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Priority setting for global WASH challenges in the age of wastewater-based epidemiological surveillance

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HIGHLIGHTS

- Mortality due to inadequate WASH facilities exceeded that of COVID-19 in the regions of South-East Asia and Africa.
- The costs and benefits of wastewater-based surveillance are not known; however, the benefits of WASH interventions greatly exceed the costs.
- The dedication of effort and resources to wastewater-based surveillance and WASH in low- and middle-income countries should reflect disease burdens and cost/benefit assessments.

1. COVID-19 AND WASTEWATER-BASED SURVEILLANCE

During the early period of the COVID-19 pandemic, researchers worldwide joined efforts to address the pandemic by rapidly developing, deploying, and improving methods for wastewater-based surveillance (WBS) of the SARS-CoV-2. Partnerships were established among academic environmental microbiologists, civil/environmental engineers, public health laboratories, epidemiologists, data scientists, wastewater treatment facilities, government agencies, and administrators of congregate living facilities. During much of 2020, when clinical testing for COVID-19 was limited, WBS had the potential to provide public health officials with early warnings about surges in case counts. However, as clinical testing became widely available with short turn-around times (at least in high-income countries), the potential lead-time benefits of WBS relative to clinical testing likely diminished (Bibby *et al.* 2021). Nevertheless, data generated by WBS were shared with public health officials to promote situational awareness (Centers for Disease Control and Prevention; Naughton *et al.* 2023). In addition to reflecting the epidemiology of COVID-19, WBS also became a means for identifying and monitoring SARS-CoV-2 variants. Beyond COVID-19-related work, the analyses of wastewater samples using molecular methods have contributed to advancements in various other areas of environmental microbiology, particularly in virology (Tisza *et al.* 2023).

The World Health Organization (WHO) COVID-19 global health emergency officially ended on 5 May 2023, and elements of the WBS systems are being repurposed for additional public health applications. These include biosecurity, surveillance of antibiotic-resistant microbes, and for monitoring drug abuse in communities. The International Water Association (IWA) Specialist Group in Health-Related Water Microbiology, a group that had a strong emphasis on global water, sanitation, and hygiene (WASH), established a new cluster, Wastewater-based Epidemiological Surveillance (International Water Association 2023). It is certainly possible that these efforts will lead to actions that improve public health. The establishment of the new IWA cluster is consistent with a recent publication that stated, 'Wastewater monitoring and support for dashboard development must also be expanded to lower-income countries and areas' (Naughton *et al.* 2023).

Committing limited global health resources to the advancement of WBS in low- and middle-income countries (LMICs) should consider whether WBS is a priority for improving the health of the public in those countries. WBS of polio virus in areas where the disease is thought to be absent appears to have prompted clear public health action that would likely not have occurred otherwise (Manor *et al.* 2014; Thompson *et al.* 2023). As was the case with poliovirus detection prior to the onset of cases of paralytic polio, the greatest value may be in monitoring for highly virulent infectious agents that are thought to be absent in a community. However, whether monitoring microbes other than polio by WBS may produce reductions in morbidity or mortality is yet to be determined. Whether, where, or how WBS reduced COVID-19 morbidity and mortality are yet to be established.

As WBS research in LMICs is being planned, UN Water estimates that 26% of the world's population – 2 billion people – rely on water sources that are not safely managed; in Sub-Saharan Africa, that figure is 70% (UN Water 2021). The same report notes that globally, 46% of the population lacks access to safely managed sanitation and nearly 500 million people practice open defecation. Funds for WBS- and WASH-related research and implementation do not come from a single source of money. Nevertheless, how water research funds should be allocated between those two efforts is worth considering. We proposed four components that may advance priority-setting regarding the value of WBS relative to that of efforts to prevent diseases by improving WASH in LMICs.

1.1. What was the mortality burden of COVID-19 during the pandemic relative to that of inadequate WASH?

Mortality burden: Direct comparisons of COVID-19- and WASH-related fatalities during the global health emergency are not simple, as no single global surveillance system measured both. To develop an initial comparison of mortality due to COVID-19 and inadequate WASH facilities during the global health emergency, we utilized two data sources. WASH-related mortality estimates were obtained, from the Institute for Health Metrics and Evaluation (IHME) for 2019, the most recent for which data are available (Institute for Health Metrics and Evaluation (IHME) 2023). COVID mortality data for the period 3 January 2020 through 5 May 2023 (the end of COVID global public health emergency) were obtained from the WHO (World Health Organization 2023a, 2023b). An estimated 696,143 (lower and upper range estimates: 528,126 and 891,660) people in Africa died due to inadequate water, sanitation, and hygiene (WASH) in 2019; of those, 409,952 (~59%) were children under the age of 5 years. WHO data indicate that 175,359 people died of COVID-19 in Africa during the global health emergency. IHME data indicate that in 2019 an estimated 696,143 (low and higher range estimates: 528,126 and 891,660) died due to inadequate water, sanitation, and hygiene (WASH); of those, 409,952 (~59%) were children under the age of 5 years. If WASH-related mortality numbers remained the same from 2019 through the end of COVID-19 global health emergency, 2,323,028 people would have died in Africa due to inadequate WASH (Figure 1), more than 13 times the number of people who have died of COVID-19 in Africa during the same period. Even if only 50% of COVID cases in Africa were counted, and if mortality related to inadequate WASH facilities decreased by 10% over the pandemic, inadequate WASH facilities would have resulted in more than 5.96 times as many deaths in Africa than did COVID-19. As

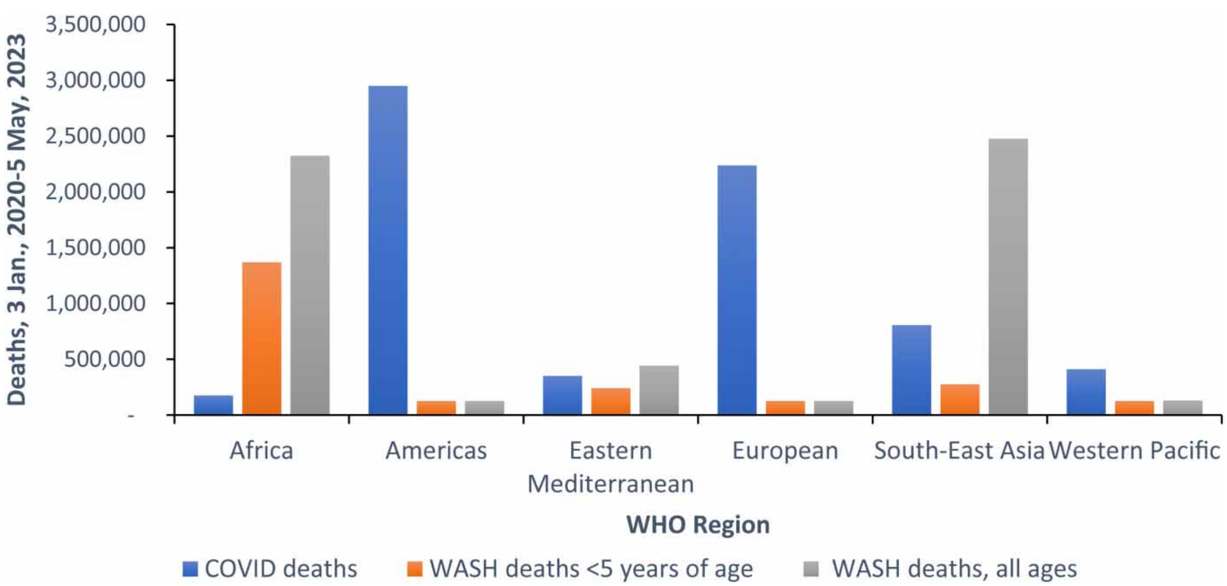

Figure 1 | Estimated number of deaths due to COVID-19- and WASH-related factors during 3 January 2020 -5 May, 2023. COVID-19 data are from the WHO, WASH-related deaths are from IHME.

indicated in Figure 1, the majority of the deaths due to inadequate WASH facilities were among children <5 years of age. In the regions of South-East Asia, the number of deaths due to inadequate WASH facilities were 3.07 times greater than deaths due to COVID-19. Again, assuming only 50% of deaths due to COVID-19 in South-East Asia were counted and a 10% reduction in deaths due to inadequate WASH facilities during the pandemic, still inadequate WASH facilities was responsible for 1.38 times as many deaths as COVID. Thus, even at the height of a devastating global health emergency, it appears that the burden of mortality due to inadequate WASH was substantially greater than that of COVID-19 in the regions of Africa and South-East Asia.

1.2. What are the costs of and return on investment for WBS and WASH interventions?

Although many COVID-19 WBS studies use terms such as 'low-cost' or 'cost-effective,' very few studies measure costs or define effectiveness. Several studies report the costs of WBS in high-income countries. For example, the per-sample costs of WBS analyses in Utah, USA were estimated to be $220 per sample (Weidhaas *et al.* 2021). In the European Union, costs to analyze one sample were estimated to be €176 (excludes field sampling and shipment) and costs for analyzing control samples alone at a centralized laboratory that receives samples and analyzes two controls/week = €25,000 per year. Approximately €1.5 million per year was thought to be needed for WBS-related sampling, transport of samples, laboratory analysis, and personnel charges at 42 wastewater treatment plants in Belgium (Gawlik *et al.* 2021). A simulation study compared estimated costs of mandatory daily clinical testing residents of congregate living facility (such as an Olympic Village) using daily clinical COVID-19 testing for 4 consecutive days vs. WBS testing, which if positive, would be following by PCR testing of facility residents (Yoo *et al.* 2023). Simulation and observational studies have concluded that screening a population by clinical testing is about 50–100 times more costly than WBS (Hart & Halden 2020; Wright *et al.* 2022). The US Centers for Disease Control and Prevention (CDC) reported that '[s]ince 2020, CDC has awarded more than $100 million to support wastewater surveillance and related activities in 46 states, 5 cities, and 2 territories' (US Centers for Disease Control and Prevention 2022), a figure that does not include funds from state or local governments, of federal agencies, or from foundations.

Perhaps the best analysis of SARS-CoV-2 WBS costs in LMICs was conducted in Balantyre, Malawi, and Kathmandu, Nepal (Ngwira *et al.* 2022). The costs per sample in Blantyre were $25–$74 (US dollars) while in Kathmandu they were $120–$175, varying (in both settings) by monthly testing volume. We have been unable to identify any reports of reduction of COVID-19 morbidity or mortality due to WBS, monetized health impacts of WBS, or cost–benefit analyses from either the first year of the pandemic (when only supportive care was available) or beyond (when vaccination and pharmacotherapy were available). It is possible that such studies may in the future show health benefits attributable to WBS. However, that would require (1) timely use of WBS data by public health officials and (2) demonstrable reductions in COVID-19 disease burden attributable to the use of WBS data.

By contrast, WASH cost studies – and importantly – cost–benefit analyses – have been conducted over the past 25 years and strong economic arguments can be made for investing in WASH. Those analyses have generally found that every dollar invested in WASH programs typically yield $2–$15 in monetized health benefits (Haller *et al.* 2007; Hutton *et al.* 2007; Hutton 2013; Cha *et al.* 2015; Hutton *et al.* 2020). The specific cost–benefit ratios vary by the specific safe water or sanitation initiative, the program, and location of deployment. Importantly, the cost–benefit ratios appear to be most favorable in low-resource settings. The benefits of universal sanitation (based on health care costs, reductions in mortality, increases in productivity, and time savings) are about 8 times greater than the costs in East Asia, while in Latin America and the Caribbean the benefit-to-cost ratio was estimated to be 7.3 (Hutton 2013).

1.3. Practical considerations

WBS as generally implemented requires a sewered sanitation and a wastewater treatment system from which samples can be collected for analysis. Sewered sanitation is rare in rural areas and peri-urban informal settlements of LMICs. WHO/UNICEF estimated that even health care facilities often lack sanitation services (10% of health care facilities overall and 60% of those in 'least developed countries') (World Health Organization UNICEF 2021). WBS programs in such settings could prove useful and may generate new knowledge; however, they are not easy to implement. Policymakers should consider whether funds that might go to WBS in areas with very limited WASH resources would have greater health impacts by being directed to WASH, including health care facilities and schools. For less than $1 per capita per year, all health care facilities within a least developed country can meet basic levels of WASH (including point-of-care handwashing facilities) and waste management (Chaitkin *et al.* 2022).

1.4. Ethical considerations

Deaths due to preventable waterborne infections are a major cause of mortality, as the world remains far from meeting the Sustainable Development Goal 6 ('clean water and sanitation for all'). Hrudey and colleagues published ethical guidance for those conducting COVID WBS in 2021 (Hrudey *et al.* 2021). One guidance item was that '[t]he values and concerns of communities should be taken into account in planning, implementing, and using data from surveillance.' This guidance would certainly apply to researchers from high-income countries who seek to deploy WBS in LMICs where communities from where wastewater is sampled are unlikely to be translated into local public health benefits. Importantly, engaging communities in LMICs where WBS would be performed about their water priorities (WASH vs. WBS) would be important. Dialogs with communities about their priorities and the likely local benefits (or the lack thereof) of WBS are essential.

2. CONCLUSIONS

Even as WBS methods and applications evolve, the need to address the heavy burden of disease related to inadequate WASH persists. As academic researchers who have participated in COVID-19 WBS in the United States and Kenya, we note that decisions regarding research efforts in health-related water microbiology endeavors ought to consider the ongoing need for effective, affordable, and sustainable efforts to reduce the global burden of waterborne diseases by addressing Sustainable Development Goal 6. Given convincing evidence of return on investment, WASH research and implementation should remain a major focus for scholars, practitioners, and funders.

DATA AVAILABILITY STATEMENT

COVID-19 mortality from the WHO and inadequate WASH mortality data from IMHE have been uploaded to DRYAD and are available at https://doi.org/10.5061/dryad.fj6q5742f .

CONFLICT OF INTEREST

The authors declare there is no conflict.

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