World Health Organization

Results of Round II of the WHO International Scheme to Evaluate Household Water Treatment Technologies

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This report describes the products evaluated in Round II of the WHO International Scheme to Evaluate Household Water Treatment Technologies (the Scheme) as meeting the WHO-recommended performance levels at the time of testing. WHO cannot guarantee that the products that met a stated performance level will continue to do so.

The figures and tables included in this report do not provide an exhaustive overview of available household water treatment (HWT) products. They reflect those products that were submitted to WHO for evaluation in Round II of the Scheme, were found to meet the eligibility criteria for such evaluation and were subsequently evaluated. The fact that certain products are not mentioned in this report does not mean that they are not eligible for evaluation; nor does it mean that, if evaluated, they would not be found to meet any of the WHO-recommended performance levels.

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Abbreviations and acronyms

C. parvum	*Cryptosporidium parvum*
cfu	colony-forming units
CTW	Challenge Test Water
E. coli	*Escherichia coli*
EoI	expression of interest
FRC	free residual chlorine
GDWQ	WHO Guidelines for Drinking-water Quality
GTW	General Test Water
HIV/AIDS	human immunodeficiency virus/acquired immunodeficiency syndrome
HWT	household water treatment
HWTS	household water treatment and safe storage
IAC	Independent Advisory Committee
IEC	International Electrotechical Commission
ISO	International Organization for Standardization
NaDCC	sodium dichloroisocyanurate
Network	International Network on Household Water Treatment and Safe Storage
NOM	natural organic matter
NTU	nephelometric turbidity unit
Scheme	WHO International Scheme to Evaluate Household Water Treatment Technologies
SDG	Sustainable Development Goal
TOC	total organic carbon
UN	United Nations
UV	ultraviolet
WAPI	water pasteurization indicator
WASH	water, sanitation and hygiene
WHO	World Health Organization
WSP	water safety plan

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Joe Brown, Georgia Institute of Technology, USA
Charles P. Gerba, University of Arizona, USA
Tamar Kohn, École Polytechnique Fédérale de Lausanne, Switzerland
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BOX 1
Water safety and point-of-use / household water treatment

A preventable crisis

2 billion people
drink water that is contaminated with faeces

2.9 million people
are affected by cholera and other waterborne disease outbreaks annually

829 000 deaths
deaths are due to diarrhoeal disease annually

26% of health care facilities
lack basic water services

31% of schools
lack an improved* source of drinking-water

* Improved drinking water sources are those that have the potential to deliver safe water by nature of their design and construction, and include: piped water, boreholes or tubewells, protected dug wells, protected springs, rainwater, and packaged or delivered water.

Improving water safety

Waterborne diarrhoeal disease is largely preventable through interventions aimed at identifying and managing water safety risks, including water safety planning. Household/point-of-use water treatment as an interim measure, allows households, schools and health care facilities to take charge of water safety

HWTS

When effective products are used correctly and consistently, HWTS **can reduce diarrhoeal disease** by as much as **61%**

Promoting maximum, sustained diarrhoeal disease reductions

HWT Scheme
Coordinate independent evaluation of HWT products against WHO norms, and strengthen capacity of countries to regulate and conduct complementary testing of HWT

HWTS Network
Support effective, collective action, share implementation strategies and disseminate knowledge

WHO's work on HWTS

Establish norms on HWT performance and evaluate products of global relevance

Support countries in implementing norms through risk-based approaches

Convene stakeholders on water safety

HWT: household water treatment; HWTS: household water treatment and safe storage; HWT Scheme: WHO International Scheme to Evaluate Household Water Treatment Technologies; HWTS Network: International Network on Household Water Treatment and Safe Storage; WHO: World Health Organization

1 Highlights

Since the establishment of the International Scheme to Evaluate Household Water Treatment Technologies (the Scheme) in 2014, WHO has been independently evaluating the performance of household water treatment (HWT) technologies in removing microbial contaminants from drinking-water. The Scheme is one part of WHO's normative programme of work on drinking-water quality. It provides the evidence to inform Member States and United Nations procuring agencies' selection of effective HWT technologies to reduce the risk of diarrhoeal disease from unsafe drinking-water. In particular, the Scheme helps to ensure that products that provide limited or no pathogen removal are kept off the market.

This Round II report of the Scheme adds to the growing number of HWT products for which comprehensive, health-based performance evaluations are available. The report summarizes the results of 19 of 20 HWT products evaluated in Round II of the Scheme[1]. These represent a range of treatment methods, including chemical, solar and ultraviolet (UV) disinfection and ceramic and membrane filtration.

1.1 Improving water safety

Unsafe drinking-water still accounts for over half of the diarrhoeal disease burden globally

Although significant progress has been made in increasing access to drinking-water services, these do not always provide water that is safe at the point of consumption, including in homes, schools and health care facilities. Over 2 billion people globally lack access to safely managed drinking-water services, and approximately 485 000 diarrhoeal deaths in low- and middle-income countries each year are attributable to unsafe drinking-water.

Sustainable Development Goal (SDG) 6.1 calls for safe drinking-water along the entire water service delivery chain

SDG 6.1 represents a higher level of ambition than the previous Millennium Development Goal target related to drinking-water. SDG 6.1 focuses on the type of infrastructure available and emphasizes the quality of the service that is delivered, including safety of drinking-water. This necessitates ensuring that water safety risks are minimized from catchment to consumer, including in households where unsafe collection, storage and handling can result in contamination.

Drinking-water safety can be improved through effective household water treatment and safe storage

Household water treatment and safe storage (HWTS) can reduce the risk of diarrhoeal disease by as much as 61% when *effective* HWT methods are used *correctly and consistently* by *populations at risk* of waterborne disease (Box 2). HWTS should therefore be targeted to where the safety of water supplies is uncertain; in emergencies and outbreaks of waterborne disease such as cholera; and among vulnerable populations relying on unsafe water sources, such as young children, the malnourished and people living with HIV/AIDS. Through the Scheme, WHO works to maximize health gains from HWT by ensuring that products on the market meet global, health-based performance criteria. Governments are ultimately responsible for progressive improvements to safe drinking-water and towards achieving universal access.

[1] Testing is in progress and results are pending for one product. The results from this product will be published in a product-specific test report in Q3 2019.

BOX 2
Achieving health gains from HWTS

Both quantitative microbial risk modelling and epidemiological evidence indicate that appreciable health gains from HWTS are achieved under three main conditions. These are: (i) the water treatment method sufficiently removes contaminants; (ii) rates of use are high that is, over 90% of the time; and (iii) HWTS is actually needed.

Treating water that has low levels of contamination to begin with does not result in appreciable health gains. Supporting correct and consistent use of accepted technologies through, for example, regular promotional messaging and user training is particularly important for achieving health gains. Results of recent field trials from Bangladesh and Kenya suggest that not sufficiently engaging users in HWTS selection as well as intermittent messaging results in incorrect and inconsistent use and little to no reduction in childhood diarrhoea. Thus, significant effort is required in understanding contextual factors, including the most appropriate HWTS technology in a given setting, supporting correct and consistent use, and how technologies perform with specific source water quality characteristics.

1.2 Round II of the Scheme

Increased demand for product evaluation under the Scheme

In Round II, 39 expressions of interest (EoIs) for evaluation were received. Of these, 20 products were evaluated – twice the number evaluated in Round I (Fig. 1).

More HWT products meet WHO performance criteria

The performance criteria are shown in Table 1. Of the 19 products for which results are available, 15 meet these performance criteria.

FIG. 1
EoIs submitted to the Scheme, Rounds I–II

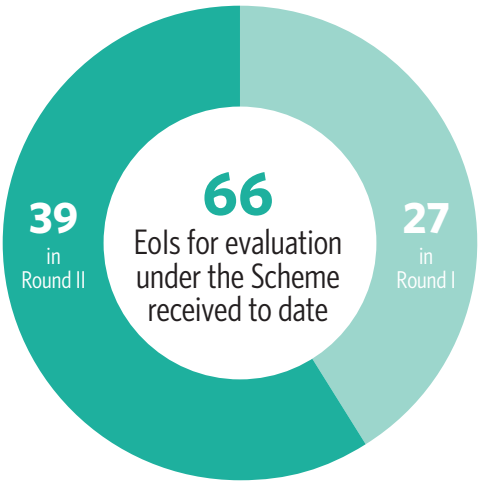


TABLE 1
WHO performance criteria for HWT technologies

Performance classification	Bacteria (log_{10} reduction required)	Viruses (log_{10} reduction required)	Protozoa (log_{10} reduction required)	Interpretation (with correct and consistent use)
★★★	≥ 4	≥ 5	≥ 4	Comprehensive protection
★★	≥ 2	≥ 3	≥ 2	
★	Meets at least 2-star (★★) criteria for two classes of pathogens			Targeted protection
–	Fails to meet WHO performance criteria			Little or no protection

Building on the 10 products evaluated in Round I, a total of 30 products have been evaluated under the Scheme to date, and 23 of these meet WHO performance criteria[2] (Table 2).

[2] Testing is in progress and results are pending for one product. The results from this product will be published in a product-specific test report in Q3 2019.

30
products have been evaluated under the Scheme

23 ✔
meet WHO performance criteria

TABLE 2
Products that meet WHO performance criteria

Treatment technology	Product	Manufacturer	Evaluation Round	Performance classification
Membrane filtration	LifeStraw Family 1.0	LifeStraw (part of the Vestergaard Group)	I	Comprehensive protection ★★★
	LifeStraw Family 2.0		I	Comprehensive protection ★★
	LifeStraw Community		I	Comprehensive protection ★★★
	Uzima Filter UZ-1	Uzima Water Filters	II	Targeted protection (bacteria and protozoa only) ★
Ceramic filtration	Nazava Water Filters	PT Holland for Water/Nazava	II	Targeted protection (bacteria and protozoa only) ★
	SPOUTS Water Purifaaya Filter	SPOUTS of Water Ltd	II	Targeted protection (bacteria and protozoa only) ★
	Tulip Table Top Water Filter	Basic Water Needs B.V.	II	Targeted protection (bacteria and protozoa only) ★
Flocculation–biofiltration	BlueQ™ Two-Stage	Amway Corporation	II	Targeted protection (bacteria and protozoa only) ★
Flocculation–disinfection	AquaSure Tab10	AquaSure	II	Comprehensive protection ★★
	P&G™ Purifier of Water	The Procter & Gamble Company	I	Comprehensive protection ★★
Flocculation–disinfection–filtration	DayOne Waterbag™	DayOne Response, Inc.	II	Comprehensive protection ★★
UV disinfection	Mesita Azul®	Fundación Cántaro Azul	II	Targeted protection (bacteria and protozoa only*) ★
	Water Elephant	Years of Water	II	Targeted protection (bacteria and protozoa only) ★
	Waterlogic	Qingdao Waterlogic Manufacturing Company	I	Comprehensive protection ★★
Solar disinfection	AquaPak	Solar Solutions	II	Comprehensive protection ★★★
	JAMEBI Solar Water Pasteurizer	Relevant Projects Ltd	II	Comprehensive protection ★★
	SolarBag®	Puralytics	II	Comprehensive protection ★★★
	WADI	Helioz GmbH	I	Targeted protection (bacteria and protozoa; some protection against viruses) ★

* Effective removal of bacteria and protozoa in non-turbid water only

TABLE 2
Products that meet WHO performance criteria (continued)

Treatment technology	Product	Manufacturer	Evaluation Round	Performance classification
Chemical disinfection	Aquatabs®	Medentech Ltd	I	Targeted protection (bacteria and viruses only) ★
	Aquatabs Flo		II	Targeted protection (bacteria and viruses only) ★
	H2gO Purifier	Aqua Research, LLC	I	Targeted protection (bacteria and viruses only) ★
	Oasis Water Purification Tablets	Hydrachem Ltd	II	Targeted protection (bacteria and viruses only) ★
	WATA-Standard™	Antenna Technologies	II	Targeted protection (bacteria and viruses only) ★

UV: ultraviolet
Results pending for one product

A number of available products, however, do not sufficiently protect the health of users

Of the 30 products tested in Rounds I and II, six fail to meet minimum performance criteria. It is likely that their performance under actual use conditions, especially where use instructions are not followed or are unclear, is worse. *Informed selection* by procurers based on detailed consideration of candidate product performance data, and *strengthened regulation* by governments to keep poor performing HWT products off the market, are essential.

Quality of HWT products is variable and should be strengthened

The performance of several of the products that do not meet the performance criteria varies widely across production lots or units. This highlights the importance of strengthening manufacturing quality assurance/quality control measures and ensuring that products consistently treat water at or above minimum performance standards.

Effective chlorination requires appropriate dosing and regular monitoring of free residual chlorine (FRC)

The effectiveness of chlorine products depends on the characteristics of the water being treated, including the presence of natural organic matter (NOM), temperature and pH. As these parameters vary in natural waters, the chlorine demand and, ultimately, the required chlorine dose varies. These findings underscore the importance of appropriate site-specific dosing that is based on the chlorine demand of the water to be treated and regular monitoring to ensure that FRC concentrations of 0.2–0.5 mg/L are maintained. Making these adjustments requires competent technical support and regular monitoring, which may be difficult to achieve in individual households. Efforts are therefore needed to shift towards safely managed central chlorination at point of collection, in tanker trucks, in community/health care facility water storage tanks or in piped water systems.

1.3 Interpretation and application of results

Health gains from two-star (★★) and three-star (★★★) products are similar although three-star products provide some added protection

The results of a quantitative microbial risk assessment (QMRA) modelling study (Bivins et al., 2019) undertaken in Round II indicate that while three-star products offer superior pathogen protection, under most water quality conditions similar health gains can be achieved from two-star products when these are used correctly and consistently. Essentially,

- both two- and three-star products provide comprehensive protection and are effective when a range of pathogens causing diarrhoeal disease is present or when the causative pathogen(s) is(are) unknown; and
- when choosing between two- and three-star products, the focus should not be on the product with a higher classification but on the product most likely to achieve high rates of correct and consistent use, and factors that support effective implementation, including supply chains, cost, etc.

Selection of one-star (★) products should be informed by an understanding of water quality characteristics and risks

Findings from the aforementioned modelling study also highlight that some one-star products can achieve health gains comparable to two-star products, depending on the source water quality and pathogen classes they protect against. For example, for water quality of low risk (i.e. <10 *Escherichia coli* colony-forming units/100 mL) and very high adherence (that is, used correctly and over 90% of the time), health gains from a one-star product that protects against bacteria and viruses are similar to those from a two-star product that protects against all three classes of pathogens. Thus, selection of one-star products requires more careful analyses of microbial contamination in source water and the limitations of the product.

Along with microbial performance, HWT selection should be informed by the likelihood of achieving correct and consistent use

Achieving health gains from HWT depends on multiple factors; microbial performance is critical, but not the sole factor. Once it is confirmed that a product meets minimum performance targets, other factors to consider include specific relevant water quality conditions, safe storage and the likelihood of correct and consistent use and the factors that influence such use (Fig. 2).

1.4 Strengthening national capacity and impact of the Scheme

A global evaluation scheme fills an important gap in limited national testing capacity

Unlike other health interventions, HWT technologies are diverse and must work against a number of different pathogens and different types of waters. This complicates the testing and requires highly skilled technicians and extensively equipped laboratories. As such, many low- and middle-income countries have limited capacity to conduct HWT performance testing. While WHO is working to simplify protocols for use in low-resource settings, research is ongoing and requires continued investment.

National regulatory oversight of HWT is vital and must be strengthened

National regulatory authorities can play a vital role in ensuring that available HWT products are effective and safe through assessment, certification and control of the products. However, many low-resource countries that commonly use HWT do not yet have comprehensive assessment and certification criteria on product performance, highlighting the need to continue strengthening capacity in this area.

FIG. 2
Using Scheme results in HWT selection

Laboratory capacity in HWT evaluation should be improved and mainstreamed within broader efforts to strengthen water quality surveillance and regulation

Efforts to strengthen the technical expertise, infrastructure and mandate of national water quality laboratories and research institutions should be comprehensive to make effective use of resources and to ensure sustainability of capacity-building efforts. Efforts to support stronger HWT national assessments should be carried out alongside broader efforts to assess and improve safe drinking-water services and regulation as part of efforts to meet SDG 6.1 targets and improve water safety for all consumers.

HWTS should be targeted for among high-risk groups and within key health and water safety efforts

HWTS has the greatest health impacts in populations that use water with high levels of faecal contamination and/or those who are particularly at risk for waterborne diseases. At risk populations include pregnant women and young children; people living with HIV/AIDS; malnourished individuals and those living in cholera hotspots. Thus, policies and programmes should integrate effective HWTS options into water safety efforts and comprehensive health programmes to maximize gains.

2 Introduction

SDG 6.1 seeks to ensure universal access to safe drinking-water. Underpinning SDG 6.1 is an emphasis on incrementally improving water safety. A systematic and comprehensive approach to assessing and managing water safety risks, from catchment to consumer, known as Water Safety Planning (WSP) is widely recognized as the most effective way to consistently ensure the safety of water supply and to protect public health (WHO, 2017).

Since the introduction of WSPs in the third edition of the WHO *Guidelines for Drinking-water Quality* (GDWQ) in 2004, 93 countries have adopted this approach (WHO/IWA, 2017).

2.1 Targeted settings for HWTS

Although 90% of the global population has access to a basic drinking-water source[1], contamination is widespread and at least 2 billion people use drinking-water sources that are contaminated with faeces (UNICEF/WHO, 2019). In particular, the prevalence of intermittently piped water supplies (Kumpel & Nelson, 2016) and deterioration in water quality during collection, transport and storage (Shields et al., 2015) in many low- and middle-income countries increase water safety risks.

Within the WSP framework, HWTS is an effective intervention to improve drinking-water quality where continuous access to safe piped-in water is not available. Aside from households, HWTS/point-of-use water treatment is increasingly important in institutional settings such as schools and health care facilities. Emerging data indicate that water safety is often compromised in these settings, where populations are particularly vulnerable to waterborne disease.

Ensuring water safety is critical in all emergencies. With 25 major health emergencies currently requiring international response[2], provision of safe drinking-water, including through rapid, portable water treatment units, is critical. This is especially true in health care facilities in emergency settings where high-risk and vulnerable populations receive curative care, including in the current Ebola virus disease outbreaks in the Democratic Republic of the Congo.

In addition, HWTS is a key component of preventing and responding to cholera outbreaks; these currently affect 47 countries (Global Task Force on Cholera Control, 2017). The global plan to end cholera by 2030 highlights HWTS as a particularly important intervention that, like the oral cholera vaccine, can be rolled out rapidly while longer-term investments in water, sanitation and hygiene (WASH) are underway (Global Task Force on Cholera Control, 2017; Montgomery et al., 2018).

[1] Basic drinking-water sources are defined as those that are (i) potentially capable of delivering safe water by nature of their design and construction, and include piped water, bore-holes or tube-wells, protected dug wells, protected springs, rainwater and bottled and delivered water; and (ii) are within a round-trip collection time of 30 minutes from the household. Full definitions of source types can be found at https://washdata.org/monitoring/methods/facility-types

[2] As of July 2019 there were eight Grade 3 and 17 Grade 2 health emergencies. Source: http://www.who.int/emergencies/crises/en/

2.2 The Scheme

To comprehensively assess effectiveness, WHO (2011) developed health-based performance criteria for HWT products based on the removal of the three main groups of pathogens that cause waterborne diarrhoeal disease: bacteria, viruses and parasitic protozoa. Pathogens in these three microbial groups, that is, enterotoxigenic *Escherichia coli* (*E. coli*) and *Shigella*, rotavirus, and *Cryptosporidium* were found to be the main causes of moderate-to-severe diarrhoea in a multicluster study of 20 000 children (Kotloff et al., 2013). The WHO criteria thus provide the basis for evaluating and classifying HWT performance against these microbial groups in three ascending tiers of performance: ★ (one-star), ★★ (two-star) and ★★★ (three-star).

Many low- and middle-income countries have neither the resources nor the capacity to assess HWT performance against WHO recommendations. Therefore WHO established the the Scheme in 2014 to support implementation of the aforementioned criteria by independently evaluating the performance of commercially available HWT products. Since then, harmonized testing protocols that detail the approach and testing conditions for various treatment technologies have been developed[3].

The results of the Scheme evaluations are used to inform procuring United Nations agencies, national governments and nongovernmental organizations. Since the report from Round I of the Scheme in 2016, the evaluation results have helped guide HWT product selection and are catalysing the shift towards better-performing products and better-informed users.

Alongside these efforts, WHO works to strengthen the capacity of national regulatory authorities and reference laboratories in regulating and carrying out complementary evaluations of HWT performance. This includes facilitating training and knowledge transfer on HWT performance evaluation, and supporting development of national health-based certification criteria for HWT products.

2.3 Report overview

This *Round II* report summarizes the results of 19 of the 20 HWT products recently evaluated under the Scheme. These products represent a range of treatment technologies, including chemical, solar and UV disinfection; ceramic and membrane filtration; and combined flocculation–disinfection.

Sections 1 and 2 highlight the key messages from the report, and outline the role of HWTS as a water safety intervention. The sections also introduce the Scheme and its objectives.

Section 3 presents an overview of Round II of the Scheme and outlines some of the key lessons from Round I and how they have been applied in improving how the Scheme works. The section draws attention to lessons learned from testing chlorine products and the importance of understanding water quality conditions for both performance testing and chlorination practice. The evaluation procedure and descriptions of each of the products evaluated in Round II are also outlined.

Section 4 summarizes the results from Round II, highlighting that there are additional products that meet WHO performance criteria. This section also notes that of the products that fail to meet WHO criteria, inconsistent performance across production units – suggestive of poor manufacturing quality – is a challenge.

[3] The testing protocols are available from: http://www.who.int/water_sanitation_health/water-quality/household/household-water-treatment-scheme-resources/en/

Section 5 discusses key concepts and considerations in interpreting the Scheme results and applying them in HWT selection. It emphasizes that HWT selection should be context specific, that is, based on understanding of water quality conditions, the performance/limitations of an HWT product relative to those conditions and the likelihood of achieving high rates of correct and consistent use.

Section 6 gives an update on the work of WHO in strengthening national regulation and complementary evaluations of HWT. It outlines how these efforts are improving understanding of HWT performance and of risk-based management of water safety as a whole.

The report concludes with an overview of lessons learned from the two rounds of evaluation under the Scheme and outlines priorities for future evaluations and national capacity-building efforts.

3 Round II of the Scheme

In Round II, WHO worked to improve programme efficiency and increase awareness of the Scheme among manufacturers and procurers. This section of the report summarizes the evaluation procedure and changes made to testing protocols, and how these changes have allowed for more products to be tested, without compromising scientific rigour. This section also provides an overview of the products evaluated.

3.1 Updates and applied lessons from Round I

3.1.1 Simplifying testing for wider uptake by laboratories

The Scheme testing protocols are designed to guide WHO-designated testing laboratories as well as laboratories seeking to evaluate HWT products in the most scientifically rigorous, efficient and cost-effective way possible. Cost-effectiveness is especially important to ensure that all products of public health relevance are evaluated and to allow for adaptation of protocols for testing local products in low- and middle-income countries. Between Rounds I and II, WHO simplified testing protocols, thus expanding where and how HWTS can be tested. In particular, the following amendments were made to the protocols:

- Reduction in the total number of posttreatment samples collected per product from 18 to 12, based on a review of the data from the products evaluated in Round I. This review highlighted that the number of posttreatment samples collected exceeded the number necessary to determine performance and added time and cost to the testing.

- Reduction in the number of microbial groups tested, depending on the best available evidence for the performance of technologies against the relevant microbial groups. For example, free chlorine is ineffective against protozoan cysts, especially *Cryptosporidium*. In the case of filters that are based mainly on size exclusion, if they can effectively remove bacteria and viruses, they can reasonably be expected to effectively remove *Cryptosporidium*, which is the largest in diameter of the test organisms. Therefore, these technologies are not tested against protozoan cysts.[1]

Further amendments are outlined in the Scheme Harmonized Testing Protocol (WHO, 2018a).

3.1.2 Increasing awareness of the Scheme and understanding of HWT performance

The findings of a rapid market assessment of HWT in sub-Saharan Africa, South-East Asia and the Western Pacific in 2015 indicated that awareness of key considerations in HWT performance evaluation and WHO performance criteria was limited (WHO, 2016a). Given the relatively high proportion of HWT users in these regions (WHO, 2014), these findings point to an opportunity to strengthen user awareness and assist governments, procurers and users in understanding the importance of the WHO performance criteria for health. Thus, following the publication of the Round I report in 2016, WHO has been working to disseminate the results and performance criteria among key stakeholders, including national regulatory and laboratory authorities, HWT manufacturers and implementers. A particular focus has been emergency actors (i.e. Global WASH and Health clusters) who often deploy HWT to address acute water quality concerns.

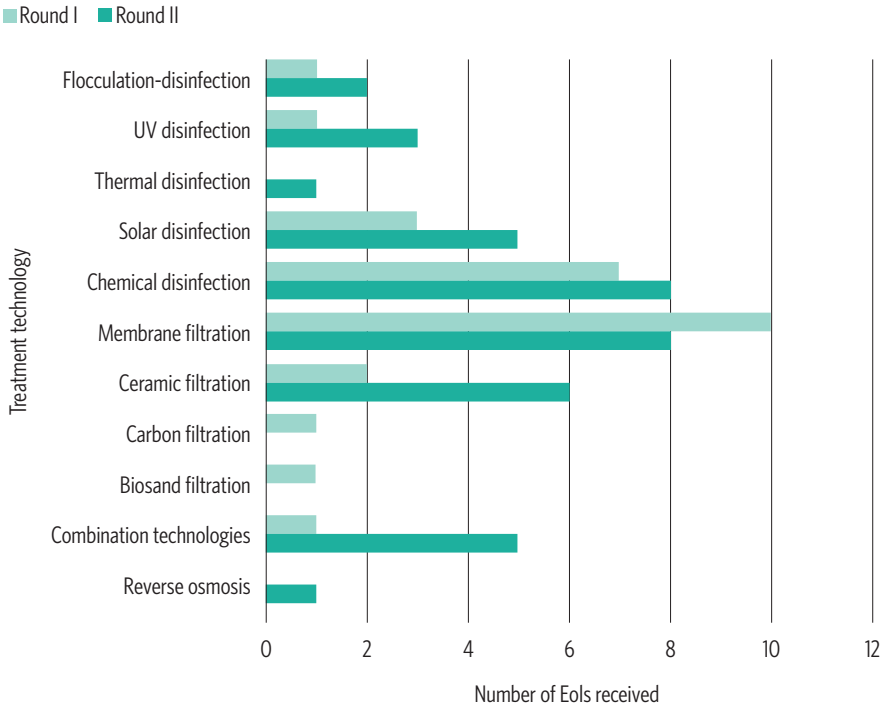
[1] In all cases, the decision to conduct an abbreviated microbial test is at the discretion of WHO, with input from the Independent Advisory Committee (IAC).

3.1.3 Demand for testing under the Scheme has grown

In Round II, 39 EoIs were received for evaluation under the Scheme, compared to 27 in Round I (Fig. 3).

The majority of EoIs received in Round II were membrane filtration and chemical disinfection technologies. Round II saw the inclusion of three relatively large-scale products that would be applicable in institutional settings such as health care facilities and schools. Given the salient need, and increased global attention to improving WASH, including water safety, in such settings (UNICEF/WHO, 2018; WHO/UNICEF, 2018a,b), future rounds will likely include more products of a similar scale.

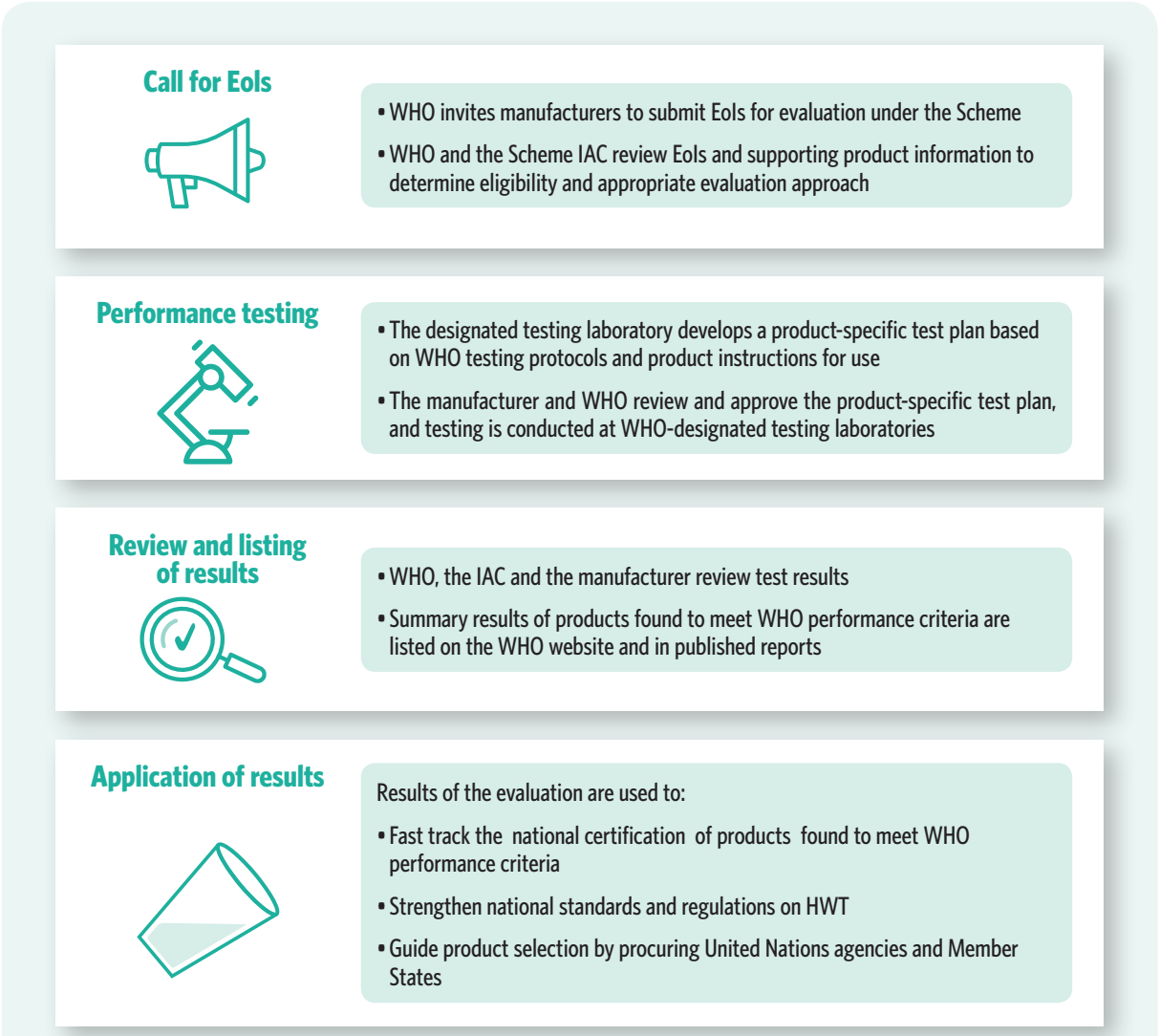
FIG. 3
EoIs submitted to the Scheme in Round I and Round II



3.2 Evaluation procedure

Evaluation of HWT products under the Scheme is based on manufacturers voluntarily submitting an EoI form and product dossier to WHO (Fig. 4).

FIG. 4
Scheme evaluation procedure



EoI: expression of interest; IAC: Independent Advisory Committee; WHO: World Health Organization.

Products prioritized for evaluation under the Scheme are relatively low cost; are intended for use in low- and middle-income settings; and are market-ready. EoIs meeting these screening criteria are selected for detailed review by the Scheme Secretariat, with input from the Scheme Independent Advisory Committee (IAC). Upon receipt of the evaluation fee[2], WHO works with the designated testing laboratories and the IAC to develop a product testing protocol. Testing is overseen by WHO, with input from the IAC who also review test reports and provide input on performance classification. Test reports are shared with manufacturers for review and comment before publication.

[2] WHO charges a subsidized fee for evaluation under the Scheme. The subsidy criteria are outlined in the *Procedure for Evaluation: WHO International Scheme to Evaluate Household Water Treatment (HWT) Technologies* https://www.who.int/water_sanitation_health/water-quality/household/how-evaluation-scheme-works/en/

3.2.1 Testing protocols and evaluation criteria

The philosophy of the Scheme evaluation is to provide a comparative and consistent assessment of HWT performance, to distinguish between products that are protective of health and those that are not. Testing is conducted in defined water quality conditions, in two test waters, according to the product use instructions. As much as possible, test conditions are set to simulate actual source waters and use in order to yield data that more closely estimate the effectiveness of the product in actual use.

WHO has developed protocols that are specific to the treatment technology (for example, solar/ultraviolet (UV) disinfection or ceramic filtration) that a product may employ, taking into account parameters such as temperature and turbidity that may impact performance (WHO, 2018a). The product-specific test plan is developed based on the technology-specific protocol in accordance with the product use instructions.
Evaluation under the Scheme comprises laboratory performance testing and review of product information, including labelling and instructions for use. The evaluation criteria are outlined in Box 3, with further details provided in Annex 1.

BOX 3
What does the Scheme evaluation consider?

Evaluation criteria	Specific considerations
Microbial performance	**Microbial groups:** Product should meet at least two-star (★ ★) performance targets for 2 of the 3 microbial groups. **Test water characteristics:** Product should be effective across a range of water quality conditions, i.e. both GTW or "clean" water and CTW or "dirty" water.
Consistency/product quality	**Manufacturing quality management:** Evidence of quality management system in place. **Consistent microbial reduction:** For devices, at least 3 production units should be tested. For consumables, samples from at least 2 manufacturing lots should be tested. **Disinfectant concentrations:** For consumables such as chlorine, the product samples should deliver the expected concentrations in deionized/dechlorinated tap water.
Product safety	**Leachates** from wetted contact material should not exceed health-based values specified in the GDWQ.[a] **Residual disinfectant concentrations** should be sufficient to prevent recontamination but not exceed concentrations that would be harmful to health or be rejected by consumers for reasons of taste or odour.
Labelling and instructions for use	**Product information** should include product name, manufacturer name and contact. **Labelling** should include a list of chemical contents, manufacturing lot number /manufacture date and expiration dates, if applicable. **Instructions** should be simple; consistent across product literature (packaging, website, etc.); have a minimal number of steps; and with illustrations where appropriate, including • **for devices:** procedures for cleaning and maintenance; indication of completed treatment; and restoration of flow (where applicable) • **for disinfectants:** dosage; mechanism to deliver dose; contact time; instructions to stir/mix.

[a] Testing is currently limited to arsenic and silver leachates from ceramic filters in contact with water, and a desk review of materials in contact with drinking-water that may be potentially toxic.

CTW: Challenge Test Water; GDWQ: Guidelines for Drinking-water Quality; GTW: General Test Water

In brief, evaluation under the Scheme considers performance across three microbial groups: bacteria, with *E. coli* as the test organism; viruses, with bacteriophages MS2 and phiX174[3] as the test organisms; and protozoa, with *Cryptosporidium parvum* (*C. parvum*) oocysts as the test organism. As outlined in section 3.1.1, the number of microbial groups tested may be reduced based on available evidence of performance against various microbial groups.

[3] Performance classification is based on the lower performing phage.

Products are tested in two types of test waters: General Test Water (GTW), representative of relatively "clean", nonturbid water such as groundwater, and Challenge Test Water (CTW), representative of relatively "dirty", turbid water, such as surface water.

Variation in performance across production lots or units can be indicative of poor manufacturing quality. For devices, consistency in performance is assessed by testing three randomly selected units from a production cycle. For consumable products such as chemical disinfectants, sufficient sample units from two manufacturing lots, randomly selected, should be provided for testing. In addition, for chemical disinfectants expected to deliver a certain dose, the concentration in dechlorinated tap water is assessed.

Materials in contact with drinking-water must comply with the GDWQ (WHO, 2017). For products that have a wetted contact material that may have a contaminant leach, residual concentrations are measured in the posttreatment water samples. For example, for ceramic filters, posttreatment samples are analysed for arsenic (Box 4) and silver.

For chemical disinfectants, the dose delivered in dechlorinated tap water and residual concentrations in posttreatment samples are analysed. In the case of chlorine, for example, maintaining an FRC concentration of at least 0.2–0.5 mg/L is important to prevent recontamination. However, the concentration of total chlorine should not exceed the health guideline value of 5 mg/L.

Safe storage is important to prevent recontamination of treated water (Box 5).

Evaluation under the Scheme considers aspects such as product labelling and instructions for use. Clarity of instructions, including dose and contact time in the case of consumable disinfectants, and cleaning and maintenance of devices are reviewed. Also reviewed is consistency of instructions in online and printed materials.

BOX 4

Arsenic leachates from ceramic filters

Variations in the chemical composition of source materials used in the production of ceramic water filters may pose a hazard to users through leaching of arsenic into filtered water. The GDWQ (WHO, 2017) set out a provisional guideline value of 10 µg/L for arsenic. The guideline value is provisional because of uncertainties in health impacts at low exposure as well as practical limitations regarding detection and removal of arsenic. However, given the possibility of adverse health impacts at low exposures, every effort should be made to keep concentrations as low as reasonably practicable and below the guideline value when possible.

Participating organizations of the International Network on Household Water Treatment and Safe Storage (the Network), including the Ceramics Manufacturing Working Group, have developed quality management and best practice guides for the local production of ceramic filters. Current best practices in arsenic mitigation include predicting leaching by testing contamination in source water and raw clay as well as in fired filters and treated water effluent. Studies have shown that arsenic leaches rapidly (van Halem et al., 2007; Schaeffer et al., 2018), and flushing filters with water several times before using is recommended to reduce arsenic concentrations (The Ceramics Manufacturing Working Group, 2011).

BOX 5

Safe storage can significantly reduce risk of diarrhoeal disease

Results from a recent meta-analysis indicate that filtration and integrated safe storage can reduce the risk of diarrhoeal disease by 61% compared to 51% from filtration only (Wolf et al, 2018). Thus, efforts should be made to include safe storage in HWT technology design.

3.2.2 Evaluation of chlorine disinfectants

Chlorination is one of the most common methods of disinfecting drinking-water. It is especially common as a secondary or final treatment after filtration and/or coagulation. Chlorine is also widely applied as a primary household/point-of-use treatment method in low- and middle-income settings and in many emergencies where there is risk of waterborne disease.

A variety of chlorine products are available; some are in granular form and some in liquid, and the efficacy of these products varies. The efficacy of chlorine disinfection correlates with the chlorine dose applied and the residual concentration subsequently available, the contact time and the type of microorganism. Chlorine is generally effective against bacteria and some viruses, but ineffective against most protozoan cysts including *Cryptosporidium*. In addition, site-specific water quality conditions also affect the efficacy of chlorine disinfection (Box 6).

BOX 6

What is chlorine demand and why does it matter?

The efficacy of chlorine disinfection is influenced by water quality characteristics such as the presence of organic and inorganic matter, pH, turbidity and temperature. Disinfection generally occurs more quickly at higher temperatures and is more effective at pH less than 8, and at low levels of turbidity and inorganic or organic matter. When added to water, chlorine reacts with natural inorganic (e.g. iron, ammonia) and organic (e.g. fulvic and humic acids) matter present. These reactions "consume" the chlorine, decreasing the concentration available for microbial disinfection. High levels of turbidity also contribute to decreased disinfection efficacy by shielding microbes and preventing them from coming into contact with chlorine.

Chlorine demand refers to the amount of chlorine added minus the amount consumed by these reactions. What is not consumed, the free residual chlorine (FRC), is available for additional disinfection.

Chlorine demand varies *across water sources* and *over time* due to, for example, seasonal changes in source water quality such as during dry/wet season, algal blooms and floods

The chlorine dose applied should be site-specific and achieve three objectives: (i) meet the chlorine demand of the water and sufficiently inactivate microbes; (ii) maintain an FRC concentration of ≥0.5 mg/L after 30 minutes of contact time, or ≥0.2 mg/L in stored household water to provide protection against recontamination; and (iii) not exceed taste and odour thresholds that may lead to rejection by consumers (WHO, 2017). *Note: the WHO recommendation is on the concentration of FRC to be maintained and* ***not*** *the dose to be applied, as the dose will vary depending on water quality conditions.*

Understanding the chlorine demand of water is important as it affects how much chlorine is required to ensure adequate disinfection

For effective disinfection, it is important to determine chlorine demand through preliminary testing with a set dose of chlorine. Once the chlorine demand has been determined, sufficient dose should be applied to meet that demand and maintain FRC. For instance, if the chlorine demand is determined to be 1.5 mg/L, a dose of at least 2 mg/L of chlorine should be applied in order to ensure the maintenance of at least 0.5 mg/L of FRC in the treated water. Treated water should be regularly monitored to ensure that targeted residual concentrations are met. Where changes in the residual concentration are detected and/or seasonal and other changes to the quality of the water supply occur, the dose should be adjusted accordingly to achieve the minimum FRC.

Most commercially available chlorine products are designed to deliver a dose of 2 mg/L in clear water. The recommendation is to double-dose in turbid water (i.e. 4 mg/L). Assuming chlorine demands of 1.5 mg/L in clear water and 3.5 mg/L in turbid water, these doses would be sufficient to maintain at least 0.2–0.5 mg/L of FRC in the treated water.

3.2.2.1 Round II chlorine technology evaluation protocol

In light of varying chlorine demands in natural waters, chlorine products were tested against a panel of four test waters with different chlorine demand, including the existing GTW and CTW. Preliminary tests indicated that the existing GTW and CTW exert chlorine demands that are higher than what limited data would suggest are average demands in groundwater and surface water[4]. Few products delivered a chlorine dose sufficient to overcome these demands, as evidenced by low reduction of bacterial and viral surrogates.

Products were then tested against two additional waters, with adjusted total organic carbon (TOC) concentrations to generate chlorine demand values that more closely reflect natural waters. For these additional test waters, testing against coliphages MS2 and phiX174 (viral surrogates) was not conducted[5]. The evaluation protocol used for chlorine products is outlined as follows:

- *Creating two types of test waters, with chlorine demand values of 1.5 ± 0.2 mg/L and 3.0 ± 0.2 mg/L*, set to mimic a range of chlorine demand levels likely to be found in natural waters;
- *Testing bacterial inactivation of the product*, as a comparative assessment in the two test waters and as indication of microbial performance across a range of water quality conditions;
- *Measuring FRC in posttreatment samples of the two test waters*, to verify that at least 0.2–0.5 mg/L of FRC is available after 30 minutes of contact time. In addition, the chlorine concentrations in dechlorinated tap water were measured to verify the ability of the product to deliver a dose of at least 2 mg/L, as an indication of the product quality; and
- *Reviewing literature and existing test data to determine expected viral inactivation.*

The formal testing results derived from these adjusted chlorine-specific test waters are presented in Section 4.

3.2.2.2 Interpretation of chlorine results

Free chlorine is generally ineffective against protozoan oocysts, especially *Cryptosporidium*, and testing against this microbial group was not conducted (Section 3.1.1). Thus, at best chlorine can only meet the one-star performance category or provide targeted protection against bacteria and viruses only. While in Round II it was not possible to test for viruses, information from literature along with posttreatment concentrations of free available chlorine provide a basic indication of overall microbial performance and product quality.

3.2.2.3 Key considerations and recommendations for chlorination practice

While no test waters can replicate the variability of source water quality conditions around the world, the test waters present two sets of scenarios that are broadly representative of the range of these conditions, that is, varying levels of organic matter and turbidity, temperature and pH. Accounting for these factors is important in performance testing and also when disinfecting with chlorine. Key recommendations include the following:

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[4] A rapid review that considered data from 24 countries was conducted to determine chlorine demand values that are more representative of those found in natural source waters. While chlorine demand varies depending on seasonality, type of water source, etc., the data suggest mean and 95th percentile values in groundwater and surface water of 0.9 mg/L (1.7 mg/L) and 1.4 mg/L (2.9 mg/L), respectively.

[5] In the chlorine evaluation protocol outlined above, the amount of TOC added as an adjustment material for GTW and CTW was reduced to meet these 95th percentile chlorine demand values. However, methods commonly used to propagate the coliphages MS2 and phiX174 for testing use organic-based media that exert additional chlorine demand. Thus, including the coliphages would have led to chlorine demands higher than the target values of 1.5 mg/L and 3 mg/L in GTW and CTW, respectively.

- **Use an effective high quality product:** A variety of chlorine products are available, and as the results in Section 4 show, the quality and microbial efficacy of these products vary. A critical initial consideration in selecting a product is whether it works.

- **Dose based on the chlorine demand of the specific water source:** Chlorine demand varies between sources and over time, necessitating regular monitoring and adjustment of the applied dosage, when necessary (Box 6).

- **Ideally, chlorine should be used as part of a multibarrier treatment approach:** The efficacy of chlorine disinfection is diminished in turbid or organic-rich waters with a high chlorine demand. In addition, chlorine is ineffective against protozoan cysts such as *Cryptosporidium*. Combining chlorination with, for example, flocculation or filtration has the microbial and aesthetic advantages of treating against a wider range of pathogens by reducing turbidity and organic matter, as well as improved taste and smell. Chlorination is therefore an important last barrier in such a treatment approach, as it helps maintain the safety of treated water by providing residual disinfectant.

- **Monitor FRC:** The efficacy of chlorine disinfection for the specific water quality conditions should be verified by ensuring maintenance of adequate residual[6].

Taken together, the findings emphasize the importance of understanding source water quality conditions when implementing chlorination programmes, and suggest that effective chlorination at household level may be difficult to achieve given variability in chlorine demand and the skill and resources required to monitor it and adjust dosing. As such, household chlorination may only be appropriate in the short term, and options to chlorinate at source or transition to more centrally managed systems supported by trained technicians and monitoring systems are preferable.

3.2.3 Performance classification

A critical aspect in HWT evaluation is whether a product is able to consistently treat water to the required level and thus reliably protect health. Sample units should consistently meet or exceed the performance target for each microbial group in both test waters (GTW and CTW). However, a maximum deviation of 0.2 $\log_{10}$ is acceptable for 25% of sample points at the two-star performance tier and of 0.4 $\log_{10}$ at the three-star performance tier[7]. This permissible deviation means that to be classified as a two-star product, up to three of the 12 sample points can achieve a reduction of 1.8 $\log_{10}$ for bacteria or protozoan cysts (instead of 2 $\log_{10}$), or 2.8 $\log_{10}$ for viruses (instead of 3 $\log_{10}$).

3.2.4 Data management and quality assurance

Evaluation under the Scheme follows standard operating procedures for data management and quality assurance as detailed in the *Procedure for Evaluation* (WHO, 2018b) and summarized in Annex 1.

[6] Guidance on measuring chlorine in water supplies can be found at https://www.who.int/water_sanitation_health/emergencies/WHO_TN_11_Measuring_chlorine_levels_in_water_supplies.pdf?ua=1

[7] These cut-off values were determined using quantitative microbial risk assessment (QMRA) modelling and selecting ranges that still resulted in appreciable health gains within a specific performance tier.

3.3 HWT products evaluated in Round II

Of the 39 EoIs received in Round II, 20 products were selected for evaluation (Table 3) after screening for eligibility. Details of the eligibility criteria and screening process are provided in Annex 2.

TABLE 3
Products evaluated in Round II

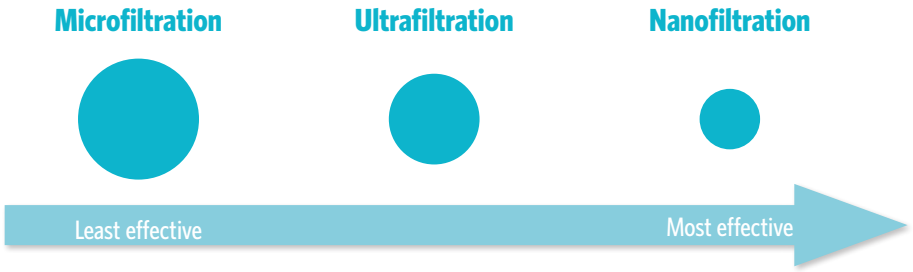
Technology	Product trade name	Manufacturer	Microbial groups evaluated
Membrane filtration	Grifaid®M3	Safe Water Trust	Bacteria and viruses
	LifeFilta LFJC Jerrycan with backwash	AquaNano Water Filters	Bacteria and viruses
	Uzima Filters UZ-1	Uzima Water Filters	Bacteria and viruses
Ceramic filtration	Nazava Water Filters	PT Holland for Water	Bacteria and viruses
	SPOUTS Water Purifaaya Filter	SPOUTS of Water Ltd	Bacteria, viruses and protozoa
	Tulip Table Top Water Filter	Basic Water Needs B.V.	Bacteria and viruses
Flocculation–biofiltration	BlueQ™ Two-Stage	Amway Corporation	Bacteria, viruses and protozoa
Flocculation–disinfection	AquaSure Tab10	AquaSure	Bacteria and protozoa
	Rubicon	Prideco Holdings	Bacteria, viruses and protozoa[a]
Flocculation–disinfection–filtration	DayOne Waterbag™	Day One Response, Inc.	Bacteria and viruses
UV disinfection	Water Elephant	Years of Water	Bacteria and viruses
	Mesita Azul®	Fundación Cántaro Azul	Bacteria and viruses
Solar/thermal disinfection	AquaPak	Solar Solutions	Bacteria, viruses and protozoa
	JAMEBI Solar Water Pasteurizer	Relevant Projects Ltd	Bacteria and viruses
	SolarBag®	Puralytics	Bacteria, viruses and protozoa
Chemical disinfection	BioCool Clean Water	BioCool AB	Bacteria and viruses
	Chloritard	Karnis & Hals Chemicals Pvt Ltd	Bacteria[b]
	Aquatabs Flo	Medentech Ltd	Bacteria[b]
	Oasis Water Purification Tablets	Hydrachem Ltd	Bacteria[b]
	WATA-Standard™	Antenna Technologies	Bacteria[b]

[a] Testing is in progress and results are pending. The results from this product will be published in a product-specific test report in Q3 2019
[b] Viral inactivation based on literature and test water data (see section 3.2.2)

3.3.1 Membrane filtration

Membrane filtration removes microorganisms from drinking-water through size exclusion. The filters typically comprise hollow membrane fibres in a cartridge through which microbes are removed by physical straining. Key determinants of the performance of the membrane filtration systems are the pore size of the filter, integrity of the filter medium and seals, and the manufacturing quality. Not all membrane types are effective against viruses, the smallest of the three microbial groups evaluated under the Scheme (Fig. 5).

FIG. 5
Relative effectiveness of membrane filter pore sizes against viruses



An overview of the microbial performance, limitations and advantages of membrane filtration is provided below.

Microbial performance	• Effective against bacteria, viruses (depending on the integrity and pore size of the membrane) and protozoa
Key factors affecting efficacy	• Membrane pore size relative to pathogen size • Membrane fouling • Integrity of membrane, seals and interconnecting plumbing
Advantages	• Minimal likelihood of recontamination (when there is integrated safe storage container) • Appearance of treated water is improved, providing a visual indicator that reinforces benefits of treatment • Minimal change in taste of water • Often simple to use • Typically no power source is required
Limitations	• Need to clean receptacles and membrane regularly • Membrane fouling • Difficulty in sourcing spare parts
Application	Most appropriate where: • the pathogen of concern is unknown (depending on membrane integrity and pore size) • external funding or microfinance schemes are available to support the initial cost of the filter in low-income populations

Sources: Lantagne & Clasen, 2009; WHO/UNICEF, 2012

Grifaid® M3

Manufacturer: Safe Water Trust

Manufacturer location: United Kindom

Treatment technology
Membrane ultrafilter

Product description[a]
The Grifaid®M3 is a membrane ultrafiltration device that is operated by manual pumping. The filter is clamped to a vessel containing raw water. Manual pumping forces water through hollow fibre membranes that trap the microorganisms and to dispense filtered water. The filter does not have an integrated clean water receptacle, and a separate storage container is required.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.grifaid.org.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Maintenance and lifespan	Daily backwashing is recommended Regular greasing of the O ring may be required, and the O ring should be changed after 1 year Estimated lifespan of up to 5 years
	Integrated safe container/residual protection	None
	Energy requirements	None
	Estimated annual production (no. of units)	5 000

[a] Based on information provided by the manufacturer

Product evaluation
Testing of the Grifaid® M3 followed requirements of the Batch Membrane Filtration Technology Protocol. Testing investigated the ability of the Grifaid®M3 to reduce bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial reduction achieved.

LifeFilta Jerrycan LFJC with backwash

Manufacturer: AquaNano Water Filters

Manufacturer location: Belgium

Treatment technology

Membrane nanofilter

Product description[a]

The LifeFilta Jerrycan LFJC with backwash is a membrane nanofiltration device. The filter is operated by filling the jerrycan with raw water and manually pumping; once the pump is pressurized, a tap outlet is opened to dispense the filtered water. The mechanical pumping forces water through hollow fibre membranes that trap the microorganisms. The filter does not have an integrated clean water receptacle, and a separate collection/storage vessel is required.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.lifefilta.com.

Product specifications [a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Maintenance and lifespan	Backwash after every use or when filter is clogged Lifespan capacity of 100 000 L; reusable for 5–10 years
	Integrated safe container/residual protection	None
	Energy requirements	None
	Estimated annual production (no. of units)	150 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the LifeFilta Jerrycan LFJC with backwash followed requirements of the Batch Membrane Filtration Technology Protocol. Testing investigated the ability of the LifeFilta Jerrycan LFJC with backwash to reduce bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial reduction achieved.

Uzima Filter UZ-1

Manufacturer: Uzima Water Filters

Manufacturer location: USA

Treatment technology

Membrane microfilter

Product description[a]

The Uzima Filter UZ-1 is a gravity-fed membrane microfiltration device. The assembled filter set comprises two 20 L buckets stacked on top of each other. These buckets serve as receptacles for raw and filtered water. The filter cartridge is screwed to the bottom of the raw water bucket. Water flows through the cartridge under gravity into the clean water.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.uzimafilters.org.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Maintenance and lifespan	The filter should be back-flushed using the included syringe with clean/filtered water after each use The filter should also be back-flushed when flow rate is diminished when filtering turbid water Reusable; estimated lifespan up to 10 years
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	25 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the Uzima Filter UZ-1 followed requirements of the Batch Membrane Filtration Technology Protocol. Testing investigated the ability of the Uzima Filter UZ-1 to reduce bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial reduction achieved.

3.3.2 Ceramic filtration

Ceramic filtration removes microorganisms physically from water by a combination of size exclusion and adsorption. The ceramic filter matrix is composed of clay and combustible material such as rice husks or sawdust that provide a porous structure through which water is filtered under gravity. The filters are often impregnated or coated with bacteriostatic agents such as colloidal or nanoparticles of silver or copper. Pore size and quality of manufacturing are key determinants of the performance of ceramic filters; they are typically not effective against smaller microorganisms such as viruses. Ceramic filters are commonly available as pots and candles, although discs are also available.

An overview of the microbial performance, limitations and advantages of ceramic filters is provided below.

Microbial performance	• Effective against most bacteria and protozoa • Limited effectiveness against viruses[a]
Key factors affecting efficacy	• Filter media and pore size • Quality of manufacturing • Flow rate
Advantages	• Minimal likelihood of recontamination when held in integrated safe storage container • Appearance of treated water is improved, providing a visual indicator that reinforces benefits of treatment • Minimal change in taste of water • Simple to use • No power source is required • Possibility of local production may benefit economy and allow easy supply • Low relative cost per litre of water treated
Limitations	• Variability in quality of locally produced filters • Fragile; difficult to transport over long distances • Filters and receptacles need to be cleaned regularly • Flow rate is low at 1–3 L/hour (slower in turbid waters)
Application	Most appropriate where: • the pathogen of concern is known (e.g. *Cryptosporidium*) as ceramic filtration does not provide protection against enteric viruses • there is capacity and proven quality ceramic filter production

[a] Because of this limitation, products based on ceramic filtration alone are unlikely to achieve a performance classification higher than one-star (★).
Sources: Lantagne & Clasen, 2009; WHO/UNICEF, 2012

Nazava Water Filter

Manufacturer: PT Holland for Water

Manufacturer location: Indonesia

Treatment technology

Ceramic candle filter

Product description[a]

The Nazava Water Filter is a ceramic candle filter that is impregnated with silver. Microorganisms are physically removed from water as it filters through the candle under gravity. The ceramic candle also contains active carbon to remove taste and odour from water. The assembled filter set comprises two 13.5 L buckets stacked on top of each other; these buckets serve as receptacles for raw and filtered water. The ceramic candle is screwed to the bottom of the raw water bucket. Water is filtered through the ceramic candle and into the clean water bucket.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.nazava.com.

Product specifications[a]

	**Water quality conditions**	Includes a fabric prefilter to be used when treating turbid water; this prefilter fits around the candle
	**Fail-safe/indicator of treatment complete**	Includes a plastic tool to measure the diameter of the candle; once the diameter is less than 5 cm, the candle must be replaced
	**Maintenance and lifespan**	Depending on the turbidity of the water, the filter candle should be cleaned regularly; the prefilter should be washed periodically The filter candle should be cleaned gently with the scrub pad included with the filter Estimated lifespan of 3 years
	**Integrated safe container/residual protection**	Yes
	**Energy requirements**	None
	**Estimated annual production (no. of units)**	100 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the Nazava Water Filter followed requirements of the Filtration Batch System Technology Protocol. Testing investigated the ability of the Nazava Water Filter to reduce bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial reduction achieved. Posttreatment silver and arsenic concentrations were collected and analysed.

SPOUTS Water Purifaaya Filter

Manufacturer: SPOUTS of Water Ltd

Manufacturer location: Uganda

Treatment technology

Ceramic pot filter

Product description[a]

The SPOUTS Water Purifaaya Filter is a silver-coated ceramic pot filter. Microorganisms are physically removed from water as it filters through the ceramic pot under gravity. The assembled unit set comprises a ceramic pot in a 20 L bucket. This pot serves as a receptacle for the filtered water.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.spoutsofwater.org.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Maintenance and lifespan	Every 14 days the filter pot should be gently cleaned with a scrub pad and clean water and the bucket should be cleaned with soapy water Estimated lifespan of 2 years
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	20 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the SPOUTS Water Purifaaya Filter followed requirements of the Filtration Batch System Technology Protocol. Testing investigated the ability of the SPOUTS Water Purifaaya Filter to reduce bacteria (*E. coli*); viruses (coliphages MS2 and phiX174); and protozoa (*C. parvum*). Posttreatment silver and arsenic concentrations were collected and analysed.

Tulip Table Top Water Filter

Manufacturer: Basic Water Needs B.V.

Manufacturer location: Netherlands

Treatment technology

Ceramic candle filter

Product description[a]

The Tulip Table Top Water Filter is a ceramic candle filter with activated carbon that is impregnated with colloidal silver. Microorganisms are physically removed from water as it filters through the ceramic candle under gravity. The assembled filter set comprises two 9 L buckets stacked on top of each other; these buckets serve as receptacles for raw and filtered water. The ceramic candle is screwed to the bottom of the raw water bucket. Water is filtered through the ceramic candle into the clean water bucket.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.basicwaterneeds.com.

Product specifications[a]

	Water quality conditions	Includes a fabric prefilter that fits around the candle, to be used when treating turbid water
	Fail-safe/indicator of treatment complete	Includes a plastic tool to measure the diameter of the candle; once the plastic sensor fits around the thinnest part of the candle, the candle must be replaced
	Maintenance and lifespan	Depending on the turbidity of the water, the filter candle should be cleaned regularly; the prefilter should be washed periodically The filter candle should be cleaned gently with the scrub pad included with the filter Treats up to 7000 L of water, depending on the turbidity of the untreated water
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	45 000 complete Table Top water filters 80 000 Tulip filter elements Sold in more than 35 countries around the world

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the Tulip Table Top Water Filter followed requirements of the Filtration Batch System Technology Protocol. Testing investigated the ability of the Tulip Table Top Water Filter to reduce bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial reduction achieved. Posttreatment silver and arsenic concentrations were collected and analysed.

3.3.3 Flocculation–biofiltration

Flocculant biofilters employ a multibarrier approach to water treatment. The flocculant aggregates suspended and larger microorganisms such as protozoa to form flocs , which are removed by subsequent biofiltration. The biofilter component comprises a filtration medium such as sand or granular activated carbon, with a biologically active layer (biofilm) attached to the medium. The flocs and other contaminants dispersed in the water are trapped as the water filters through the biofilm under gravity.

An overview of the microbial performance, limitations and advantages of flocculant biofilters is provided below.

Microbial performance	• Effective against bacteria and protozoa
Key factors affecting efficacy	• Maturity of the bioactive layer • Flocculant material • Flow rate
Advantages	• Minimal likelihood of recontamination when held in integrated safe storage container • Appearance of treated water is improved, providing a visual indicator that reinforces benefits of treatment • No power source is required
Limitations	• Requires regular supply chain for flocculant material • Periodical cleaning of filtration medium is required
Application	Most appropriate where: • water is of relatively high turbidity

Sources: Lantagne & Clasen, 2009; WHO/UNICEF, 2012

BlueQ™ Two-Stage System

Manufacturer: Amway Corporation

Manufacturer location: USA

Treatment technology

Flocculation–biofiltration

Product description[a]

The BlueQ™ Two-Stage System is a gravity-fed device that combines coagulation, flocculation and biological filtration. The assembled unit comprises a series of three stacked buckets. Untreated water is poured into the top bucket, and aluminium sulfate is added as a coagulant/flocculant. The water passes through a prefilter that traps the resulting floccules. In the next bucket the water filters through a foam filter with a bioactive layer around it. The filtered water then passes into the third bucket with a spigot, through which the treated water can be collected.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.amway.com.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Maintenance and lifespan	Sediment from the flocculation should be discarded after each batch is treated The bio-foam should be removed and gently rinsed with clean water if there is a reduction in the flow rate of the water Estimated lifespan of 10 years
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	Not provided

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the BlueQ™ Two-Stage System followed requirements of the Batch Coagulation, Flocculation and Bioactive Layer Batch Technology Protocol. Testing investigated the ability of the BlueQ™ Two-Stage System to reduce bacteria (*E. coli*), viruses (coliphages MS2 and phiX174) and protozoa (*C. parvum*).

3.3.4 UV disinfection

UV irradiation inactivates microorganisms by damaging their intracellular proteins and nucleic acids, thus impairing their cell binding ability and/or ability to replicate.

The effectiveness of UV disinfection depends on the delivered fluence/dose, which is based on intensity and exposure time. UV disinfection is most effective at UVC wavelengths, that is, 200–280 nm. Most household or small-scale water treatment technologies employ low-pressure lamps that emit UV radiation at 254 nm. Typically, these technologies allow water in a vessel or in flow-through reactors to be exposed to the UV radiation from the UV lamps at sufficient fluence/dose to inactivate waterborne pathogens.

An overview of the microbial performance, limitations and advantages of UV technologies is provided below.

Microbial performance	• Effective against bacteria, some viruses (depending on the type of UV lamp[a]) and protozoa
Key factors affecting efficacy	• Turbidity or suspended matter (measured as transmittance or absorbance) • Lamp power • Flow rate/contact time
Advantages	• Simple to use • Minimal change in taste of the water
Limitations	• Need to pretreat waters of higher turbidity e.g. > 30 NTU by filtration or flocculation • Does not provide residual protection against recontamination unless the treated water is safely stored • Often requires a power source and a clean UV lamp to operate effectively • High relative cost per litre of water treated
Application	Most appropriate where: • water is of low turbidity • electricity or another power source is available

[a] Medium-pressure UV is more effective than low-pressure UV in activating resistant viruses (Hijnen, Beerendonk & Medema, 2006; Eischeid, Meyer & Linden, 2009)
Sources: Lantagne & Clasen, 2009; WHO/UNICEF, 2012; WHO/UNICEF, 2012; Linden & Murphy, 2017

Water Elephant

Manufacturer: Years of Water Ltd

Manufacturer location: Israel

Treatment technology

UV disinfection

Product description[a]

The Water Elephant is a manually operated UV disinfection device. The device comprises a 5 L jerrycan with a UVC lamp that is powered by a manual crank. An integrated prefilter removes larger particles prior to UV disinfection.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.yearsofwater.com.

Product specifications[a]

	Water quality conditions	Should only be used in nonturbid water (<5 NTU)
	Fail-safe/indicator of treatment complete	Red lamp flashes and water is not dispensed if it is too turbid to treat
	Maintenance and lifespan	Expected lifespan of 3 years
	Integrated safe container/residual protection	None
	Energy requirements	None
	Estimated annual production (no. of units)	Not provided

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the Water Elephant followed requirements of the UV Batch Disinfection Technology Protocol. Testing investigated the ability of the Water Elephant to inactivate bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial inactivation achieved. The device includes an alarm which indicates whether the source water can be treated. As such, the CTW specifications were set to just below the alarm point, in order evaluate its ability to function and warn users when the source water is not appropriate for UV disinfection.

Mesita Azul® ("little blue table")

Manufacturer: Fundación Cántaro Azul

Manufacturer location: Mexico

Treatment technology

UV disinfection

Product description[a]

The Mesita Azul® ("little blue table") is a flow-through UV disinfection device comprising a table with an integrated chamber with a low-pressure UV lamp. The device can be connected to a piped water supply, or alternatively operated by gravitational flow by filling a bucket from which untreated water is drawn into the UV chamber.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.cantaroazul.org.

Product specifications[a]

	Water quality conditions	Should only be used in nonturbid water (<5 NTU)
	Fail-safe/indicator of treatment complete	None
	Maintenance and lifespan	Weekly: rinse the system with a 10% bleach and water solution. Monthly: check prefilters for potential replacement; bulb should be replaced when it runs out Expected lifespan of 3 years
	Integrated safe container/residual protection	None
	Energy requirements	Electricity or solar power
	Estimated annual production (no. of units)	Not provided

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the Mesita Azul® followed requirements of the UV Disinfection Technology Protocol. Testing investigated the ability of the Mesita Azul® to inactivate bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial inactivation achieved. The device does not include an alarm to indicate whether the source water is appropriate for UV disinfection. As such, the CTW specifications were set to the general requirements of the UV protocol for devices without an alarm.

3.3.5 Solar disinfection

Solar disinfection inactivates microorganisms through a combination of UV irradiation, visible light radiation and heat. The UV irradiation damages nucleic acids, thus impairing their ability to replicate. Meanwhile, photosensitive molecules in the water absorb the visible light, resulting in oxidative activities that damage cell structures. The exposure to sunlight also results in temperature increases that denature proteins within the microorganisms and/or cause oxidative damage associated with dissolved oxygen products and heat. The effectiveness of solar disinfection depends on the sun's intensity, which is affected by weather conditions and geographical location. Solar disinfection is most effective in tropical or subtropical regions of up to 35 degrees latitude.

A variety of solar disinfection technologies are available, including dark/opaque containers that rely on heat from the sun to disinfect water; clear polyethylene terephthalate (PET) containers that rely on the combined action of UV radiation, oxidative activity associated with dissolved oxygen and heat; or combinations of these effects in other types of containers, such as UV-penetrable bags and panels.

An important aspect in solar disinfection is an indicator to provide feedback on the process and signal when sufficient sunlight has been received for effective disinfection.

An overview of the microbial performance, limitations and advantages of solar technologies is provided below.

Microbial performance	• Effective against viruses, bacteria and protozoa
Key factors affecting efficacy	• Weather conditions • Type of container material • Water quality matrix, including turbidity
Advantages	• Minimal likelihood of recontamination when held in disinfecting container • Simple to use • Low relative cost per litre of water treated • Little to no maintenance • Minimal change in taste of the water
Limitations	• Need to pretreat waters of high turbidity (e.g. >30 NTU) by filtration or flocculation • Volume to treat dependent on availability of clean, intact containers • The time needed to treat water is relatively long and varies depending on the intensity of the sun (approximately 6 hours under 50% cloudy sky) • Containers must be placed where they will be exposed to sunlight and not disturbed (e.g. on a roof) • May not have a visual indicator to indicate treatment complete
Application	Most appropriate where: • water is of low turbidity • there is sufficient solar radiation; between 35°N and 35°S latitude • clean, transparent and intact containers for treatment are available

Sources: Lantagne & Clasen, 2009; WHO/UNICEF, 2012

AquaPak

Manufacturer: Solar Solutions, LLC

Manufacturer location: USA*
*indicator only; pasteurization bag manufactured locally

Treatment technology
Solar disinfection (pasteurization)

Product description[a]
The AquaPak is a pasteurization device that uses solar and thermal energy. The device consists of a 5 L polyethylene bag with a bubble pack layer of clear plastic on the front and a black plastic layer on the back. When the device is exposed to sunlight, the black layer radiates heat, which pasteurizes water in the bag. The bubble pack layer insulates the bag. The AquaPak has a "treatment complete" water pasteurization indicator (WAPI), namely, a glass cap filled with orange-coloured wax that melts to a clear colour at 65 °C when the water has been sufficiently treated.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.solarcleanwatersolution.com.

Product specifications[a]

	Water quality conditions	Includes a cloth prefilter for turbid water
	Fail-safe/indicator of treatment complete	Wax in the "WAPI" indicator melts when water is sufficiently treated
	Maintenance and lifespan	The lifespan of the pasteurization bag is 3 years; the "WAPI" should last indefinitely if not broken
	Integrated safe container/residual protection	Treated water is held in the disinfection bag
	Energy requirements	Direct sunlight
	Estimated annual production (no. of units)	1 500

[a] Based on information provided by the manufacturer

Product evaluation
Testing of the AquaPak followed requirements of the Solar (UV and heat) Batch Disinfection Technology Protocol. Testing investigated the ability of the AquaPak to inactivate bacteria (*E. coli*), viruses (coliphages MS2 and phiX174) and protozoa (*C. parvum*).

JAMEBI Solar Water Pasteurizer

Manufacturer: Relevant Projects Ltd

Manufacturer location: United Kingdom

Treatment technology

Solar disinfection (pasteurization)

Product description[a]

The JAMEBI Solar Water Pasteurizer is a flow-through solar pasteurization disinfection device. It comprises a solar thermal panel with an internal thermostatic control valve and an external heat exchanger. Water heated to 75 °C in the outer pipe of the heat exchanger flows into the solar thermal panel, where it is pasteurized at approximately 80 °C for 4 minutes. The thermostatic control valve located at the panel exit then opens and regulates the flow rate to ensure that the water is sufficiently treated. The pasteurized water then flows into the inner pipe of the heat exchanger, where it is cooled before release.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.jamebi.com.

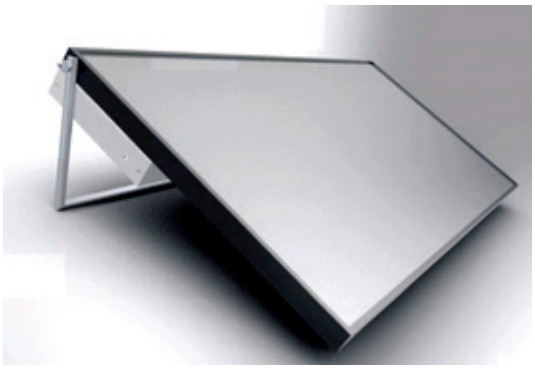
Product specifications[a]

	**Water quality conditions**	Not suitable for water with a high mineral content (hard water)
	**Fail-safe/indicator of treatment complete**	A thermostatic control valve opens to allow water to exist the system when water is sufficiently treated
	**Time to treat**	6–7 hours, depending on intensity of sunlight
	**Maintenance and lifespan**	Weekly visual maintenance checks for leaks Annual maintenance to take apart and clean heat exchanger Standby lifespan of 20 years when in clean dry storage
	**Integrated safe container/residual protection**	No
	**Energy requirements**	Direct sunlight
	**Estimated annual production (no. of units)**	50 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the JAMEBI Solar Water Pasteurizer followed requirements of the Solar/Thermal Disinfection Technology Protocol. Testing investigated the ability of the JAMEBI Solar Water Pasteurizer to inactivate bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174). Performance against protozoan cysts (*C. parvum*) was assigned based on the bacterial reduction achieved.



SolarBag

Manufacturer: Puralytics

Manufacturer location: USA

Treatment technology

Solar/UV disinfection

Product description[a]

The SolarBag® is a solar/UV disinfection product comprising a 3.5 L plastic pouch with a nanomesh photocatalyst insert that is activated by UV radiation. When exposed to sunlight for 4–6 hours, microbial contaminants in the water are inactivated through a combination of photocatalytic oxidation and thermal and direct UV processes. The SolarBag® includes accessories used for prefiltration and to indicate treatment completion.

The full product description, illustrations and instructions can be found on the manufacturer's website at www.puralytics.com.

Product specifications[a]

	Water quality conditions	Includes a prefilter for turbid water
	Fail-safe/indicator of treatment complete	Includes a small bottle of a food-safe PUR-Blue dye; a drop of this colours the water at the start of treatment. Clearing of the colour indicates treatment completion
	Time to treat	4–6 hours, depending on intensity of sunlight
	Maintenance and lifespan	No maintenance Reusable: lifespan depends on source water
	Integrated safe container/residual protection	Treated water is held in the disinfection bag
	Energy requirements	Direct sunlight
	Estimated annual production (no. of units)	14 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the SolarBag® followed requirements of the Solar (UV and heat) Batch Disinfection Technology Protocol. Testing investigated the ability of the SolarBag® to inactivate bacteria (*E. coli*), viruses (coliphages MS2 and phiX174) and protozoa (*C. parvum*).

3.3.6 Flocculation–disinfection

Flocculant–disinfectants employ a multibarrier approach to water treatment. The coagulant–flocculant (e.g. iron or aluminium salts) aggregates suspended particles and larger microorganisms such as protozoa to form flocs, which are removed by subsequent sedimentation. The disinfectant (e.g. calcium hypochlorite or sodium dichloroisocyanurate [NaDCC]) inactivates the smaller microorganisms such as bacteria and viruses through oxidative processes that degrade their biochemical building blocks and disrupt vital cell functions.

Flocculant–disinfectants are commonly available as powders although some are available in tablet form.

A brief overview of the microbial performance, limitations and advantages of flocculant–disinfectants is provided below.

Microbial performance	• Effective against bacteria, viruses and protozoa
Key factors affecting efficacy	• Flocculant/disinfectant material • Contact time • Mixing conditions
Advantages	• Residual protection against recontamination • Visual improvement in treated water • Reduction of some heavy metals (e.g. arsenic) and particle-associated pesticides • Portable; lightweight, easily packaged and easy to transport in emergencies
Limitations	• Multiple steps required to use the product • High relative cost per litre of water treated • Potential user taste and odour objections
Application	Most appropriate where: • water is of relatively high turbidity

Sources: Lantagne & Clasen, 2009; WHO/UNICEF, 2012

AquaSure Tab10

Manufacturer: AquaSure

Manufacturer location: France

Treatment technology
Flocculant–disinfectant

Product description[a]
Aquasure Tab10 is a flocculant–disinfectant tablet containing ferric sulfate and NaDCC. The ferric sulfate acts as a coagulant and flocculant that aggregates particulates and some microorganisms suspended in water. The resulting floccules sediment at the bottom of the water vessel, and the NaDCC acts as a disinfectant. The product is available a tablet that can treat 10 L of water.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Time to treat	45 min contact time before consumption
	Maintenance and lifespan	Single-use tablets
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	Not provided

[a] Based on information provided by the manufacturer

Product evaluation
Testing of the AquaSure Tab10 followed the Coagulation–Flocculation and Disinfection Technology Protocol requirements. Testing investigated the ability of the AquaSure Tab10 to reduce bacteria (*E. coli*) and protozoa (*C. parvum*). Performance against viruses was based on review of existing evidence on effectiveness of chlorine against viruses (see section 3.2.2). Free residual and total chlorine concentrations were collected and analysed in dechlorinated tap water prior to treatment, and in the treated water.

Rubicon

Manufacturer: PrideCo Holdings

Manufacturer location: South Africa

Treatment technology

Flocculant–disinfectant

Product description[a]

Rubicon is a flocculant–disinfectant powder containing polydiallyldimethylammonium chloride (polyDADMAC) and persulfate. PolyDADMAC is a coagulant and flocculant that aggregates particulates and some microorganisms suspended in water. The resulting floccules sediment at the bottom of the water vessel, and the persulfate acts as a disinfectant. The product is available in 3.5 g sachets that can each treat 25 L of water.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.pridecoholdings.com.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Time to treat	45 min contact time before consumption
	Maintenance and lifespan	Single-use sachet Shelf life of 2 years
	Integrated safe container/residual protection	No
	Energy requirements	None
	Estimated annual production (no. of units)	20 million sachets

[a] Based on information provided by the manufacturer

Product evaluation

Testing of the Rubicon followed requirements of the Coagulation–Flocculation and Disinfection Technology Protocol. Testing investigated the ability of the Rubicon to reduce bacteria (*E. coli*), viruses (coliphages MS2 and phiX174) and protozoa (*C. parvum*).

DayOne Waterbag™

Manufacturer: DayOne Response, Inc.

Manufacturer location: USA

Treatment technology

Flocculant–disinfectant and filter bag

Product description[a]

The DayOne Waterbag™ is a 10 L backpack that combines flocculation–disinfection, using the P&G™ Purifier of Water sachet, and membrane filtration. The P&G™ Purifier of Water contains ferric sulfate and calcium hypochlorite. Ferric sulfate acts as a coagulant and flocculant by aggregating suspended particulates and some microorganisms in water; calcium hypochlorite acts as a disinfectant. The resulting floccules sediment at the tapered bottom of the bag. The dispensing outlet is about 10 cm from the bottom of the bag; water flows from this outlet via the tubing, into the in-line water filter at an estimated flow rate of 1.5 L/min.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.DayOneResponse.com.

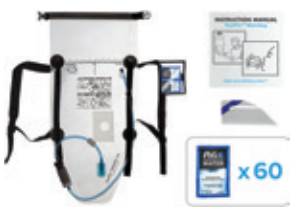
Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions, except salt water
	Fail-safe/indicator of treatment complete	None
	Time to treat	30 min contact time before consumption
	Maintenance and lifespan	Clean the floc from the WaterBag daily/after each use Single use sachets with a shelf life of 3 years The Waterbag is reusable for up to 10 years
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	20 000–50 000

[a] Based on information provided by the manufacturer

Product evaluation

The complete DayOne Waterbag™, which incorporates combined flocculation-disinfection followed by filtration was not evaluated as a single system due to limitations with the test protocol. Evaluation of the DayOne WaterBag™ was in three components: laboratory testing of the filter component, the flocculant-disinfectant component and desk review of data on the P&G Purifier of Water which comprises the flocculant-disinfectant component. Due to limitations with the disinfection protocol evaluation of the flocculation-disinfection component investigated its ability to reduce bacteria (*E. coli*) only. Performance against viruses for the flocculation-disinfection component was based on review of existing evidence on effectiveness of chlorine against viruses (see section 3.2.2.) and on a review of the data submitted in Round I for the P&G™ Purifier of Water. Free residual and total chlorine concentrations were collected and analyzed in dechlorinated tap water prior to treatment and in the treated water. Evaluation of the filtration component investigated its ability to reduce bacteria and PhiX74 and MS2. Future protocols are being investigated for chemical products and once validated, it will be possible to conduct a targeted evaluation of virus removal on the full DayOne Waterbag™ combined treatment process.



3.3.7 Chemical disinfection: free chlorine

Chemical disinfectants inactivate microorganisms by oxidizing their biochemical building blocks and disrupting vital cell functions. Chlorine is the most commonly used chemical disinfectant for drinking-water although oxidants such as bromine, iodine and peroxide are available.

The efficacy of chemical disinfectants depends on how reactive they are against specific microorganisms, the concentration/dose delivered, the contact time and water quality characteristics such as pH, oxidant demand and temperature. For example, chlorine is ineffective against microorganisms with strong cell walls, such as *Cryptosporidium* oocysts and some bacterial spores. In addition, chlorine reacts rapidly with organic and inorganic compounds in water, which exert a demand on the chlorine, affecting the concentration available for microbial disinfection (see section 3.2.2).

For treatment at the household level, chlorine is generally available in liquid form as hypochlorous acid (commercial household bleach or more dilute sodium hypochlorite solution) or in dry form as calcium hypochlorite or NaDCC.

A brief overview of the microbial performance, limitations and advantages of chlorine products is provided below.

Microbial performance	• Effective against viruses and bacteria • Ineffective against protozoan cysts such as *Cryptosporidium*[a]
Key factors affecting efficacy	• Organic content and turbidity • Free chlorine concentration • Contact time
Advantages	• Residual protection against recontamination • Simple to use • Local production may benefit economy • Low cost • Portable; light weight, easily packaged and easy to transport in emergencies
Limitations	• Less effective in inorganic- and inorganic-rich or turbid waters[b] • Users may object to taste and odour • Need to adjust dosing to meet variable chlorine demand in water • Need to ensure quality control of locally manufactured chlorine
Application	Most appropriate where: • the pathogen of concern is known (e.g. *Vibrio cholerae*) as chlorine does not provide protection against some protozoa • water is of relatively low turbidity and organic content

[a] Because of this limitation, products based on free chlorine alone are unlikely to achieve a performance classification higher than one-star (★).
[b] High levels of organic material in water can react with chlorine to form potentially hazardous disinfection by-products. However, the health risks from these by-products at the levels at which they occur in drinking-water are relatively small in comparison with the risks associated with inadequate disinfection. As such, disinfection should not be compromised in an attempt to control such by-products (WHO, 2017).
Sources: Kohn, Decrey & Vinneras, 2017; Lantagne & Clasen, 2009; WHO/UNICEF, 2012

The chemical disinfectants evaluated in Round I and the evaluation procedure used are outlined on the following pages.

BioCool CleanWater

Manufacturer: BioCool AB

Manufacturer location: Sweden

Treatment technology

Sodium percarbonate (hydrogen peroxide) disinfectant

Product description[a]

BioCool CleanWater are disinfection tablets whose active ingredient is sodium percarbonate. The tablets dissolve when added to water and the sodium percarbonate dissociates into hydrogen peroxide and sodium and carbon ions. The peroxide disinfects microbial contaminants through oxidative processes. The product is available as a tablet that can each disinfect 5 L of water.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.biocool.se.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Time to treat	3 hours contact time before consumption
	Maintenance and lifespan	Single-use tablets Estimated shelf life of 5 years
	Integrated safe container/residual protection	No
	Energy requirements	None
	Estimated annual production (no. of units)	40 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of Biocool CleanWater followed the requirements of the Chemical Disinfection Technology Protocol. Testing investigated the ability of Biocool CleanWater to inactivate bacteria (*E. coli*) and viruses (coliphages MS2 and phiX174).

Chloritard

Manufacturer: Karnis & Hals Chemicals Pvt Ltd **Manufacturer location:** India

Treatment technology

Chlorine disinfectant

Product description[a]

Chloritard is a fabric pouch containing calcium hypochlorite powder. The product is intended for disinfection of bulk water supplies. The pouch is suspended in water storage tanks, and the chlorine is slowly released. The pouches are available in different sizes depending on the volume of water to be treated, from 500 to 50 000 L.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.vmbiotech.com.

Product specifications[a]

	Water quality conditions	Suitable for all water quality conditions
	Fail-safe/indicator of treatment complete	None
	Time to treat	1 hour contact time before consumption
	Maintenance and lifespan	No maintenance required Consumable; continuous release pouch lasting up to 30 days. The pouch should be replaced every month
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	50 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of Chloritard followed the requirements for Chlorine Disinfection Technology Protocol. Testing investigated the ability of Chloritard to inactivate bacteria (*E. coli*). Performance against viruses was based on review of existing evidence on effectiveness of chlorine against viruses (see section 3.2.2). Free residual and total chlorine concentrations were collected and analysed in dechlorinated tap water prior to treatment and in the treated water.

Aquatabs Flo

Manufacturer: Medentech Ltd

Manufacturer location: Ireland

Treatment technology

Chlorine disinfectant

Product description[a]

Aquatabs Flo is a chlorine dispenser comprising a plastic cartridge unit containing trichloroisocyanuric acid tablets. The device is intended for disinfection of bulk water supplies. It is installed in the inlet of a water storage tank. Water comes into contact with the disinfection tablets as it flows into the tank.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.medentech.com.

Product specifications[a]

	Water quality conditions	Suitable for nonturbid water only
	Fail-safe/indicator of treatment complete	None
	Time to treat	45 min contact time before consumption
	Maintenance and lifespan	Consumable; continuous release unit treating up to 90 000 L of water Estimated shelf life of 3 years
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	300 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of Aquatabs Flo followed the requirements for Chlorine Disinfection Techhnology Protocol. Testing investigated the ability of Aquatabs Flo to inactivate bacteria (*E. coli*). Performance against viruses was based on review of existing evidence on effectiveness of chlorine against viruses (see section 3.2.2). Free residual and total chlorine concentrations were collected and analysed in dechlorinated tap water prior to treatment and in the treated water.

Oasis Water Purification Tablets

Manufacturer: Hydrachem Ltd

Manufacturer location: United Kingdom

Treatment technology

Chlorine disinfectant

Product description[a]

Oasis Water Purification Tablets contain NaDCC as the active disinfection ingredient. The tablets are available in foil-wrapped strips of different strengths, according to the volume of water to be treated, from 1 to 200 L.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.hydrachem.co.uk.

Product specifications[a]

	Water quality conditions	Suitable for nonturbid water only
	Fail-safe/indicator of treatment complete	None
	Time to treat	30 min contact time before consumption
	Maintenance and lifespan	Single-use tablets Estimated shelf life of 5 years
	Integrated safe container/residual protection	Yes
	Energy requirements	None
	Estimated annual production (no. of units)	774 000 000

[a] Based on information provided by the manufacturer

Product evaluation

Testing of Oasis Purification Tablets followed the requirements for Chlorine Disinfection Techhnology Protocol. Testing investigated the ability of the Oasis Purification Tablets to inactivate bacteria (*E. coli*). Performance against viruses was based on review of existing evidence on effectiveness of chlorine against viruses (see section 3.2.2). Free residual and total chlorine concentrations were collected and analysed in dechlorinated tap water prior to treatment and in the treated water.

WATA-Standard™

Manufacturer: Antenna Technologies

Manufacturer location: Switzerland

Treatment technology

Chlorine disinfectant

Product description[a]

The WATA-Standard™ produces a sodium hypochlorite solution from salt and water (brine) through an electrolytic process. The brine is passed through the electrolytic plates of the device, and a solution of sodium hypochlorite is produced.

The WATA-Standard™ produces sufficient sodium hypochlorite to treat water volumes of 1, 2, 5, 10, or 20 L.

The full product description, illustrations and use instructions can be found on the manufacturer's website at www.antenna.ch.

Product specifications[a]

	Water quality conditions	Suitable for nonturbid water; prefiltration is recommended when water is turbid
	Fail-safe/indicator of treatment complete	Includes the WataBlue® reagent to test for free residual chlorine
	Time to treat	30 min contact time before consumption
	Maintenance and lifespan	Rinsing with clean water after each use is recommended. If there are white marks after several uses, clean using a solution of 50% vinegar and 50% clean water. Leave the device to soak for several hours and then rinse it with clean water. Never scrub the titanium plates Estimated lifetime capacity is 10 000 hours
	Integrated safe container/residual protection	Yes
	Energy requirements	Battery, electricity or solar power
	Estimated annual production (no. of units)	250

[a] Based on information provided by the manufacturer

Product evaluation

Testing of WATA-Standard™ followed the requirements for Chlorine Disinfection Techhnology Protocol. Testing investigated the ability of WATA-Standard™ to inactivate bacteria (*E. coli*). Performance against viruses was based on review of existing evidence on effectiveness of chlorine against viruses (see section 3.2.2). Free residual and total chlorine concentrations were collected and analysed in dechlorinated tap water prior to treatment and in the treated water.

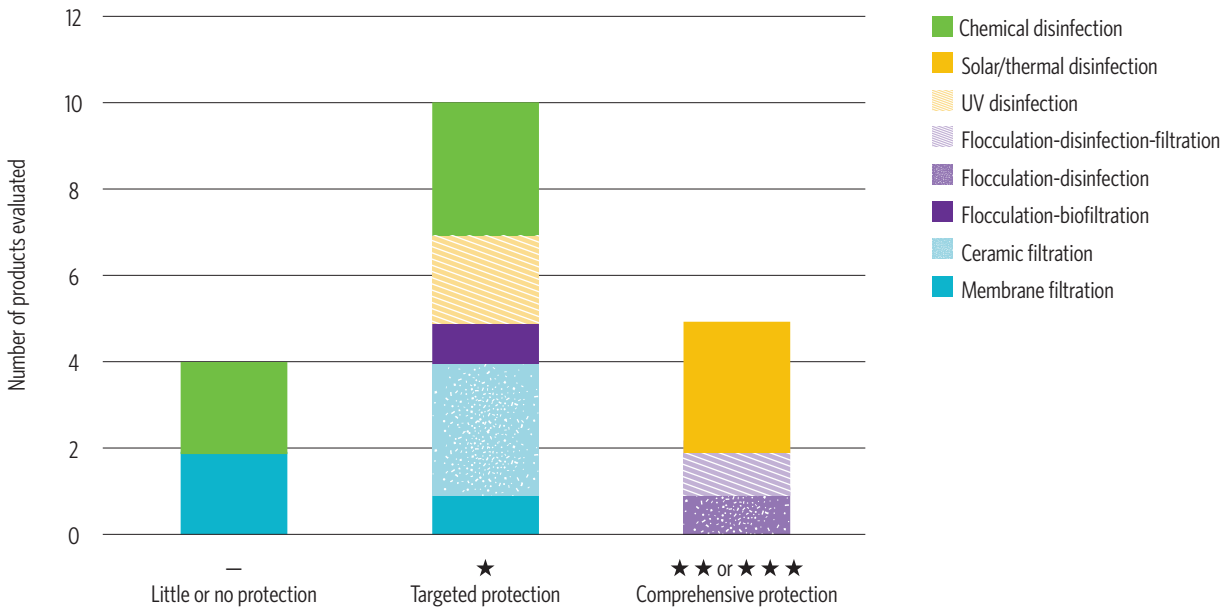
4 Results and key findings

This section summarizes results of the microbial performance of 20 products evaluated in Round II, as well as related findings on product manufacturing quality and labelling

4.1 Microbial performance

Fig. 6 outlines performance results for products evaluated in Round II, by treatment technology. The product-specific reports are available on the WHO website.

FIG. 6
Overview of microbial performance of products evaluated in Round II



Results pending for one product.

Results are available for 19 of the 20 products evaluated in Round II. Of these 19 products,

- 15 meet WHO performance criteria;
- 10 meet one-star criteria and are classified as providing *targeted protection*. They include membrane and ceramic filters, UV devices and chlorine disinfectants;
- Five meet criteria for either two- or three-star and are classified as providing *comprehensive protection*;
- Four do not meet any of the performance criteria and are classified as providing limited or no protection.

Table 4 presents the performance classification of 29 of the 30 products evaluated to date (10 in Round I and 20 in Round II), grouped by treatment technology.

TABLE 4
Summary results of products evaluated in Rounds I and II

Treatment technology	Product	Manufacturer	Evaluation round	Meets WHO performance criteria	WHO performance classification
Membrane filtration	GrifAid®M3	Safe Water Trust	II	No	Little or no protection —[a,b] (see note)
	LifeFilta LFJC Jerrycan with backwash	AquaNano Water Filters	II	No	Little or no protection —[a]
	LifeStraw Family 1.0	LifeStraw SA (part of the Vestergaard Group)	I	Yes	Comprehensive protection ★★★
	LifeStraw Family 2.0		I	Yes	Comprehensive protection ★★
	LifeStraw Community		I	Yes	Comprehensive protection ★★★
	Uzima Filters UZ-1	Uzima Water Filters	II	Yes	Targeted protection (bacteria and protozoa only) ★
Ceramic filtration	Nazava Water Filters	PT Holland for Water / Nazava	II	Yes	Targeted protection (bacteria and protozoa only) ★
	SPOUTS Water Purifaaya Filter	SPOUTS of Water	II	Yes	Targeted protection (bacteria and protozoa only) ★
	TEMBO Filter Pot	MSABI Women's Group	I	No	Performance undetermined[c]
	Tulip Table Top Water Filter	Basic Water Needs B.V.	II	Yes	Targeted protection (bacteria and protozoa only) ★
Flocculation–biofiltration	BlueQ™ Two-Stage	Amway Corporation	II	Yes	Targeted protection (bacteria and protozoa only) ★
Flocculation–disinfection	AquaSure Tab10	AquaSure	II	Yes	Comprehensive protection ★★
	P&G™ Purifier of Water	The Procter & Gamble Company	I	Yes	Comprehensive protection ★★
Flocculation–disinfection–filtration	DayOne WaterBag™	DayOne Response, Inc.	II	Yes	Comprehensive protection ★★
UV disinfection	Mesita Azul®	Fundación Cántaro Azul	II	Yes	Targeted protection (bacteria and protozoa) ★
	Water Elephant	Years of Water	II	Yes	Targeted protection (bacteria and protozoa) ★
	Waterlogic Hybrid / Edge Purifier	Qingdao Waterlogic Manufacturing Company	I	Yes	Comprehensive protection ★★

TABLE 4
Summary results of products evaluated in Rounds I and II (continued)

Treatment technology	Product	Manufacturer	Evaluation round	Meets WHO performance criteria	WHO performance classification
Solar disinfection	AquaPak	Solar Solutions	II	Yes	Comprehensive protection ★★
	JAMEBI Solar Water Pasteurizer	Relevant Projects Ltd	II	Yes	Comprehensive protection ★★
	SolarBag®	Puralytics	II	Yes	Comprehensive protection ★★
	WADI	Helioz GmbH	I	Yes	Targeted protection (bacteria and protozoa; limited protection against viruses) ★
Chemical disinfection	Aquatabs®	Medentech Ltd	I	Yes	Targeted protection (bacteria and viruses only) ★
	Aquatabs Flo		II	Yes	Targeted protection (bacteria and viruses only) ★
	BioCool CleanWater	BioCool AB	II	No	Little or no protection —
	Chloritard	Karnis & Hals Chemicals Pvt Ltd	II	No	Little or no protection —
	H2gO Purifier	Aqua Research LLC	I	Yes	Targeted protection (bacteria and viruses only) ★
	Oasis Water Purification Tablets	Hydrachem Ltd	II	Yes	Targeted protection (bacteria and viruses only) ★
	Silverdyne	World Health Alliance Inc.	I	No	Little or no protection —
	WATA-Standard™	Antenna Technologies	II	Yes	Targeted protection (bacteria and viruses only) ★

★★★ Removes at least 4 $\log_{10}$ of bacteria, at least 5 $\log_{10}$ of viruses and at least 4 $\log_{10}$ of protozoa.
★★ Removes at least 2 $\log_{10}$ of bacteria, at least 3 $\log_{10}$ of viruses and at least 2 $\log_{10}$ of protozoa.
★ Meets the performance targets for at least two-star (★★) for *only two* classes of pathogens.
— Does not meet any of the performance criteria.
[a] The results indicate that the product design is capable of meeting WHO performance criteria; however, performance is inconsistent across production units.
[b] The quality management system for the manufacturing processing has subsequently been revised and an updated version of the product has been submitted for evaluation in Round III.
[c] Performance could not be determined due to low flow in the filter.

The results of the microbial performance evaluation highlight the following:

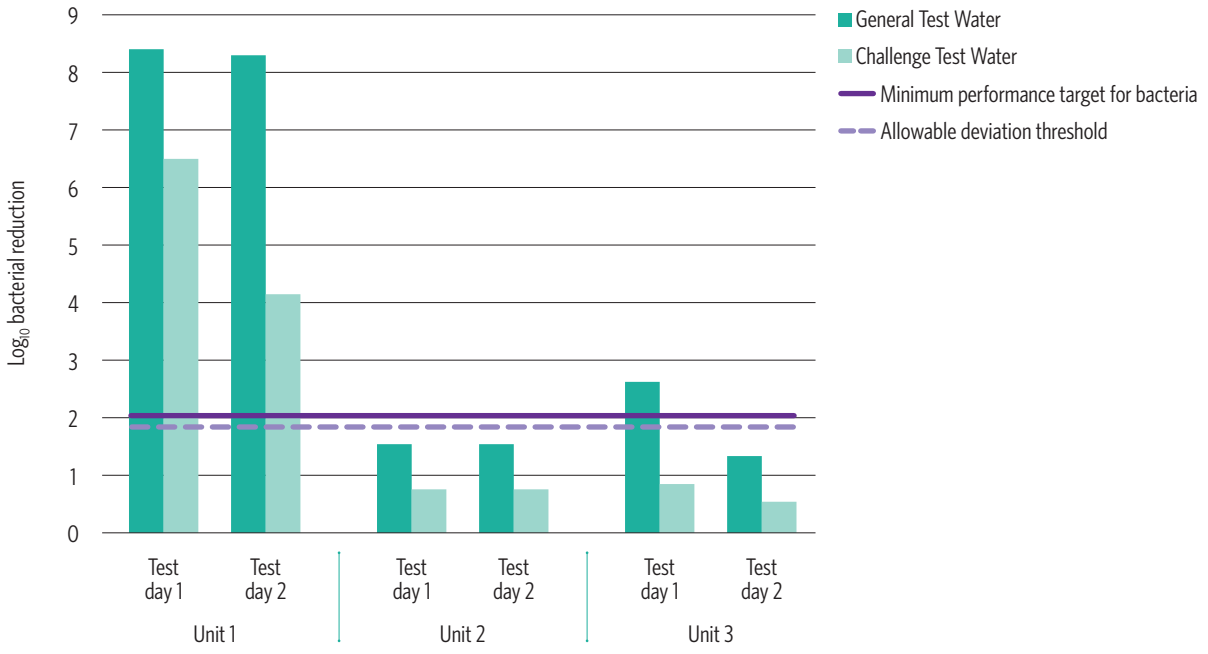
There are more HWT products that meet WHO performance criteria.

In total, 10 of the 30 products evaluated in Rounds I and II are classified as providing *comprehensive protection* and 13 as providing *targeted protection*.

4.2 Consistency across production units

In general, performance across production units was highly variable. Even among products that do meet minimum performance criteria, bacterial reductions ranged from 2 $\log_{10}$ to 8 $\log_{10}$ for some filters. Two filters failed to consistently meet the minimum performance criteria. In the example shown in Fig. 7, bacterial reduction for a filter ranged from 0.5 $\log_{10}$ to 6.6 $\log_{10}$.

FIG. 7
Variation in performance across three units of a membrane filter



Thus, while the mean log reduction exceeds the performance target of 2 $\log_{10}$, only one of the three filter units, Unit 1, consistently met or exceeded the performance target.

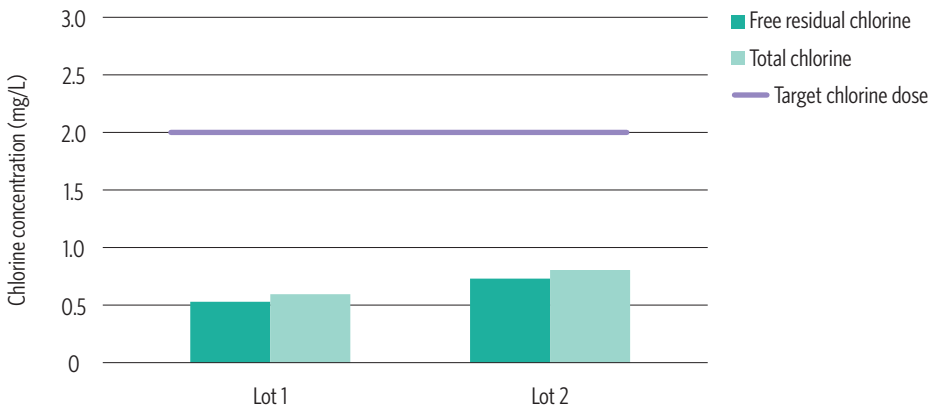
For the six products that utilize chlorine as a disinfectant, the dose of chlorine delivered in dechlorinated municipal tap water was measured as a general indication of product quality. While most products delivered at least 2 mg/L of chlorine, two did not, including the example shown in Fig 8.

For the two lots tested, the mean dose of total chlorine delivered was 0.7 mg/L, and the product failed to meet the minimum microbial performance criteria.

4.3 Product safety

Of the six products that utilize chlorine as a disinfectant, the majority had at least 0.5 mg/L of FRC after 30 minutes of contact time. One product had average FRC concentrations of 0.13 mg/L, and bacterial inactivation was less than 2 $\log_{10}$. Concentrations of total chlorine for all products were below the maximum health guideline value of 5 mg/L.

FIG. 8
Chlorine dose delivered in dechlorinated tap water



Arsenic and silver leachate concentrations were tested in the posttreatment water for the three ceramics filters evaluated in Round II. Leachate concentrations were below GDWQ values. For one filter, arsenic leachate concentrates were initially above 10 mg/L on the first day of testing but decreased over the course of the test period.

4.4 Labelling and instructions for use

Labelling and instructions for use were reviewed based on the criteria outlined in Section 3.2.1. These include clarity of labelling and instructions on dosing, contact time and maintenance procedures. Most products met these criteria. A few exceptions are outlined below.

Disinfectant contact times and mechanisms to ensure sufficient dosing are sometimes unclear

For three chemical disinfectants, contact times were unclear. For one product, the labelling indicated a contact time of 3–24 hours, depending on the pathogens to be treated. Households are unlikely to know the specific pathogens in their drinking-water, or wait 24 hours before drinking the water. Another product did not specify a contact time. In addition, instructions included adjusting the disinfectant dose delivered but did not include the chlorine test strips with the product as distributed/sold. For a third product, the use instructions and contact times indicated on the samples provided for testing differed to those indicated on the product brochure and website.

User instructions and maintenance procedures need to be simplified

The effort required to assemble or maintain a device may compromise the likelihood of it being correctly and consistently used. The main issues identified in the evaluated devices were ease of use/assembly and maintenance. One of the devices required 32 steps to assembly it; another required backwashing after each use.

5 Applying Scheme results

Selection of HWT products should consider microbial effectiveness and whether products are appropriate for the context in which they are to be used. No product is appropriate for all settings and all users. This section discusses the application of the Scheme results in HWT selection.

5.1 Selecting HWT products: matching performance to context

In order to maximize health gains from HWT, selection should take into account the following contextual factors:

Source water characteristics: Selection should be informed by an understanding of existing environmental risks, including source water quality and contamination risks. For example, for surface waters likely contaminated by animal waste, the product should remove protozoa; in cholera-endemic areas, the product should remove bacteria. Physicochemical parameters such as turbidity and TOC also affect the effectiveness of treatment and should be considered in light of the limitations of various technologies. For instance, disinfection of turbid / organic-rich waters with UV or chlorine is most effective when part of multibarrier treatment approach that includes flocculation/ filtration to reduce turbidity and organic matter.

Correct and consistent use: A product that has a very high microbial removal but is not used consistently will yield little if any health benefits. After microbial performance, a product should be selected for use based on whether it is most likely to achieve high adherence (i.e. be used correctly and consistently over time). As outlined in Box 7, both two- and three-star products are capable of removing all three classes of pathogens and, under most water quality conditions and with high adherence, provide comparable health gains. Thus, selection should be based on which product in one of these tiers is most likely to have high adherence.

BOX 7
Which 'star' product to select?

The dissemination of the Round I results (WHO, 2016a) has increased awareness about the importance of meeting minimum performance criteria. However, in selecting HWT products there is a common assumption that three-star (★★★) products yield the highest health gains, with minimal consideration as to whether such products are likely to be used correctly and consistently over time. WHO has been working to improve understanding of the Scheme performance criteria and related health impacts in order to better inform procurer decision making. As part of these efforts, a modelling study (Bivins et al., 2019) was conducted to evaluate reductions in diarrhoeal disease burden associated with HWT products in the three tiers of performance (★, ★★ and ★★★ across varying conditions of source water quality and across varying levels of adherence (correct and consistent use).

The results of the study illustrate two key points:

- Health gains from two-star and three-star products are generally comparable at high levels of adherence, with the difference between these two tiers being only 8% in disability-adjusted life years (DALYs) for diarrhoeal disease averted. An exception is when source water is highly contaminated and adherence is high; under these conditions three-star products yield significantly higher health gains. **Thus, choosing between a three-star and a two-star product should be based on factors such as ongoing support to achieve correct and consistent use, cost and familiarity.**
- Products classified as one-star can yield health gains similar to those from two-star products, depending on which pathogen classes the product is protective against, and, again, on high adherence. **Selection of one-star products should be based on an understanding of specific microbial water quality risks and the limitations of the treatment technology.**

A number of factors support high adherence to HWT; some relate to the product itself, such as acceptability/aesthetic appeal, or familiarity and ease of use. Having a minimal number of steps to follow when using the product, along with simple instructions in an appropriate language, support high adherence (Murray et al., 2015). Other factors supporting high uptake include making the product easily accessible (e.g. reliable supply chains with local stores); training on how to use and maintain the product; and provisions for product repair (Box 8).

BOX 8
Achieving high adherence to HWT

In field studies, filters often show higher uptake initially and over time compared to other HWT technologies. In a recent study of 269 households in Rwanda, 86% of filters were confirmed to be in use 12–24 months after they had been distributed (Kirby et al., 2017). Notably, the levels of use were higher than those that had been previously reported for an earlier model of the filter. Possible reasons cited for the observed high rates of use include:

- the recent model of the filter being *easier to use*;
- having an *integrated safe storage* compartment;
- follow up support on filter use and maintenance;
- technical support, including *repair/replacement* of broken filters; and
- *repeated behaviour change messaging*.

5.2 HWTS in emergencies: a focus on cholera

Having access to safe water is an important and immediate priority in nearly every emergency. For cholera outbreaks in particular, safe water is critical as it is needed to prevent the spread of disease, administer oral rehydration salts and/or antibiotics, create the main curative treatments and ensure safe and quality care for cholera patients at the health care facilities.

As many as 2.9 million individuals in 47 countries are affected by cholera annually. In sub-Saharan Africa alone, 40–80 million people live in cholera hotspots (Fig. 9). This places a considerable – and preventable – burden on health systems and costs tens of millions of dollars in treatment costs and lost work and education hours. In some cases, cholera infection results in death.

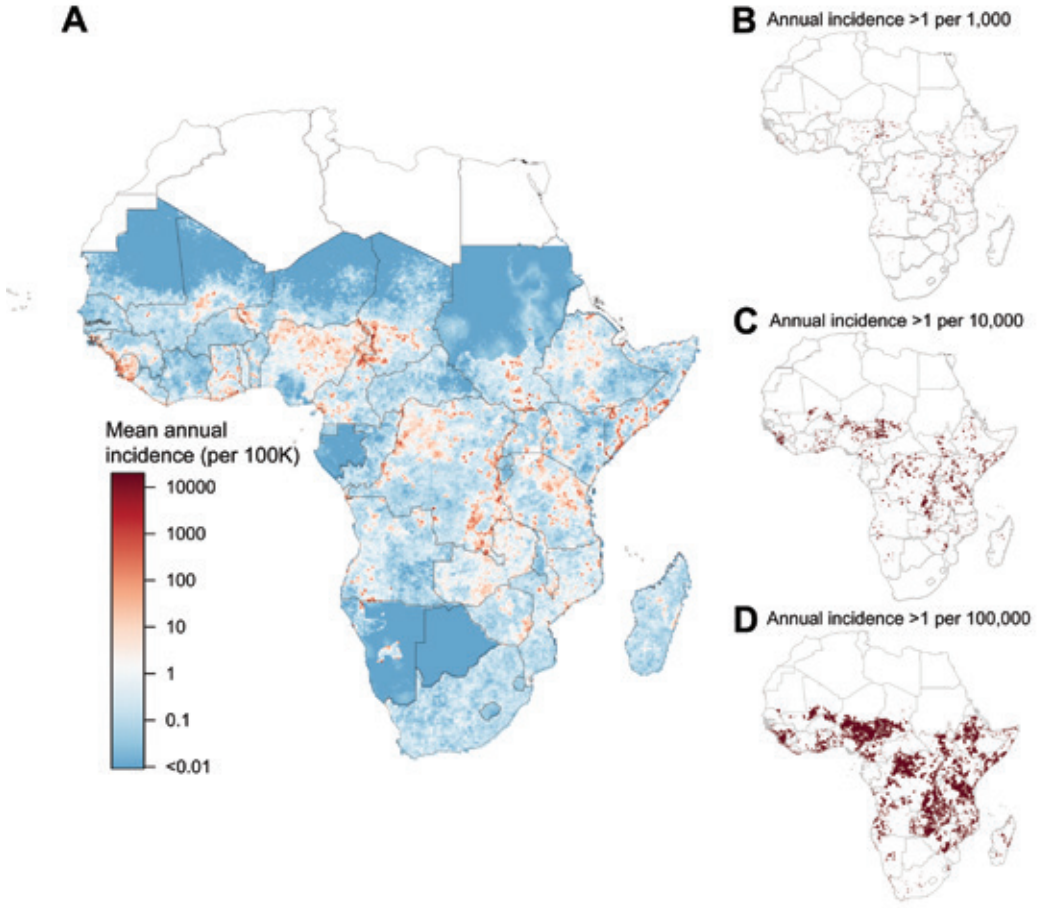
The Global Taskforce on Cholera Control (GTFCC) recently revamped efforts to end cholera by 2030. The Taskforce considers water sanitation and hygiene investments as the foundation to meeting this target.

HWTS is one of several important interventions to reduce cholera risks. It complements the oral cholera vaccine, as it can be rolled out immediately, and it provides a first step towards improving WASH while longer-term water systems improvements are planned and financed.

Understanding water quality characteristics, user preferences for HWTS and the need to pre-position and sensitize populations to the most appropriate options available would help support consistent and correct use of HWTS once an outbreak occurs.

At the same time, HWTS should not be viewed as the only near- or medium-term WASH solution. A broader package of prevention strategies should include centralized chlorination of piped supplies, point-of-collection sources and tanker trucks as well as rapid sanitary surveys to identify contamination risks. For example, during the 2017–2018 cholera outbreak in Lusaka, Zambia, which affected 5000 people and caused nearly 100 deaths, intensive door-to-door hygiene promotion, hygiene kit distribution and enhanced water quality testing and monitoring in the most affected subdistricts of Lusaka helped curb the outbreak in these areas (Republic of Zambia, 2019).

FIG. 9
Cholera hotspots in sub-Saharan Africa



Source: Lessler et al., 2018.

However, the elimination of cholera in Zambia will require investing in both short- and long-term water sanitation and hygiene services in all hotspots.

WHO has evaluated over 20 products that are effective in removing/inactivating bacteria and thus preventing the spread of cholera in drinking-water, including some of the chlorine disinfectants most commonly used in cholera response, and a range of filters.

6 Strengthening national capacity and impact of the Scheme

The main contribution of the Scheme to water safety lies in its potential to influence product selection and shift procurement towards products that perform more effectively. To achieve this goal, WHO is working on a number of efforts aimed at strengthening HWT at country level regulation by ensuring that health criteria are comprehensively addressed; and by supporting the broader enabling environment. This section outlines progress in these efforts and the impact of the Scheme this far.

6.1 Strengthening HWT regulation

WHO has developed training resources to support countries establishing or revising HWT regulations. To date, training workshops have been conducted in Ethiopia and Ghana. Efforts are underway to expand these to other countries. The training workshops aim to strengthen the skills of both regulatory and health staff in interpreting evaluation results of the Scheme and equivalent laboratory efficacy data, and determining how such data can be applied in developing certification criteria for HWT products. An example of the draft certification criteria developed in Ethiopia is shown in Fig. 10.

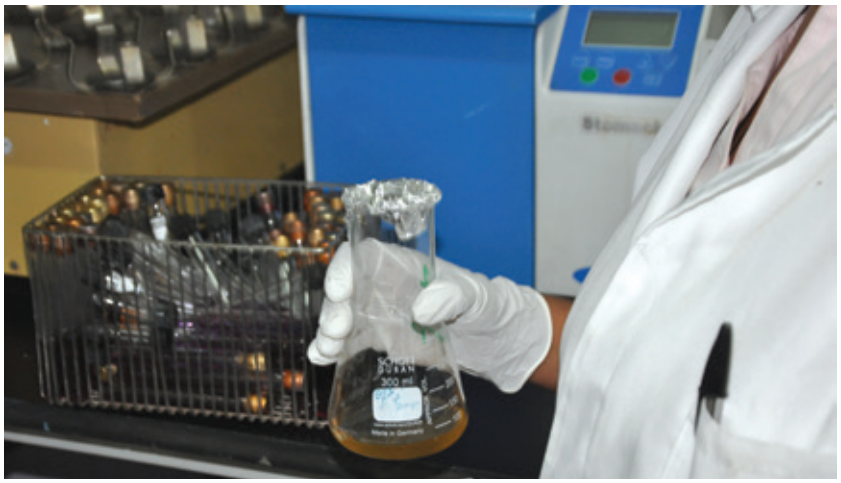
FIG. 10
Draft certification criteria for HWT in Ethiopia

Microbial efficacy	• Microbial groups tested • Test water characteristics • Number of units tested • Test procedure relative to use instructions
Product quality	• Consistency of performance across test units • Flow rate (if applicable) • Disinfectant dose delivered (if applicable) • Evidence of manufacturing quality management system
Product safety	• Product composition / wetted components in contact with water • Leachates / residual concentrations in posttreatment water
Product information and labelling	• Product and manufacturer details: product (trade) name; batch/lot number/manufacturing date; manufacurer name and contact • Use instructions: simple, in local language(s); pictoral illustrations; dosing procedure and dosing instruments • Maintenance and cleaning procedures • Fail safe • Indicator of treatment complete

The key focus of the training workshops is how WHO performance criteria can be considered in HWT regulatory frameworks and how the scope of regulation can be expanded beyond chemical disinfectants to include other HWT technologies. Ultimately, these efforts seek to ensure that HWT products that do *not* work are kept off the market and that consumers have clear and accessible information about those products that do meet minimum performance standards.

6.2 Strengthening capacity of water quality laboratories

As part of the capacity-building efforts under the Scheme, WHO has developed training resources on HWT performance evaluation. These resources are aimed at strengthening complementary testing in countries. The training resources focus on key concepts in risk-based approaches in water safety as part of the core recommendations of the GDWQ.



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Understanding and applying these concepts is important for HWT performance and for strengthening water quality management functions such as surveillance and monitoring. As such, WHO is linking activities aimed at strengthening laboratory capacity in HWT evaluation with broader efforts to improve water quality surveillance as part of national plans to meet SDG 6.1 on water safety.

6.3 Supporting the broader enabling environment

In addition to strengthening HWT regulation, WHO continues to engage with organizations participating in the International Network on Household Water Treatment and Safe Storage (the HWTS Network) to share experience on how governments, implementing organizations and the private sector are working together to improve other aspects of the HWT-enabling environment.

As part of these efforts, an interregional workshop held in Addis Ababa, Ethiopia, in 2016 reviewed experiences in, among other things, implementation of existing national policies and strategies on HWT, including barriers and enabling factors (WHO, 2016b). Participants shared innovative approaches to reaching populations in need of HWT and ensuring that products are affordable and have reliable supply chains. Discussions highlighted that, despite existing policies and strategies on HWT, there are limitations in funding and linking with wider efforts in water safety. Discussions at a recent

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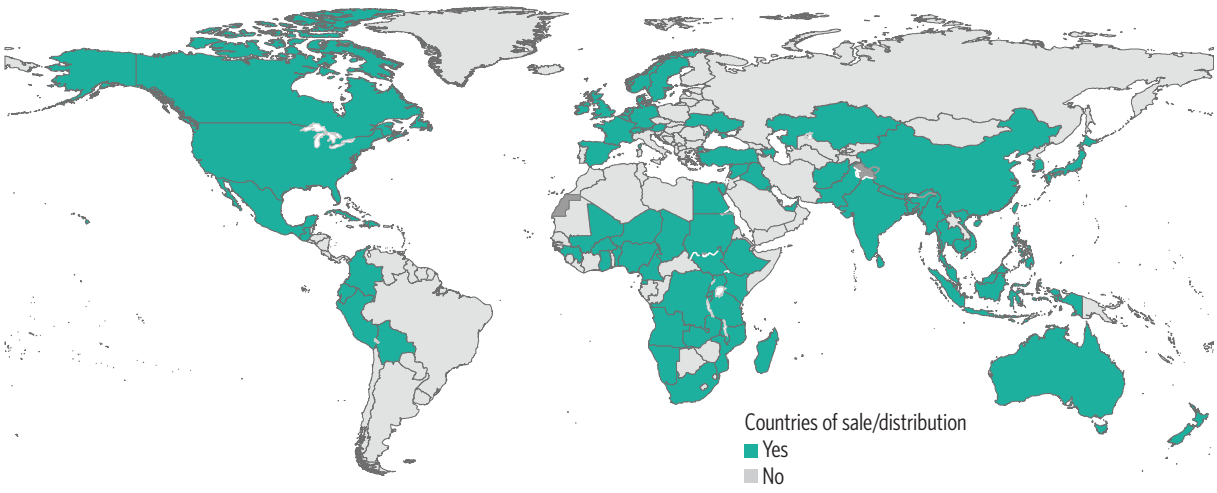
interregional workshop in Accra, Ghana, highlighted the need to increase coordination across levels of government (national/subnational) and sectors (water, health, environment, commerce) and improve accountability (WHO, 2019).

6.4 Impact

Products evaluated in Round II of the Scheme are sold/distributed in at least 80 countries around the world (Fig. 11).

FIG. 11
Global reach of products evaluated in Round II



Influencing procurement towards effective HWT products

Through the work of the Scheme, WHO is increasingly called upon to provide ongoing guidance to procurers and those responding to emergencies. For example, technical guidance on ensuring products meet minimum performance standards is being provided to WASH partners responding to cholera outbreaks and the humanitarian emergencies in Ethiopia and Bangladesh.

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Strengthening multisectoral engagement

Among the key recommendations from the 2016 interregional workshop was the need to establish/revitalize national working groups on water safety, including HWTS. Such working groups have been instrumental in developing national strategies and policies on HWTS in the past, as part of the Network's efforts. In follow-up to the recommendation, a national working group on water safety / HWTS was established in Ethiopia. The working group comprises representatives from the ministries of health and water, the national regulatory and standards authorities, implementing organizations and manufacturers. With support from WHO Ethiopia, the working group meets regularly to provide strategic guidance to the ongoing capacity-building efforts, and ensure linking with other water safety and public health efforts.

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7 Reflections and recommendations

The two evaluation rounds have provided key lessons and insights that have been applied to improve the functioning of the Scheme. Based on the lessons from Round I, testing protocols were simplified and subsequently validated for use in Round II. This simplification allowed for testing of a larger number of products and will facilitate their application in limited resource settings.

In addition, there has been important progress with regard to awareness of WHO performance criteria for HWT. More manufacturers are requesting product evaluations under the Scheme, and procurers and regulatory authorities are increasingly aware of the performance criteria and their application in product selection and certification. To maximize impact of HWTS and its implementation, WHO has made the following specific recommendations:

For manufacturers:

- **Submit your product for evaluation under the Scheme:** Include easily understood and consistent labelling and use instructions on the product, the product-specific manufacturer's website and all other relevant material.

- **Invest in robust manufacturing quality:** By setting out clear demands for quality from material suppliers, adhering to clear internal quality management systems such as checks of parameters along the production line (seal/flow tests, visual inspections, etc.) and training of manufacturing personnel.

For procurers and implementers:

- **Use WHO performance criteria and Scheme results to inform HWT selection:** First, consider microbial performance based on the evaluation criteria and results in this report. Once a list has been narrowed down to include only those that meet at least minimum performance criteria, explore water quality conditions in targeted locations, familiarity, supply chains and other factors that impact correct and consistent use.

- **Use HWTS as a tool within broader efforts to increase access to safe water:** HWTS is one option for improving water quality and health, especially among vulnerable populations. Evaluating HWTS should be considered within the context of WSP, hygiene and sanitation improvements and integrated environmental health interventions at the household level.

For national regulatory and laboratory authorities

- **Initiate a process to develop or strengthen national certification programmes:** Convene the relevant ministries (health, water, environment, commerce) and discuss options for expanding technical capacities in HWT regulation. Such a programme should also outline requirements for easily understood labelling and use instructions. Work with laboratories to strengthen existing protocols and testing of bacterial indicators and surrogates. Start by testing the most commonly sold and used devices.

- **Consider fast-tracking certification of products already evaluated by WHO:** Products that are sold and distributed internationally and have been evaluated under the Scheme may not need to undergo additional laboratory testing in-country.

Priorities under the Scheme include further improving the efficiency of the evaluation process, maintaining the same high scientific rigour but reducing turn-around time and cost. Building on initial efforts to strengthen regulatory and laboratory capacity in-country, WHO aims to scale up capacities in water quality management, supported by a network of laboratories in high-income settings, including the two designated testing laboratories, NSF International and KWR Watercycle Research Institute. More broadly, WHO will work in a more integrated manner to improve national approaches to improving water safety. This will ensure that capacity building under the Scheme is packaged within a broader framework for water safety management that recognizes and promotes synergies with water quality surveillance and monitoring efforts, WSP and health-based targeting setting and assessments.

Currently 30 HWT products – including those most commonly used in emergencies – have had their performance independently evaluated against WHO performance criteria. Of these products, 23 meet WHO performance criteria; however, as illustrated in the results, HWT performance varies greatly and a number of products have minimal microbial reduction and are therefore of little or no public health benefit. In this regard the Scheme continues to fulfil an important need for objective and health-based evaluation of HWT.

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Annex 1

Data management and quality assurance

Data management

EoIs and supporting product information received from manufactures were stored in a secure WHO database. As per standard operating procedure, this information was available only to the Scheme Secretariat and members of the IAC. Individual product testing protocols were sent to manufacturers for review before commencement of testing. The results of product laboratory testing conducted at NSF International and KWR Watercycle Research Institute were recorded by each technician individually. All source documents and electronic records of the laboratory testing are maintained in a secure database for 10 years.

Quality assurance

The two laboratories currently designated to conduct testing under the Scheme, NSF International and KWR Watercycle Research Institute, meet several criteria[1]. They are accredited by the International Organization for Standardization (ISO)/ nternational Electrotechnical Commission (IEC) for ISO/IEC 17025: 2017, the internationally accepted standard for developing laboratory management systems for quality, administrative and technical operations. Laboratories that achieve compliance with ISO/IEC 17025 have demonstrated that they operate using sound management practices; are technically competent to perform specific tests, calibrations and/or measurements; and are able to generate technically valid results for which they hold accreditation.

In addition, the designated laboratories have significant experience evaluating HWT technologies, which is important for understanding and correctly operating the technologies in the laboratory during the evaluation. Both laboratories are WHO Collaborating Centres and have undergone rigorous legal review for objectivity. They engage, without profit, in a number of technical activities with WHO. Results of product testing and raw data are sent to WHO and reviewed in detail by the Scheme Secretariat and the IAC. Potential discrepancies are identified and cross-checked against laboratory bench sheets.

1 Criteria for designated testing laboratories can be found at http://www.who.int/water_sanitation_health/water-quality/household/testing-laboratories/en/

Annex 2

Evaluation procedure

Initial screening of dossiers

Evaluation of HWT products under the Scheme is based on manufacturers voluntarily submitting an expression of interest (EoI) and product dossier to WHO. The dossier should contain information describing the product and its specifications, its operation and maintenance, evidence of user uptake and strategies for reaching the underserved and those most in need. Invitations to interested manufacturers to submit EoIs are published on the WHO website and through various listservs. The criteria for manufacturers eligible for submitting an EoI are as follows:

- An established manufacturing process for market-ready HWT products;
- Evidence of quality management systems;
- Use of materials of known composition with well-described safety properties; and
- Robust and tested operation and use instructions (that are used as the basis for developing product-specific test plans).

Evaluation under the Scheme is fee-based. Subsidies are awarded by WHO subject to the availability of funds. The criteria for determining whether a manufacturer is eligible for a subsidy are outlined in the *Procedure for Evaluation* (WHO, 2018b).

Products prioritized for evaluation under the Scheme are relatively low cost, appropriate for low- and middle-income settings; generally free-standing and not requiring installation; and able to treat enough water a day to serve the number of individuals typically in a household or small public facility such as a tertiary health care centre. EoIs that meet these initial screening criteria are selected for review by the Scheme Secretariat with input and advice from the IAC.

Dossier review

The dossier review seeks to determine whether HWT products meet the WHO performance recommendations. Product data and information on safety, performance and user testing as well as production and manufacturing quality control processes are considered. Key criteria include the following:

- Do the existing laboratory data demonstrate that the product meets WHO microbiological performance criteria for all three classes of pathogens?
- Are the testing protocols and test methods used comparable to those of the Scheme?
- Is there sufficient evidence to demonstrate the independence of the testing laboratory and quality management procedures employed?

- Is there demonstrated uptake of the product, for example, through field studies of acceptability or reported sales volumes?

Depending on the extent to which a product meets these criteria, the IAC makes one of three possible recommendations:

1. *Full laboratory testing:* criteria have not been met and testing against all three pathogen classes at one of the Scheme designated testing laboratories is required;

2. *Abbreviated laboratory testing and desk review of existing data:* criteria have been partially met, and a combination of testing against one or two of the pathogen classes at one of the Scheme designated testing laboratories and review of existing data is required; or

3. *Desk review of existing data:* the criteria have been fully met and no laboratory testing under the Scheme is required.

WHO has developed technology-specific testing protocols that are adapted by the laboratories to create specific product needs and use requirements. WHO reviews these product-specific testing protocols and shares these with the manufacturer for comment before testing commences.

With input from the IAC, WHO communicates the outcome of the evaluation to the manufacturer. A list of all evaluated products, their performance level and the relevant test protocols for each of the technology classes is published on the WHO website.

WHO's work on household water treatment and safe storage

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