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Invited Perspective: Understanding the Links between Weather and Environmental Health to Strengthen Climate Resilience

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In their paper[1] on the effectiveness of water, sanitation, and handwashing (WASH) interventions to reduce child diarrhea, published in this issue of *Environmental Health Perspectives*, Hubbard et al. write that we need to consider seasons in such assessments. The inclusion of seasons is not a new idea, but it remains a significant gap in the literature, and it is worthwhile to build the evidence base.

The authors used a systematic review and meta-analysis of 50 randomized and nonrandomized controlled WASH intervention trials to compare the impact on diarrhea by seasons. They demonstrated a stronger effect of WASH interventions, particularly drinking water and handwashing interventions, in the dry season than in the wet season. Water interventions were twice as effective in the dry season; however, the researchers should include a caveat noting consideration of the types of interventions for which data were available. Most water studies included in the review focused exclusively on household water treatment interventions. These represent low-cost interventions that can be applied at a single household scale; they do not address many aspects of safely managed drinking water services[2] known to affect health outcomes, such as distance to water sources, disruptions, or source water quality.[3]

Hubbard et al. explored two potential explanations for the seasonal differences: *a*) that there is more diarrhea in the wet season through non-WASH pathways, so the contribution of WASH is less significant; and *b*) that WASH interventions are less effective in rainy seasons. I believe it is likely a combination of both, but there is clear evidence for the latter; the increase in diarrhea and reduced effectiveness may be due to WASH services having been inadvertently designed for dry conditions, driven by the reality that data tend to be collected during the dry season (as highlighted by Hubbard et al.), when conditions are favorable for access.

A study on drinking water quality in Bangladesh, Nepal, and Tanzania found large drops in safe drinking water provision in the wet season based on detection of *E. coli* at the point of collection.[4] Nationally representative data collection in Bangladesh also demonstrated the seasonality of water quality across improved water systems.[5] Handwashing interventions have been shown to be ineffective in heavy rains,[6] but to this author's knowledge, no further research has been done to refine handwashing guidance to account for these weather conditions, including factors that affect pathogen growth (e.g., higher humidity) or efficacy of hygiene methods (e.g., more mud).

Although Hubbard et al. draw attention to the biases in the data, they state that these results should not be considered a new estimate of the overall impact because they are based on a partial dataset. The authors excluded 76 of 126 studies identified due to inadequate data to consider seasonal impact, including data missing on dates, seasons, location, and proximate weather information. This exclusion highlights a key challenge around how to collect data to ensure we are adequately capturing the performance of WASH services in a changing environment. Here I propose three key areas to strengthen data collection:

1. **Engage climate scientists.** Climate change is recognized as a threat to sustained delivery of WASH services,[2] and weather is a key variable in any WASH study, driving behavioral and environmental changes.[4] Weather data are widely available, but different metrics and datasets have their own biases.[7] Funders and researchers need to ensure collaboration across disciplines to embed appropriate collection and use of meteorological data into environmental health studies.
2. **Implement longitudinal data collection systems.** Planning research to capture specific weather conditions (e.g., extreme rainfall events) is challenging, and with climate change disrupting weather patterns, it is increasingly impractical.[4] However, weather events can provide natural experiments where data collection is designed to adequately capture variability in performance. The ongoing seasonal variability in performance of WASH services implies that we do not have adequate data systems in place that provide feedback to inform and motivate improvements in WASH services in ways that build climate resilience. We need longitudinal data collection to develop evidence on the performance of WASH services and health outcomes across seasons and weather extremes for use in both research and practice.
3. **Reconsider evidence needs.** The relationships between climate and the health outcomes of WASH services are complex. Building an evidence base of randomized and nonrandomized controlled trials reporting on diarrhea, which ignore environmental variables, is not fit for purpose. The focus in the literature on low-cost interventions at a household level, as identified by Hubbard et al., are not in line with current approaches to dominant policy approaches to safely managed drinking water services.[2] It is noteworthy that one study included in the review demonstrated the greatest diarrhea prevention during rainfall,[8] particularly for sanitation and hygiene, although there is no analysis as to why this context or any interventions might have led to different results.[9] Rather than repeating intervention trials, research should improve the contextualized measure of impacts that can foster learning and strengthening of systems.

The review by Hubbard et al. is part of a growing body of evidence that the WASH sector is overestimating the performance of WASH services by not considering the impact of weather. However, we need to do more than understand the impact of seasons. We need a shift in how we understand these systems and

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collect evidence on their impact to ensure that the impact remains relevant to the WASH systems being implemented and the social and environmental contexts they operate in.

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