The potential for atmospheric water harvesting to accelerate household access to safe water

With Sustainable Development Goal 6 (SDG-6), member states of the UN declared their ambition for universal access to safely managed water, recognising this as fundamental to human health, wellbeing, socioeconomic development, and gender equity.[1] Through the support of expert groups, the UN defined safely managed water as a continuous supply of uncontaminated water delivered directly to every household worldwide. Currently, 2·2 billion people (primarily in low-income and middle-income countries [LMICs]) do not have this level of water service;[1] globally, 200 million hours are spent collecting water from locations beyond the household plot each year, mostly by women and girls.[2] The appendix (p 1) provides further reading on water policy and services in low-income settings.

Research in the past 5 years has shifted two paradigms in understanding water, sanitation, and hygiene (WASH) services and human health. First, several randomised trials have shown that low-cost household WASH interventions (point-of-use water chlorination, improved latrines, and promotion of handwashing with stations not connected to a water source) might not achieve expected health benefits even when intensively implemented.[3] Second, increasing evidence shows that virtually all children in low-income settings carry asymptomatic enteropathogens from an early age, which is associated with growth and cognitive deficits.[4] Thus, the adverse health effects of faecal–oral microbial infection extend far beyond diarrhoea, and the basic WASH interventions typically available in low-income settings are inadequate to control this type of infection. As a result, researchers have called for a transformation of WASH services to hasten achievement of SDG-6, highlighting the provision of on-plot water access as a key step in this transformation.[3]

To achieve SDG-6, the WASH sector has correctly stressed the importance of strengthening government leadership and resource mobilisation. However, linear projections suggest that many LMICs are at least a century away from achieving SDG-6 with government-led provision of boreholes, pumps, and piped networks.[5] The global health community can either accept this trajectory—and the disease, gender inequity, and socioeconomic consequences—or develop alternative approaches, including new technologies.

On Oct 3–4, 2019, we convened an informal meeting to examine one such technology, atmospheric water harvesting (AWH). The meeting bridged a common gap between technology innovators and global WASH scientists. The objectives of the meeting were to update global WASH scientists on AWH, inform those involved in AWH innovation about the operational requirements of water systems in low-income settings, and consider the potential of AWH to contribute to achieving SDG-6.

AWH is the capture and collection of water from the air.[6] AWH includes: fog harvesting (effective in regions where relative humidity is 100%); 2) refrigeration-based atmospheric generators (refrigeration-based devices that condense liquid water below the dew point, producing up to 2000 L/day in regions where relative humidity is >40% and electricity is available); and 3) sorbent-based AWH,[7] commercially available from companies such as Zero Mass Water. Further reading on AWH is provided in the appendix (pp 1–3). The sorbent-based devices incorporate desiccants to capture atmospheric vapour during the night, require only solar thermal energy to release liquid water from the desiccant during the day, function across a broader spectrum of relative humidity than dewing technologies, and can be engineered to have no moving parts. However, sorbent-based AWH is currently limited by the small volume of water produced relative to total household water requirements for drinking, cooking, and hygiene.

See **Online** for appendix

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AWH offers several potential advantages. First, AWH decentralises water production to the point-of-use with off-the-grid devices, obviating the need to pipe or truck water from its source to households. Second, AWH has the potential to provide safe water because the infrastructure and the water produced are physically isolated from contaminated ground and surface water, and on-plot production controls contamination during transport and storage. Finally, AWH accesses a currently untapped, abundant water source: the atmosphere contains around 3 trillion litres. This novel supply is

Panel: Conclusions of the meeting held Oct 4–5, 2019, regarding the potential of atmospheric water harvesting (AWH) to provide water services in low-income and middle-income countries (LMICs)

- AWH technology offers the potential to provide point-of-use access to safe water from a currently untapped source.
- Sorbent-based AWH might offer additional advantages if at least 50–100 L/day of water can be produced at a cost equal to or lower than installing a borehole or a connection to a piped network, the currently available alternatives for on-plot service; the rapidly expanding field of desiccant materials and the potential for optimising engineering design provide substantial opportunities to increase capacity.
- Concurrent with technical development, formative research with early prototypes should be done in low-income settings to ensure the needs of end-users in these settings are considered in future product design.
- Other markets for AWH include water-scarce high-income settings and militaries, however, product requirements are substantially different for these markets; accordingly, we recommended seeking development donor support, to ensure technology development decisions can prioritise the requirements of LMICs.

important because fresh surface and ground water supplies fluctuate seasonally, such that 4 billion people currently experience severe water scarcity—defined as blue water consumption being at least double blue water availability—at least one month of the year.[8]

Unlike purification technologies that address only water quality, AWH also addresses water access. Several studies have shown that low-income households are more willing to pay for water quantity and convenience than quality.[9] By providing convenient water access, AWH might have potential for financial sustainability through user fees if it can meet user demands for water quantity. Furthermore, AWH might become increasingly efficient as a result of climate change: between 1979–2016, average global atmospheric water content increased by nearly 3 g/kg.[10] This increasing atmospheric water content is especially relevant for low-income countries where climate change will disproportionally affect safe water access.

The conclusions and recommendations of our meeting in October, 2019, are summarised in the panel. Briefly, AWH technology decentralises water production, thereby responding to the SDG-6 challenge of delivering clean water directly to every household in the world. Sorbent-based AWH requires only solar thermal energy, but is currently limited by the low volumes of water produced (0·25–10 L/day) relative to household requirements for consumption and hygiene (about 50 L/capita per day); although this limitation might soon be overcome by rapidly expanding new adsorbent materials, together with improvements in engineering design. New technologies are frequently unsuccessful during implementation; to reduce this risk, formative research with end-users in LMICs should be undertaken when a scalable high-performance prototype is developed.

We declare no competing interests.

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