science: Microbial pathogens, emerging contaminants, byproducts, and health risks: Preface

Regulatory and technological solutions to ensure safe drinking water are not keeping up with the scope and severity of drinking water quality problems. Drinking water resources are degrading as a result of agricultural runoff, wastewater effluents, illegal dumping of chemicals, atmospheric deposition as well as algae blooms. At the same time, many parts of the world are experiencing issues related to water scarcity as a result of climate change and population growth, resulting in demand for alternative drinking water sources, such as reclaimed wastewater.

While chemical oxidants have dramatically improved water safety for consumers over the last 125 years, their risk to long-term human health has come to light only recently. A growing body of research in analytical chemistry, toxicology, and environmental engineering has demonstrated that chemical oxidants interact with organic compounds to yield unintended consequences for water safety. The reaction of commonly used disinfectants such as chlorine, chloramine and ozone with natural and anthropogenic organic matter has been shown to result in the formation of more than 700 disinfection byproducts (DBPs). The actual number of DBPs present in disinfected water, however, is likely to be considerably higher considering that the majority of compounds remain unknown. The same is true for other oxidants that are applied for the abatement of organic contaminants such as pharmaceuticals, personal care products, or pesticides.

The formation of this large number of byproducts with largely unknown toxicities overwhelms the efficacy of existing regulations, which focus on a very small number of contaminants. Recent studies have shown that the organic DBPs that are currently regulated (trihalomethanes (THMs) and haloacetic acids (HAAs)) do not account for the risks associated with the consumption of chlorinated drinking water. In other words, THMs and HAAs do not adequately represent the quantity or toxicity of DBPs in treated water. This is concerning, given that utilities striving for compliance with standards for THMs and HAAs have shifted to using alternative disinfectants, in particular chloramination, which result in the formation of unregulated DBPs that have significantly higher toxicological importance, such as nitrosamines and haloacetonitriles.

So where are we going from here? While improving regulation has a role to play, the approach that scientists take to understand and communicate the challenge is equally important. Characterizing and assessing the large number of unknown chemicals using advanced analytical approaches such as (ultra)high-resolution mass spectrometry certainly is a critical component of a comprehensive assessment of drinking water quality. Equally important is the evaluation of the potential risks that result from people getting exposed to these unregulated byproducts. Achieving this combination of chemical and exposure risk assessment in the face of thousands of unknown compounds will require a radical rethinking of how we evaluate water quality. Chemical-by-chemical assessment, which is the status quo, is no longer feasible or sound. Rather, we need approaches that allow us to assess the toxicity of complex mixtures. This includes the application of *in vitro* toxicity assays, which are successfully being used to assess the overall toxicity of treated waters. Furthermore, new bioanalytical approaches, including effect-directed analysis (EDA) and reactivity-directed analysis (RDA), offer promising opportunities to assess toxicological effects while also providing information about the responsible contaminants. Advancing these approaches and developing implementation strategies for drinking water regulations will be critical to addressing the unintended consequences associated with the formation of toxic byproducts. A toxicity-first approach to characterizing complex drinking water mixtures will ensure safer drinking water solutions across a range of chemical classes beyond DBPs.

This special issue of the *Journal of Environmental Sciences* entitled, "Re-Imagining Drinking Water Safety based on 21st Century Science: Microbial Pathogens, Emerging Contaminants, Byproducts, and Health Risks" highlights some of the recent findings and discusses the existing challenges and opportunities in the field of drinking water research. The authors in this special issue showcase high impact research on drinking water contaminants, mitigation strategies to address

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the presence of contaminants, and health implications related to exposures to drinking water contaminants, specifically DBPs. With this special issue, we celebrate the outstanding achievements of Professor Michael Plewa, University of Urbana-Champaign, who has been a leading researcher in the assessment of DBP toxicities over the last decades. Using interdisciplinary approaches, Professor Plewa's research has contributed substantially to our understanding of toxicity drivers in disinfected drinking water, which has set the groundwork for improved drinking water regulations of the future.

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