The future of water and sanitation: global challenges and the need for greater ambition

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ABSTRACT

Water and sanitation services are critical for public health. The importance of these services is reflected in SDG 6 and the associated targets 6.1, 6.2 and 6.3. Much progress remains to be made to achieve these targets, but it is already becoming clear that greater ambition is needed. This paper looks at three global challenges: the need to increase the level of service to protect public health including infectious respiratory diseases; the role of sanitation in combatting anti-microbial resistance (AMR); and the urgent need to build more climate-resilient services. We need to upgrade the SDG targets to focus on universal access to piped water on premises, to incorporate action on AMR in definitions of safe sanitation and to embed actions to improve resilience, which take into account the greater ambition called for in the SDG 6 targets. This requires a shift in thinking in the sector, away from relying on households and communities to manage their services to properly funded, professional services staffed by trained technical, managerial and finance staff. This will require more public finance and better use of financial instruments that have proved effective in other sectors. Increasing our ambition will mean the world can achieve the aim of universal access to safe, sustainable, and resilient services and protect public health.

Key words | anti-microbial resistance, climate resilience, human resources, sanitation, SDG 6, water supply

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HIGHLIGHTS

- Protecting public health requires higher levels of water and sanitation service.
- Tackling anti-microbial resistance should become a key element of safe sanitation.
- Climate change poses challenges for water and sanitation, investing in resilience is critical.
- Greater professionalisation is needed to provide safe, sustainable and resilient services.
- More and better use of public finance is needed for services.

INTRODUCTION

Water and sanitation services are critical to protecting public health. They are also recognised human rights under international law (UNGA 2010). Ensuring effective delivery of these services is one of the most basic responsibilities of any government leading to social and economic benefits to the population of their countries. However, as the international monitoring data in Table 1 shows, the world has a long way to go to ensure everyone gets access to safe services.

These data mask huge inequalities between regions, with regions with more low- and middle-income countries (LMICs) typically having much lower rates of access.

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Table 1 | Key statistics from global monitoring by the Joint Monitoring Program

Indicator	% (global)	Year	Source
Access to safely managed water supply[a]	71	2017	UNICEF & WHO (2019)
No access to even basic water supply[a]	11	2017	UNICEF & WHO (2019)
Access to safely managed sanitation[a]	46	2017	UNICEF & WHO (2019)
No access to even basic sanitation[a]	26	2017	UNICEF & WHO (2019)
Healthcare facilities with basic water[b]	74	2016	WHO & UNICEF (2019)
Healthcare facilities with basic sanitation[b]	No data	2016	WHO & UNICEF (2019)
Schools with basic water[c]	69	2019	UNICEF & WHO (2020)
Schools with basic sanitation[c]	63	2019	UNICEF & WHO (2020)

NB: data sources.
[a]UNICEF & WHO (2019).
[b]WHO & UNICEF (2019).
[c]UNICEF & WHO (2020).

In 2017, nearly 10% of the global population continued to defaecate in the open, most of whom reside in LMICs (UNICEF & WHO 2019); while studies have indicated that nearly 2 billion people drink water that is regularly contaminated with faeces (Bain *et al.* 2014). The extent to which people with access to 'safely managed sanitation' truly enjoy safe services is questionable, given that previous studies have shown only a small proportion of households with sewer connections are linked to well-functioning treatment plants (Baum *et al.* 2013).

The Joint Monitoring Program (JMP) reports demonstrate persistent inequalities in access to water and sanitation between rural and urban areas and between the richest and poorest population quintiles (UNICEF & WHO 2019). Even in high-income countries, the levels of safety and regulation afforded to small, rural water supplies are substantially lower than those associated with larger utility water supplies. In wealthy countries such as the USA, there remain communities that lack running water, sanitary toilets or face significant contamination threats and substantial numbers of homeless people who lack sustained access to safe water and sanitation (Riggs *et al.* 2017; Capone *et al.* 2020).

GLOBAL TARGETS

The importance of water and sanitation is reflected in the Sustainable Development Goals (SDGs). SDG 6 aims to 'Ensure availability and sustainable management of water and sanitation for all' by 2030 (UNGA 2015). There are six targets under SDG 6 aimed at measurable improvements in water and sanitation and two further targets focused on how these targets should be achieved (see Box 1).

The three first targets of SDG 6 relate to the delivery of drinking water supply and sanitation services and the management of wastewater quality. There are numerous challenges in achieving global objectives for water and sanitation including urbanisation, economic growth and recession, and environmental change and pollution. However, this paper focuses on three of the most significant challenges which required concert global action: ensuring drinking water supplies are safe and support effective hygiene; the role of sanitation in combatting the spread of anti-microbial resistance (AMR); and climate change.

INCREASING LEVELS OF SERVICE TO ACHIEVE PUBLIC HEALTH BENEFITS

The underlying rationale for the provision of water and sanitation services and treating wastewater is the protection of public health (Bartram & Cairncross 2010). Our understanding of the threats has deepened and widened since John Snow's ground-breaking action in the 1850s. It has been understood that the quantity of water is as important as its quality (Waddington *et al.* 2009); that levels of sanitation

Box 1 | Sustainable Development Goal 6: ensure availability and sustainable management of water and sanitation for all

Targets:

6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all.

6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defaecation, paying special attention to the needs of women and girls and those in vulnerable situations.

6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

6.a: By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.

6.b: Support and strengthen the participation of local communities in improving water and sanitation management.

coverage within communities are important to reduce disease (Wolf *et al.* 2018); and that handwashing is critical (Mbakaya *et al.* 2017). In addition to pathogens that cause infectious diseases, we have identified a range of chemicals that cause non-communicable diseases including cancers, cardiovascular diseases and diabetes (WHO 2017a).

Despite this knowledge, the burden of disease associated with inadequate water, sanitation, and hygiene (WASH) remains high. Diarrhoea associated with inadequate WASH is estimated to cause nearly 300,000 deaths in children under 5 each year (Prüss-Ustun *et al.* 2019). When considering other diseases and conditions, Prüss-Ustun *et al.* (2019) estimate at 1.5 million deaths – 2.8% of total global deaths – can be attributed to inadequate WASH. Systematic reviews have shown the impact of WASH interventions of diarrhoea (Waddington *et al.* 2009; Wolf *et al.* 2018). In addition to the impact on diarrhoea, there is good evidence of the effectiveness of handwashing on reducing respiratory disease (Mbakaya *et al.* 2017).

Prüss-Üstün *et al.* (2008) suggested that around 50% of the disease burden from malnutrition was a consequence of repeated episodes of diarrhoea and nematode infection which could be prevented through WASH interventions. However, a systematic review by Dangour *et al.* (2013) found evidence of only a small positive effect from WASH interventions on linear growth. More recently, three robust studies into the impact of WASH on nutrition failed to detect a significant effect on linear growth from commonly used WASH interventions (Pickering *et al.* 2019).

There has been much debate about the meaning of these findings (Cumming *et al.* 2019), one conclusion that has been drawn is that the levels of service that most current WASH programmes deliver are simply inadequate to protect public health (Pickering *et al.* 2019). In addition, commentary of these findings has highlighted that few WASH programmes design interventions based on an understanding of which pathogens cause disease within specific communities (Cumming *et al.* 2019). This is despite the abundant evidence that environmental persistence and resistance to treatment are very different between bacterial, viral and protozoan pathogens. As a result, in many LMICs, generalised interventions are selected that do not interrupt the

transmission of pathogens that cause substantial disease within communities. These interventions, therefore, do not result in safe water or sanitation and do not yield the expected public health gains.

The COVID-19 pandemic that started in 2020 illustrated in stark terms the need for more consideration of the levels of water and sanitation services required to achieve public health protection (Howard *et al.* 2020). Howard *et al.* (2020) note that the frequency and intensity of handwashing recommended by public health guidance to combat transmission of COVID-19, running water on premise is necessary. This conclusion is supported by the findings of a systematic review by Wolf *et al.* (2018) who found that the largest increase in the health benefit of any incremental steps in improving water supply came from the transition from unimproved supply to higher quality piped water.

The current SDG target 6.1 calls for universal access to 'safely managed water on premises free from pathogens and priority chemicals' (WHO & UNICEF 2017). The indicator used to monitor global progress on SDG 6.1 allows for non-piped water on premise to be counted as safely managed provided it is available when needed (WHO & UNICEF 2017). The indicator falls short of defining the kind of comprehensive risk management approach required to ensure that safe water is provided. This would be best achieved through much greater uptake of water safety plans (WSPs), supported by health-based targets and independent surveillance (WHO 2017a). Gunnarsdottir *et al.* (2012) and Setty *et al.* (2019) have shown that the application of WSPs in high-income countries has led to measurable reductions in disease, although not in all settings.

To date, 93 countries have initiated programmes to develop and implement WSPs, although in many countries only a small proportion of water supplies implement WSPs (WHO 2017b). Overall, the application of WSPs appears more widespread for piped water supplies and while WSPs have been defined for non-piped water sources (Mahmud *et al.* 2007), the evidence of successful implementation is limited. Regulation of safety is generally weak outside of high-income countries, especially where supply is not managed by a utility (Crocker & Bartram 2014). Outside of high-income countries independent surveillance remains poorly developed despite evidence of its effectiveness in helping ensure delivery of safe drinking water and as a tool to support decision making in LMICs (Lloyd & Bartram 1991; Howard & Bartram 2005). There is even less evidence of the development of locally relevant health-based targets for water systems and this area requires urgent attention.

The evidence, therefore, suggests that there is a need to revise the current SDG 6.1 target to make this universal access to safe and continuous piped water supply on premises. This help ensures that there is sufficient water enhanced hygiene during outbreaks of disease, it would encourage greater numbers of water supplies to develop and implement WSPs and facilitate more effective regulation. Increasing access to piped water on premises will need to be supported by investment to reduce and intermittent supply which affects over 300 million people worldwide (Kumpel & Nelson 2016), leading to increased public health risks (Bivins *et al.* 2017) and outbreaks of disease (Jeandron *et al.* 2015). Furthermore, expanded access to piped water on premises must consider climate change. The volumes of water required will increase, distribution systems and treatment works must be designed to be resilient against future threats, and consideration must be given to the impact of increasing temperatures on biofilm development in engineered systems.

A more ambitious target for drinking water calls for better management and professionalisation of water service provision across the globe. The root of many of the problems with current water supply reflects the failure of the community management model that has dominated sector thinking since the 1980s. Communities have been asked to manage their own water supplies, often with little or no ongoing support from local governments or other agencies, despite the evidence that such support is critical to sustainability (Harvey & Reed 2006; Hutchings *et al.* 2015).

If the world is to achieve a more ambitious SDG target 6.1 and ensure long-term sustainable services, professionalisation of the sector is a key. Shifting responsibility for managing water supplies to dedicated staff operating within institutions with a mandate for delivery of water services and overseen by an effective regulator is the only way to ensure universal access to safe and sufficient drinking water. Achieving more ambitious SDG target for water supply target will require substantial investment (Hutton & Varughese 2016), but the expected health benefits yield

positive cost–benefit ratios making this a good value for money investment (Hunter *et al.* 2009).

ANTI-MICROBIAL RESISTANCE

The rise of AMR is one of the greatest health challenges for the 21st century and without action infections caused by resistant pathogens could result in 10 million deaths a year by 2050 (O'Neil 2016). An increasing number of studies and systematic reviews demonstrate how a wide range of pathogens across all continents are developing resistance (Ferri *et al.* 2017). The O'Neil (2006) report on AMR identified improvements in sanitation and hygiene as very high priority interventions, particularly for LMICs. Nadimpalli *et al.* (2020) note that the absence of adequate water and sanitation, along with other environmental factors, are creating AMR 'hotspots' in high-density informal urban settlements in LMICs.

The exact role of sanitation and hygiene in controlling AMR is somewhat unclear (Wuijts *et al.* 2017; Nadimpalli *et al.* 2020). However, there is evidence that human faecal pollution leads to increasing numbers of antibiotic genes in microorganisms found in the environment (Karkman *et al.* 2019). Pickering *et al.* (2019) note a number of studies that have isolated anti-microbial-resistant pathogens from drinking water supplies in informal urban settlements.

There are a number of ways in which improved sanitation may contribute to reduce AMR including reducing disease and antibiotic usage in communities (Nadimpalli *et al.* 2020); improving wastewater and sanitation management to reduce the risks of gene acquisition within faecally contaminated environments and within wastewater treatment (Karkman *et al.* 2017; Nadimpalli *et al.* 2020); and improving guidelines, monitoring and regulation of antibiotic-resistant organisms in wastewater discharges (Wuijts *et al.* 2017). In the first of these, improved sanitation will help reduce the number of repeated infections with diarrhoea that may lead to colonisation resistance in human microbiotas (Lawley & Walker 2012) and may help reduce demand for antibiotics (Nadimpalli *et al.* 2020).

There is uncertainty over the role of wastewater treatment systems in inhibiting or promoting the acquisition of antibiotic-resistant genes in microorganisms that are released into the environment, but sufficient evidence to raise concerns about how wastewater is treated (Bürgmann *et al.* 2018). Wuijts *et al.* (2017) note that wastewater treatment plants that accept both domestic and hospital waste are of particular concern, as the latter tends to contain more antibiotic residues, pathogens and antibiotic-resistant organisms. Wuijts *et al.* (2017) recommend the assessment of treatment processes and identifying control points in treatment works that will reduce the breakthrough of antibiotic resistance microorganisms supported by effective operational monitoring and independent surveillance and regulation.

The importance of sanitation in combatting AMR indicates that the current definition of safe sanitation and wastewater treatment (WHO & UNICEF 2017) should be expanded to encompass the prevention of release antibiotic-resistant organisms into the environment. This will require upgrading of the SDG targets 6.2 and 6.3 so that there are explicit measures related to AMR. There will need to be greater investment in wastewater treatment and faecal sludge management and their regulation, underpinned by research into AMR and sanitation.

The need for professionalisation of sanitation is possibly even more urgent than for water supply. Sanitation has increasingly been devolved to an individual household responsibility. The success of total sanitation approaches in reducing open defaecation has led to a perception that all sanitation problems must be resolved by households. However, these approaches have shown much more limited success in ensuring sustained use of sanitation and limited evidence of encouraging households to acquire safe sanitation (Crocker *et al.* 2017).

If we are to manage the threats of infectious disease, reduce the spread of AMR and ensure resilient sanitation, sanitation services need to be transformed. This does not mean a rush to invest in expensive conventional sewerage systems as in many cases this would represent maladaptation to climate change given the heavy demands for water and energy. On-site systems linked with effective measures to collect, transport, treat and reuse sludge can offer the same levels of safety and will often be more sustainable and resilient than sewerage systems (Howard *et al.* 2010). Organising such services, however, requires better-trained staff, effective regulations and adequate infrastructure.

CLIMATE CHANGE: THE URGENT NEED FOR RESILIENCE

The changes in climate already seen and projected into the future will have a major effect on water and sanitation services (Bates *et al.* 2008; Jimenez Cisneros *et al.* 2014). Climate change can be expected to impact on the full chain of water and sanitation service delivery with changes to water quality, carrying capacity of receiving waters, damage to infrastructure, contamination of water supplies and the environment, and the emergence of pathogens in engineered systems (Khan *et al.* 2015; Howard *et al.* 2010, 2016).

Changes in precipitation patterns caused by climate change will lead to more extreme events and increased flooding, while in parts of the world that are drying, risks of drought and water scarcity will increase (Bates *et al.* 2008; Jimenez Cisneros *et al.* 2014). However, threats from climate change also include wildfires (Khan *et al.* 2015), damage to water supply and energy infrastructure from wind storms and extreme heat (Kayaga *et al.* 2020), and storm surges and sea level rise leading to salinisation of groundwater and surface waters (Howard *et al.* 2016). Increases in ambient temperatures combined with the expansion of piped water systems may increase exposure to opportunistic pathogens than grow within biofilm in engineered systems (Bartram & Hunter 2015).

Adapting water and sanitation services to ensure that they become more resilient to future climate change will be a defining challenge for the sector over the coming decades. As adaptation is planned, this must consider how a shift to a target of universal access to piped water on premises and sanitation systems that help reduce the spread of AMR may impact on resilience.

Adaptations will involve actions on technology, management, policy and finance (Howard *et al.* 2010). In many parts of the world, extreme event occurrences will be likely to become more common (IPCC 2014) and service providers may be faced with new threats. Water quality changes are likely to be substantially making water treatment more complex and expensive (Howard *et al.* 2016).

Khan *et al.* (2015) make the case WSPs offers an effective mechanism to support adaptation to manage climate impacts on water safety, and WHO (2017c) have produced guidance for climate-resilient WSPs. Ricket *et al.* (2019) reviewed the global experience of integrating climate concerns into WSPs and found 18 examples of climate change being integrated into WSPs with case studies from LMICs in South-East Asia and Africa. However, it should be noted that the examples from these two regions were all associated with a single project. There continues to be substantial investment in technology development to improve the ability of systems to cope with new and emerging threats and challenges, including the efficiency and performance of water treatment technologies to cope with changing water quality, including extremely high suspected solids loads and cyanobacterial blooms in source waters (Howard *et al.* 2016).

Small systems are of special concern in relation to climate resilience and adaptation (Kohlitz *et al.* 2019). The management of small systems, often relying heavily on volunteers with limited training and expertise, in addition to simple designs that aim to reduce costs, means that they are often vulnerable to impacts from floods and droughts. Studies in LMICs and high-income countries demonstrate the relationship between poorly maintained infrastructure in small systems and contamination, frequently in response to rainfall events (Gélinas *et al.* 1996; Howard *et al.* 2003; Godfrey *et al.* 2006; Kostyla *et al.* 2015). WSPs have been developed for small systems in LMICs (e.g., Mahmud *et al.* 2007), but there is limited experience of climate change that is being integrated for such systems.

Climate threats and their management in sanitation systems are generally far less well studied or understood. Sanitation systems can be, however, highly vulnerable to climate threats and failure in sanitation systems leads to widespread faecal contamination in the environment and substantially increased risks to public health (Howard *et al.* 2010). Studies from high-income countries have assessed the resilience of wastewater treatment systems including studies of actions being taken by managers to address climate threats (Kirchhoff & Watson 2019). There are far fewer studies from LMICs, but Fleming *et al.* (2019) assessed the resilience of sanitation in the Solomon Islands and recommended changes to sanitation provision and programming to improve resilience.

In addition to improved management, other investments will be required to adapt to climate threats, including investment in upgraded infrastructure, improved environmental

protection, and policy decisions on technologies (Howard *et al.* 2016). Danilenko *et al.* (2010) describe actions including climate monitoring, diversification of sources, improved management, leakage reduction and expanded storage that would all be required in different circumstances to improve resilience. Johansson *et al.* (2014) describe a range of different investments required to protect WASH systems against climate threats using private-public partnerships.

The threat posed by climate change and the need to build greater resilience needs to be given more prominence both within the SDG 6 targets and within investments to support adaptation to climate change. This includes ensuring that the more ambitious SDG targets 6.1, 6.2 and 6.3 called for above also require evidence that services compliant with these targets are resilient to future climate change. There also needs to be a much greater effort to support more investment from global climate funds to building more resilient WASH services as a key element of adaptation. There are clear co-benefits for mitigation given sanitation is an important source of greenhouse gas emissions (Reid *et al.* 2014; Howard *et al.* 2016).

HUMAN RESOURCES, FINANCE AND TECHNOLOGY TRANSFER UNDERPIN TACKLING THESE CHALLENGES

Professionalisation of water supply and sanitation services and their regulation will require a change in mindset within the sector and concerted efforts to invest in human resources for the sector to ensure that the right skills and personnel are available and deployed (IWA 2014). This professionalisation does not mean that communities and households should not have a voice in deciding how services should be provided. The focus should, however, be ensuring that communities have a strong and effective role in developing more transparent governance, increasing accountability and more effective regulation of service providers, thus supporting the achievement of SDG target 6b.

Finance remains constrained in the water and sanitation sector and as noted in the GLAAS report (WHO 2019), the majority of LMICs continue to report a deficit in available funding against budgeted needs. This is not a new problem. However, the presumed solutions to finance have too often focused on the need to lever 'new' finance into water and sanitation with a focus on attracting private finance. The experience to date indicates very limited appetite for private investment in a sector that will provide low returns over long periods; that is subject to substantial political interference; and where regulation has often been weak. Meeting the SDG targets will require more effective use of increased public budgets at least to support the capital investment requirements, including utilisation of available budgets which many countries fail to achieve.

How finance is used is at least as important as the amount of finance available. Subsidies, for instance, have attracted criticism, which in many cases is justified as studies show that supply-side subsidies tend to benefit the wealthier sections of society and have limited benefit to poorer sections (Andres *et al.* 2019). However, in health, nutrition, and education, the use of demand-side subsidies through instruments such as conditional cash transfers have had a transformative effect on uptake of services and behaviour (Fernald *et al.* 2009; Mostert & Vall Costello 2020). To date, there has been little attempt to apply such approaches to the delivery of water and sanitation services, although when water and sanitation have featured as an element of a cash transfer programme focused on other sectors, positive impacts on access to services has been found (de Groot *et al.* 2017; Renzaho *et al.* 2018).

Funding and technology transfer from high-income countries to LMICs is important to support effective regulatory systems and to develop human resource capacity to support accountable, transparent, and efficient service provision. As the relative importance of official development assistance (ODA) declines in funding for water and sanitation (WHO 2019), focusing available ODA on building robust systems with well-trained staff and strong institutions to support and regulate service provision would be the most effective use of a scarce resource and contribute to achieving SDG 6a.

CONCLUSION

This paper has focused on three critical challenges facing the water and sanitation sector – its ability to contribute to halting transmission of infectious disease, the increasing threat of AMR and tackling the climate emergency. While

other challenges undoubtedly exist, these issues have a global impact and will define water and sanitation for years to come.

These challenges overlap and interact with each other. Investments to improve access to piped water will mean more return flows into sanitation systems and it will be important to assess what impact this may have on treatment systems designed to reduce the spread of AMR. Investments in sanitation systems to reduce the release of anti-microbial-resistant organisms into the environment should lead to reduced contamination of water sources and help improve the safety of drinking water. Investments to improve drinking water and sanitation systems must consider the likely impact of climate change and measures put in place that will enhance resilience.

The global community needs to be more ambitious in its goals for water and sanitation. Shifting to targets of universal access to continuous, safe water on premises that is resilient to future climate change and enhancing the definition of safe sanitation and wastewater quality by including actions on AMR imply substantial shifts in policy, practice and finance. While the temptation may be strong to resist increasing our ambition given current rates of progress appear to be so slow, failing to do so will mean remaining vulnerable to outbreaks of disease, continuing to consign people to poverty and limiting their economic opportunities, and increasing vulnerability to the effects of climate change.

These challenges can be met but require the sector to reassess how such essential basic services can be effectively delivered. Technology development and innovation will remain an important strand in this, but the key will be the professionalisation of services and a move away from the delegation of responsibility to communities and households. There needs to be more effective use of existing finance and expanded public investment in these services and using financial instruments from other sectors that have proved effective should be explored. Further research is required on key aspects, such as combatting AMR and improving resilience, but this should not hold back actions that can be taken now.

Ultimately, to protect public health and help reduce poverty, the world needs to increase its ambition of water and sanitation. Redefining SDG targets is an important first step and would demonstrate a long-term commitment to delivering the basic services all humanity needs.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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