WaSH Policy Research Digest

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Detailed Review of a Recent Publication: Intermittent water supply jeopardizes water quality and costs users and utilities money

Bivins, Aaron W., Sumner, Trent, Kumpel, Emily, Howard, Guy, Cumming, Oliver, Ross, Ian, Nelson, Kara, Brown, Joe, 2017. Estimating Infection Risks and the Global Burden of Diarrheal Disease Attributable to Intermittent Water Supply Using QMRA. Environmental Science and Technology 51, pp 7542-7551.

Intermittent water supply, or water provided to users on a discontinuous basis, is common in many countries. In fact, in some it is the norm rather than the exception. Interruptions in water supply can last for hours or even days, with the time that water is unavailable exceeding the time that it is available. The World Bank's online database of utility data (IBNET[1]) shows that in 28 countries more than 10% of the population experiences discontinuous water supply. In India, for instance, 83% of the population is served with intermittent water, and water is available, on average, for only 10 hours per day. In some cities, water is available for one or two hours a few times a week.

Intermittent water supply has many disadvantages. It inconveniences users, particularly the poor who lack ways to store significant amounts of water at home. It results in water wastage as users leave taps open, waiting for supply to arrive, and throw away stored water when water is once again flowing. It leads to higher maintenance costs as pressure variations damage pipes and valves, and varying water levels contribute to corrosion (Conradin et al., 2010; Christodoulou and Agathokleous, 2012). Finally, and the subject of this paper, it results in poor quality water because negative pressure in the piped network created when there is no water flowing allows water from the surrounding soil to enter, bringing with it contamination.

In a recent paper, Bivins and his co-authors estimate the extent of intermittent water supply and assess its impact on the global burden of diarrheal disease. Intermittent supply has been associated with epidemic outbreaks of disease, but the authors examine its impact on endemic gastrointestinal illness. To do this they chose three reference pathogens (Campylobacter, Cryptosporidium and rotavirus) that are commonly associated with diarrheal disease in developing countries. Using E. coli as an indicator organism, data on the ratio of E. coli to pathogens in other piped water supply systems, and models of dose-response that predict whether people will get sick depending on how much of the pathogen they ingest, they used a methodology called Quantitative Microbial Risk Assessment (QRMA) to estimate the extent of diarrheal disease as a result of intermittent water supply globally.

Key Policy and Programmatic Takeaways

- Intermittent water supply is common in many countries and puts millions of users at risk of diarrheal disease
- Short term mitigating approaches include maintaining an adequate chlorine residual and encouraging point of use treatment and safe in-home storage methods
- Longer term approaches must address the systematic problems, such as high water losses and poor management, that result in intermittent supply
- Continuous water supply is achievable and should be one of the aims of any program of utility reform

1 https://www.ib-net.org, accessed November 2017

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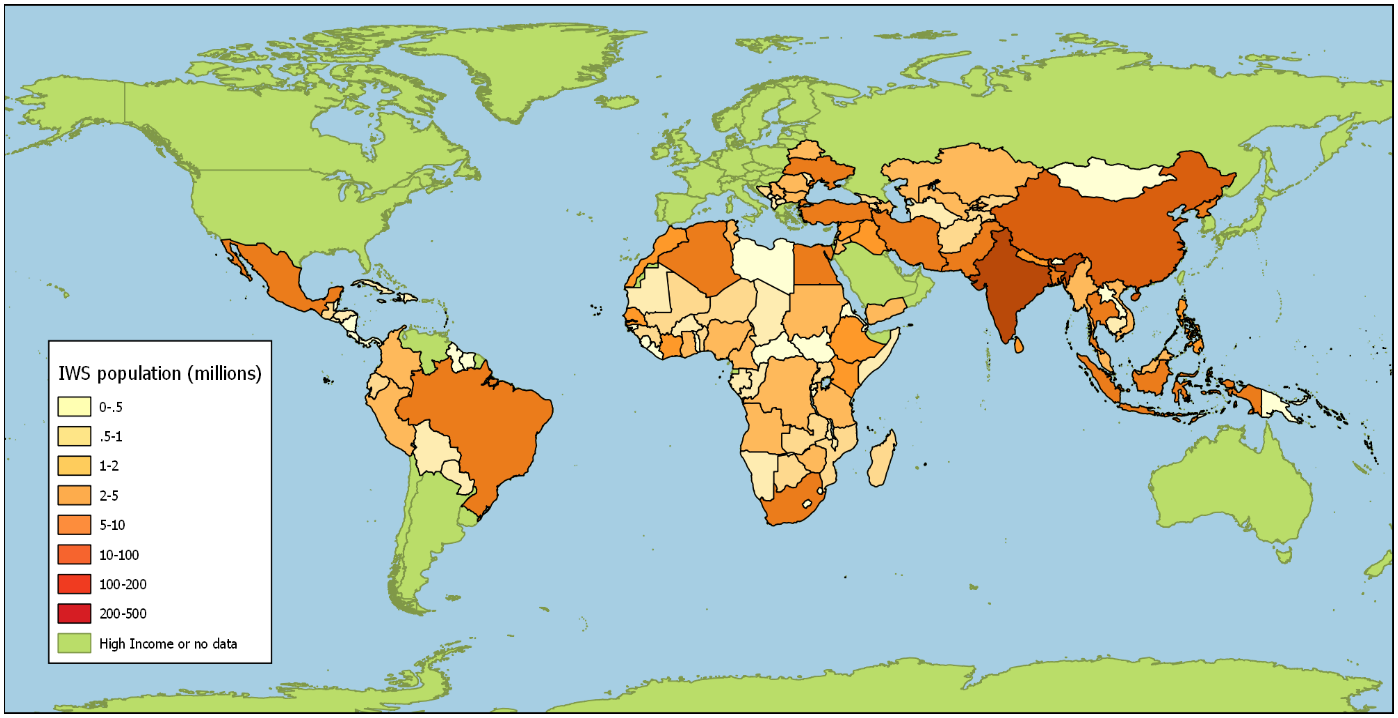

Figure 1 Estimated population experiencing intermittent water supply (Bivins, *et al.* 2017)

The authors estimate that almost a billion people around the world are served by intermittent water supply, and that this results in 4.5 million diarrheal disease cases every year. The authors also estimate that approximately 109,000 diarrheal "disability-adjusted life years" are lost every year as a result of discontinuous water supplies (DALYs are a measure of the number of years lost due to ill-health, disability or early death, combining morbidity and mortality into a single measure) and that intermittent water supplies are associated with 1560 diarrheal deaths per year.

Given the number of people served by intermittent water supplies, the authors' estimates of health impacts might appear relatively modest. However, the authors acknowledge that the methodology they employed may substantially underestimate the impact of intermittent water supplies on health. The estimates reported in the paper are conservative for a number of reasons: 1) the authors assume that water from intermittent supplies was consumed "at the moment it arrives at the tap", and unsafe handling or storage practices were not considered; 2) the datasets used to estimate the ratio of E. coli to pathogens came from the Netherlands and Germany, where pathogen loadings in sewage are likely to be lower than those in Asia or Africa; 3) the data sets used to estimate concentrations of reference pathogens using fecal indicator bacteria measurements came from India, Cambodia and Vietnam, and therefore did not reflect the full geographical range of intermittent water supply globally; no data were included from Africa; and 4) the data related to dose-response rates came from research on healthy adults in high-income settings.

The authors are very clear about the limitations of the study, and identify many data gaps that would have to be filled to obtain a more accurate estimate of the impact of intermittent water supply. They point out that their estimate does not take into account the "complex water management behavior" observed among users of water supply that is not continuous. It also does not take into account the degree of intermittency (relying on a simple dichotomy of "intermittent" and "continuous"). The authors point the way towards better estimates in the future.

The fact that intermittent water supply is so prevalent means that hundreds of millions of people do not have a level of service that meets the new definition of "safely managed drinking water" adopted under the Sustainable Development Goals. This definition requires drinking water to be both available when needed and free of fecal contamination.

In their conclusion, Bivins and his co-authors suggest that to mitigate the microbial risks utilities can maintain a chlorine residual in piped water networks, and encourage households to treat their water at home. However, these suggestions are both limited and short term. Maintaining an adequate chlorine residual is difficult if organic matter is constantly infiltrating negatively-pressured pipes, and home water treatment is costly and often not practiced routinely, especially by poor households. These measures also do not address the significant non-health related problems associated with intermittent water supplies – which impact both users and utility managers.

Review prepared by Clarissa Brocklehurst, Adjunct Professor, Department of Environmental Sciences and Engineering, The Water Institute at the University of North Carolina at Chapel Hill and David Fuente, Assistant Professor, School of Earth, Ocean & Environment, University of South Carolina

Literature review: Intermittent water supply

Intermittent water supply (IWS) is caused by a complex and diverse set of conditions, resulting in a number of negative outcomes. In an extensive meta-analysis of the IWS literature, Galaitsi et al. (2016) found evidence of a 'spiral of decline' that is caused by capacity constraints (scarcity of supply), investment in private water infrastructure by households and companies as a response to IWS, and declining revenues as services deteriorate and customers refuse to pay or disengage from the public network.

At the household level, users cope by collecting water from unsafe sources such as wells and surface water, purchasing water from tanker trucks or commercial packaged water, reducing their water consumption, pumping to obtain the largest possible amount of piped water when it is available, and installing tanks to store water (Majuru et al., 2016; Zerah, 1998). These coping strategies result in direct costs and time impacts for collection, and rescheduling of activities around water availability. Wealthier households spend money to cope, whereas poor households spend time or reduce their consumption (Gurugai et al., 2017). Some econometric studies have attempted to quantify coping costs, finding that households pay between two and five times their current utility bill to cope with intermittency, representing from 1% to 12% of their monthly income (Cook et al., 2016; Pattanayak et al., 2005; Zerah, 1998).

Microbial contamination occurs more frequently in intermittent supplies due to contaminated water leaking into pipes through cracks and fittings during low-pressure conditions, microbial biofilms that form under stagnant conditions and are released during repressurization, and contamination during household storage (Coelho, 2003; Kumpel, 2015). Compliance with the World Health Organization guidelines for E. coli was 24%, 47%, and 68% in studies of piped water systems in cities in Vietnam, Cambodia, and India, respectively (Brown et al., 2013; Shaheed et al., 2014; Kumpel et al., 2013).

Increased rates of gastrointestinal illnesses are associated with both temporary water outages and intermittent water systems (Ercumen et al., 2014). Even short-lived piped water supply outages were shown to increase the incidence of cholera in one town in the Democratic Republic of the Congo by 155%, with the maximum effect occurring 6 days after the outage (Jeandron et al., 2014). A recent case-control study in urban areas of Addis Ababa found that the odds of developing diarrhea was 4.8 times higher in households with intermittent supply (Adane et al., 2017). In the only study of an intermittent supply that was upgraded to continuous service, typhoid fever was reduced by 40% (Ercumen et al., 2015).

One major gap in the literature on IWS is a lack of rigorous longitudinal studies that measure the reduction in coping costs and other impacts following a transition from intermittent to continuous service (Majuru et al., 2016). As a result, it is not known to what extent coping costs can be converted into payments for improved services, as many costs are sunk into long-term infrastructure (tanks, pumps) and time savings may not necessarily translate into increased income in areas suffering from high unemployment. However, relatively simple methods do exist to measure a household's willingness to pay (WTP) for a better service. For example, Pattanayak et al. (2005) found that households in Nepal would on average be willing to pay over 6 times their coping costs, or 12 times the current utility bill, for a reliable service. These studies can help build the case for public and private investment in piped water systems.

The literature shows that measuring and categorizing intermittency is a challenge that still needs to be addressed (Majuru et al., 2016). Measurement needs to go beyond indicators typically reported by utilities with continuous water supply, such as average hours per week. Guragai et al. (2017) suggest that at least three measures are needed: frequency of supply (times/week), supply duration (hours/time), and total supply (hours/week). Surveys should differentiate between predictable rationing, irregular supply, and completely unreliable water systems (Galaitsi et al., 2016). Estimates of household-level water use are also important in order to measure reduced consumption under conditions of intermittency (Kumpel et al., 2017).

Many utilities have successfully transitioned to continuous and reliable service (often referred to as "24/7" service). Placed into a historical context, the current patchwork of intermittent piped water services is not unlike the situation that prevailed fairly recently in the United States, Europe, and several Southeast Asian countries that now provide reliable services (Wolman and Bosch, 1963; Melosi, 2008; Northover et al., 2016). Prioritizing continuous service was a key strategy for eight successful utilities studied by the Asian Development Bank, which also highlighted the importance of leadership from the highest levels of government and "corporatization" of utilities, or taking a business approach for better accountability and transparency in operations (Asian Development Bank, 2010). The ADB study argues that investments in efficient and effective service delivery should be prioritized ahead of large supply-side infrastructure projects. Specific strategies proposed for achieving continuous water supply reflect general best practice in utility management: increasing coverage to over 90% (including finding ways to connect the poor), accurate metering, efficient billing, good human resource management, and real time monitoring and reporting for transparency.

Macintosh (2003) offers a comprehensive sourcebook of strategies for piped water utilities wanting to achieve reliable service and, echoing the findings of coping studies, argues that full cost recovery tariffs actually help the poor, who are already paying high prices to cope with unreliable water supplies. New open-access toolkits focused on sustainable management of water resources are available to help bridge the gap between research and practice in water security and sustainability of supply (Winrock, 2017; Conradin, 2010). A recent World Bank-supported intervention in Karnataka in India demonstrated that a comprehensive approach, including household metering and improvements to supply and distribution, along with performance-based contracting tied to service levels, can lead to financially sustainable, continuous water services (Jain and Neti, 2013).

Considering the many negative impacts of intermittent service, the policy focus for piped water systems should be on transitioning to reliable 24-hour supply. This can be achieved through incremental steps, progressively improving utility management to gradually increase supply hours. The strategies discussed here have produced reliable services in a wide range of contexts, proving that IWS can be a thing of the past when the right mix of good management, operational efficiency, tariffs, and investment is applied.

Literature review prepared by John Feighery, Co-founder and Chief Operating Officer, mWater and Emily Kumpel, Assistant Professor, Civil and Environmental Engineering, University of Massachusetts Amherst

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