EDITORIAL

Wastewater-based epidemiology to assess environmentally influenced disease

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Wastewater-based epidemiology (WBE), also known as wastewater-based surveillance, is a rapidly evolving scientific discipline that leverages community wastewater to assess population health in near real-time [1]. This is accomplished by measuring captured human excreted biomarkers in composited wastewater that are indicative of various aspects of human health, behavior, exposure, and activity. Since the early 2000s, WBE has been used as a beneficial tool for monitoring population-level substance use, and has most recently gained widespread public exposure during the COVID-19 global pandemic, where SARS-CoV-2 monitoring reaffirmed early-warning capabilities and the potential to reveal hotspots of infection not otherwise detected by individualized clinical surveillance [2]. These applications demonstrated the inclusive, minimally invasive, cost-effective, and near real-time benefits of WBE. The articles included in the *Journal of Exposure Science and Environmental Epidemiology* Special Topic: "Wastewater-based Epidemiology to Assess Environmentally Influenced Disease" cover a range of topics that explore the interconnectedness between humans and the environment using wastewater analysis, including: (*i*) establishing new targets for population-level exposure assessments from community wastewater, particularly for infectious diseases, (*ii*) conducting simultaneous measurements of chemical and biological indicators of exposures and associated human impact, and (*iii*) evaluating the utility of wastewater-informed data to prompt contextually-relevant interventions in vulnerable populations as it relates to environmental exposures and connectivity in rural, low-resource, and non-sewered settings. This Special Topic includes articles authored by experts in wastewater-based epidemiology, exposure science, environmental epidemiology, engineering, water and sanitation, environmental microbiology, and beyond.

WASTEWATER-BASED EPIDEMIOLOGY: THEN AND NOW

The use of wastewater to understand the health and exposure of communities is not a novel concept [3]. In recent decades, the field has continued to evolve as public health priorities shifted, expanding from water-borne pathogens due to poor sanitation to monitoring a variety of contaminants of emerging concern, substance use (licit, illicit), and pharmaceuticals and personal care products (PPCPs). During this period, the field was considered a niche discipline conducted by experts within the fields of analytical and environmental chemistry, and engineering, where emphasis was placed on technical method development and establishing standardized protocols for chemical analyte detection in urban wastewaters (influent, effluent), as well as methods for appropriate data analysis and interpretation, (i.e., population size and consumption/dosage estimates) [4–7]. These technical developments ultimately led to large-scale international drug monitoring campaigns leveraging WBE to support public health strategies [8, 9]. This demonstration of using wastewater as a complementary data source to encourage interdisciplinary research partnerships for public health purposes served as a platform for the global COVID-19 pandemic.

ESTABLISHING GLOBAL WBE COLLABORATIVES TO COMBAT THE COVID-19 PANDEMIC

The initial threat of COVID-19 prompted a massive onboarding of new WBE practitioners around the globe to begin developing methods for SARS-CoV-2 surveillance in wastewater that expanded the expertise in the field to include other disciplines such as environmental microbiology, molecular biology, and computational modeling [10]. Global initiatives that sparked in response to the dire need for rapid development and deployment of methods for SARS-CoV-2 monitoring in wastewater facilitated sustained research partnerships, which led to significant methodological advancements in understanding the utility of WBE in this context. Most notably, this included establishing early-warning capabilities, demonstrating the ability for rapid hotspot detection, serving as an inclusive and culturally sensitive method for obtaining rapid public health information in vulnerable communities, and offering the ability to simultaneously monitor trends in disease incidence and various treatment methods. The use of WBE was also tested at a variety of geospatial scales, such as college campuses and airports, to support targeted clinical surveillance efforts and other risk mitigation strategies, demonstrating how it can be used in more unique and isolated communities for hotspot detection [11]. Showcased in this Special Topic, Lee et al. demonstrated this by successfully measuring pharmaceuticals related to COVID-19, including over-the-counter medications, and observed similar trends with SARS-CoV-2 viral RNA surveillance [12], offering a foundation for future work using wastewater to investigate the intersection of human exposure and subsequent behavior.

COMMUNITY-LEVEL EXPOSURE ASSESSMENTS USING WBE

These successful reports of monitoring COVID-19 at multiple geospatial and temporal scales that facilitated targeted, contextual, and rapid intervention deployment, positioned WBE as a prodigious resource to complement public health strategies, serving as a foundation to continue to explore these benefits in other realms of disease surveillance and exposure assessment. This Special Topic includes several novel reports of this expansion in various contexts. First, Boehm et al. explore the utility of using WBE to support surveillance efforts for human norovirus, a non-reportable, yet leading cause of disease globally, and for which data on incidence and prevalence are severely lacking [13]. The use of wastewater to support continuous surveillance of

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human norovirus could significantly reduce these data gaps and encourage continued exploration for similar pathogens. Next, conducting WBE in low-resource settings and within vulnerable populations is still relatively unexplored in terms of appropriate strategies, methods, and protocols to successfully obtain useful public health information from these locations. Enclosed in this collection, Chigwechokha et al. and Menchu-Maldonado et al. explore this concept in two successful case studies, one detecting *Vibrio cholerae* and *Salmonella typhi* in wastewater of non-sewered and resource-limited settings, and the second, determining Tribal connectivity to local wastewater treatment plants to allow for measurement of impacts from environmental contamination by WBE [14, 15]. These groundbreaking studies encourage future investigation to continue expansion of WBE to rural, low-resource, and vulnerable communities.

CONCLUSION

The field of wastewater-based epidemiology has proven to be an efficient and effective complementary tool for widescale monitoring of emerging and circulating infectious diseases and substance use in support of public health strategies. As we continue to make advancements within the field of WBE, key knowledge gaps remain, particularly in investigating application in other areas of environmental exposure assessment. This Special Topic highlights novel and pioneering advancements of the field, while also identifying areas for future exploration to support continued advancement for population-level, wastewater-based exposure assessments.

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