

Options for addressing poor quality drinking water in rural Vanuatu

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Abstract: Consumption of poor quality water can cause diarrhoea and waterborne disease. To determine how to support residents to consume safe water, the Vanuatu Department of Water Resources (DoWR) undertook an analysis. The analysis included reviewing 793 water quality test results, exploring treatment options with WASH sector stakeholders, surveying 689 community members in three provinces, demonstrating products to 510 people in 22 communities, and interviewing key informants. Analysis of water quality results compiled by DoWR between 2000 and mid-2019 found that *Escherichia coli* was detected in 60% of samples tested and total coliforms were detected in 84% of samples. Overall, 62% of individuals surveyed stated that water is in some way a daily problem. Discussion facilitators reported that most individuals had not seen or heard of water treatment options beyond boiling and most who boiled admitted they do so only occasionally. Of the water treatment options explored in this research, household water filtration systems seemed the most viable approach. However, individuals underestimated the market cost of filters and indicated a willingness to pay that is half the market price. Of the different filtration systems demonstrated, consumers stated a preference for easy-to-use units with large and transparent water storage containers.

Keywords: household water treatment, water filters, water quality, small island states, Pacific Islands

VANUATU IS A LOWER-MIDDLE-INCOME country located 2,500 kilometres east of Australia in the Pacific Ocean (World Bank, 2020). Water quality is a challenge for the 280,000 residents spread over 66 inhabited volcanic and raised coral islands. In Vanuatu, diarrhoeal disease causes 6% of deaths among children under 5 years (Carter, 2016). The 2013 Demographic Health Survey (DHS) revealed that 12% of children under the age of 5 years had diarrhoea within the two weeks prior to the survey. In addition, 29% of children in Vanuatu under the age of 5 years are stunted, which can be a sign of poor water quality, among other things (VNSO, 2014).

The United Nations Children's Fund (UNICEF) and World Health Organization (WHO) Joint Monitoring Programme (JMP) estimates that only 44% of the

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population has access to a safely managed drinking water service (WHO/UNICEF, 2019). This is predominately provided through a concession that pipes chlorinated water to residents in the urban capital, Port Vila, with some chlorination also occurring in provincial headquarters. Drinking water, especially in rural areas, is often contaminated at levels higher than WHO recommends and the Vanuatu Government standards mandate (DoWR, 2019b). Globally, climate change may increase the consumption of contaminated water (Philipsborn et al., 2016; Levy et al., 2019). In Vanuatu, drought and cyclone water system damage already result in populations using lower quality water sources they would otherwise not normally use. While some individuals obtain liquid from coconuts, fruits, and vines, for fresh water, others may turn to unclean surface water.

There are numerous household water treatment technologies designed to ensure safe water is consumed (WHO, 2019). Global studies show that to have a truly meaningful impact on human health, household water treatment options must be effective at removing faecal pathogens, accessible to the population, and consistently used (Clasen, 2015). In 2013, only 30% of households in Vanuatu reported treating their own drinking water at the household level before consumption. The percentage treating water drops to 17% if only rural households are included (UNICEF/WHO, 2017). According to both the 2007 Demographic Health Survey (DHS) and 2013 Multiple Indicator Cluster Surveys (MICS), the most common water treatment method is boiling, followed by 'other', and filtering with a cloth.

The Government of Vanuatu is committed to achieving the Sustainable Development Goals (SDGs) and ensuring, 'safe and affordable drinking water'. In the National Sustainable Development Plan, the government of Vanuatu states a target to, 'ensure all people have reliable access to safe drinking water and sanitation infrastructure' by 2030 (Republic of Vanuatu, 2016). To reach this target, new systems will need to be constructed and poor water quality in existing systems will need to be addressed. Most often, government encourages communities to prevent consumption of poor quality water by promoting the boiling of water (MoH, 2011; DoWR, 2020a) and assisting them to create Drinking Water Safety and Security Plans (DWSSPs). Unfortunately, global studies have found that compliance with boiling water is low due to various consumer preferences, inconvenience, and understanding of risks (Harding and Anadu, 2000; Willocks et al., 2000).

Also, a 2016 review of ten DWSSPs in Vanuatu found that they did not improve water quality (String et al., 2020). To improve DWSSP impact on water quality and health, DoWR now tries to include three water quality tests in all DWSSPs that they fund, promotes community no/low cost improvements, makes efforts to improve DWSSPs through a National Implementation Plan for safe and secure water (NIP), and provides funds for water system improvement through a Capital Assistance Program (CAP). However, for DWSSPs to have an impact on quality water service provision and ultimately on child health, additional efforts are needed to ensure safe water is consumed at the household level. This article describes a series of practical research activities which were conducted with the objective of identifying how government can best support individuals to consume safe water.

This paper explores many of the different barriers to household water treatment in Vanuatu. It is hoped that non-profits and private sector actors will also benefit from the results of this research.

Methods

To understand the water quality situation better and assess the types of water treatment that communities were interested in using and maintaining, research was conducted in 2019 by the Vanuatu Department of Water Resources (DoWR) with technical assistance from UNICEF and funding from New Zealand Ministry of Foreign Affairs and Trade (NZ MFAT). The research used multiple methods to better understand the situation and challenges. In total the efforts compiled 793 water quality test results, conducted activities with water, sanitation, and hygiene (WASH) sector stakeholders, surveyed 689 individuals, demonstrated products to over 510 people in 22 locations, and interviewed key informants.

The first part of the research included compiling a dataset of all water quality tests conducted by DoWR, researchers, non-governmental organizations (NGOs), and contractors facilitating DWSSPs that could be identified. Water test data from 2000 to 2017, most of which was in paper format only, was entered into a Microsoft Excel worksheet and then uploaded into an online database. An online form was created so new water quality data collected could be directly added into the dataset by external researchers, contractors, or DoWR staff. Data was tabulated to get a summary of key details. Information related to bacterial contamination was then reviewed as part of this research and a dashboard created online so practitioners and researchers could examine the dataset compiled (DoWR, 2019a).

The second part of the research involved gathering information from key informants through informal interviews and site visits with provincial and national Ministry of Health (MoH) and DoWR staff members, village water committees, and community members.

The third part of the research was conducted in March 2019. It included an initial review of attitudes toward water treatment options among WASH sector stakeholders. These stakeholders included members of the private sector, NGOs, civil society organizations, and government staff from the Ministry of Education and Training (MoET), MoH, and DoWR. During a week-long training on DWSSPs, a collection of water treatment options was displayed. Water treatment options that DoWR and UNICEF could find in country were used. Three filters had been distributed during the recovery efforts after 2015 Tropical Cyclone Pam: a bag with a membrane filter, a large community membrane filter with four taps, and a membrane filter with single bucket and pitcher. One filter was a UNICEF staff member's personal water bottle. The final water filter was a ceramic filter newly arrived in country as part of UNICEF prepositioned stock and was made of solid white plastic containers with four ceramic candles.

Stakeholders were asked a series of questions related to the water quality treatment options. The questions changed each day and it was voluntary for the workshop



Figure 1 Water treatment options on display were discussed with WASH stakeholders during training breaks. Questions related to the treatment options were changed each day. (Right: UNICEF Supply Division white four ceramic container, membrane community filter, membrane household bag filter, membrane bucket filter and membrane personal water bottle)

attendees to participate. As a result, participation varied from five to 32, but typically around 20 individuals answered some of the questions each day. The series of questions closed with a willingness to pay question and a final chance for participants to purchase the only commercially available option in stock at that time in the country: a personal water bottle with a membrane filter inside.

The fourth and fifth parts of the research included surveys of individuals and community product demonstrations. These activities were conducted in three provinces in May and June 2019 on four different islands, in three of Vanuatu's six different provinces.

A simple, short survey with just 20 questions was created in Bislama, one of Vanuatu's three national languages, spoken by most citizens (ENGIE, 2019). The individual survey data was collected directly in Bislama using a mobile phone Open Data Kit application by six enumerators. After a few demographic questions, participants were asked about attitudes, knowledge, practice, and willingness to pay related to water quality and treatment options. All questions were asked in an open-ended style, allowing each person to freely reply. The multiple choice responses were only seen by the enumerator and were not shared with individuals surveyed. As a result, 'other' was frequently selected and participants comments recorded. Survey data, related to demographic, water supply issues, health knowledge, and water treatment options was then analysed using Excel.



Figure 2 Demonstration of water treatment solutions during community product demonstrations
Photo credit: ENGIE and Red Cross

Product demonstrations were conducted during community meetings in the same locations as the individual surveys. A total of 510 people (273 female, 237 male) attended the product demonstrations. The demonstration included an open discussion about water access and water quality and a display of point of use water treatment options. The options discussed included: cloth, biosand, SODIS, water purification tablets, boiling, and four commercial filters. The commercial filters options included two filters that had been used during the WASH sector stakeholder engagement: the four ceramic filters in a white container and membrane filter with bucket. The demonstration also included two additional filters: a ceramic pot filter inside a transparent blue container and a clear single ceramic filter with one container on top of the other.

During the product demonstration, community members individually marked on a whiteboard the technology they felt would best suit them for daily use. A group discussion with raised arms then determined the price most were willing to pay.

The final part of the research was sharing and discussing the results with government officials. The results were shared with local stakeholders through written reports and provincial government meetings. A final workshop was held with MoH and DoWR officials in the capital to discuss the findings and explore next steps for different scenarios, such as different locations and emergency and regular situations.

All data used in this analysis were collected under the direction of the Government of Vanuatu DoWR or routine programmatic work by government staff members. Verbal informed consent was obtained from local officials and individuals prior to the survey. The survey did not collect individual identifying information and was deemed not to need further ethical approvals by DoWR.

Results and discussion

The main results of the compiled water quality test results, individual survey, product demonstration, and key informant interviews are shared below. Each of the results is then discussed and relevant related research highlighted.

Measured water quality

Compiling almost 20 years of water quality data was not easy and in some cases basic information, such as GPS location, was missing. The water quality tests compiled had not been systematically collected and the same parameters were not collected for all sites. For example, in some locations *Escherichia coli*, total coliforms, faecal coliforms, fluoride, enterococci, conductivity, turbidity, and pH were tested, while in others just one or some of the variables were tested. While the data was not systematically collected, the resulting compiled dataset still reveals some basic results. The most common test conducted was for coliforms using different methods such as hydrogen sulfide (H₂S), membrane filtration, and compartment bag test (<https://www.aquagenx.com/cbt-ectc/>). Sixty per cent (255/429) of samples that were tested for *E. coli* collected between 2000 and mid-2019 had come back positive (Figure 3). These results reveal that many

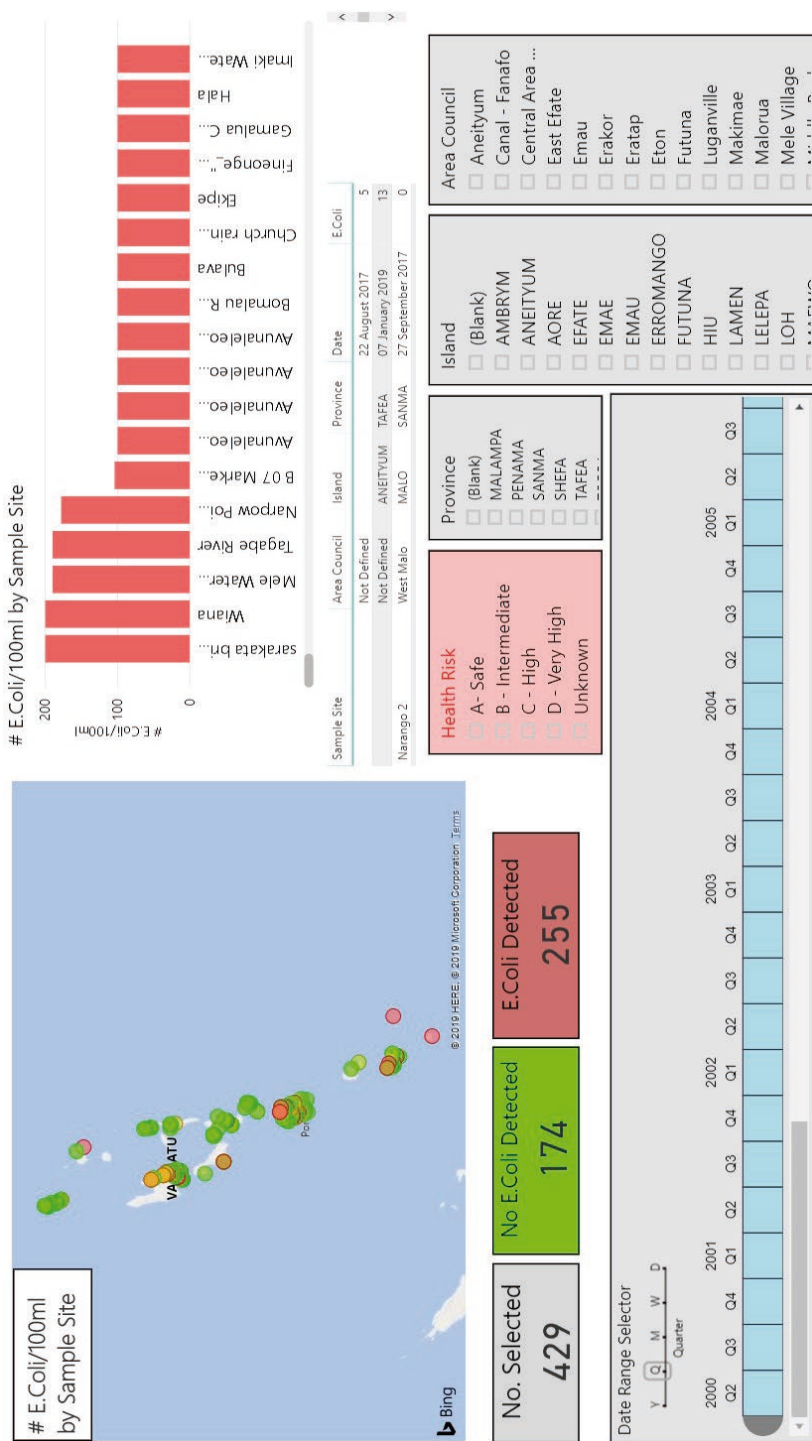


Figure 3 Screenshot of Vanuatu's Water Quality Dashboard on the Ministry of Lands & Natural Resources website
Source: DoWR, 2019a

water samples were bacterially contaminated. WHO states that, '*Escherichia coli* provides conclusive evidence of recent faecal pollution and should not be present in drinking water' (WHO, 2017).

These results do not show the full extent of contaminated water being consumed, and it is likely that these tests were taken at the point of collection, not at the point of consumption. In many cases it is unclear if the water sample was taken at the water source, tap or household, but as per discussions with DoWR water quality lab technicians, the samples were most likely taken at the source or along the pipeline and not at the household level. Globally, it has been found that even when there is clean water at the source or at the community water tap, additional contamination often occurs during transport and storage, due to poor handling processes (Clasen and Bastable, 2003). A 2016 study found this is also true for Vanuatu. A study of 10 DWSSPs revealed that water had a geometric mean for *E. coli* of 3.2 CFU/100 mL at the collection point, but that rose to 3.5 CFU/100 mL at the household. Similar results were found for total coliforms. The overall total coliform numbers were higher with 47.4 CFU/100 mL found at the collection point and 212.6 CFU/100 mL at the household level (String et al., 2017).

Historical water quality treatment

Discussions with government officials revealed that currently different water quality treatment options are seen as appropriate for different settings.

Chlorine is used to disinfect water supply in the capital city and some provincial headquarters. The capital city water supply system is run by a concession with routine testing, and functions well. However, keeping chlorine dosing mechanisms functioning in provincial headquarters can be difficult. There is sometimes a need for manual dosing that requires a vehicle and staff time to get to different storage tanks. Water purification tablets have been distributed during emergencies as part of UNICEF and other organizations' hygiene kits, but DoWR requested they be removed from future kits because they were not being used. DoWR found that they required significant explanation to prevent misuse, which is not easy to do in an emergency setting (DoWR, 2020b). In addition, people complained about the taste. Even among DoWR staff, there is a hesitancy to use chlorine or water purification tablets as it is seen negatively as a 'chemical' added to water. However, DoWR staff agreed to allow a practical training on how to shock-chlorinate rainwater tanks in emergency settings and DoWR continues to treat provincial capital water with chlorine, which some staff strongly support.

Previously, some filters were distributed as part of the Cyclone Pam response or as part of NGO or church projects. There are lots of anecdotal stories of free filters not being used and being left in the bag, but there are examples of positive deviance where the filters are still used, especially the membrane filters, for multiple years. Similar results were found in a meta-regression combining 28 studies on household water treatment in developing countries which found that water filters are the most effective form of household water treatment. This finding was in part because of a higher rate of long-term compliance compared to other point of use water treatment options (Hunter, 2009).

WASH stakeholder perceived value of water treatment options

To start to understand preferences, filters were displayed during a WASH sector stakeholders workshop. For many participants, this was the first time they had seen most of the household filter options. At the start of the first day, a poster asked how participants currently treat water, and all participants answered that they boil their water when needed, though one DoWR staff member reporting having used the Sawyer membrane filter in his own home since 2016 having received it post-Cyclone Pam. Without consideration for cost, most workshop attendees who participated preferred the solid white plastic containers and four ceramic candles (44%, 15/34), 13% (13/34) preferred the personal water bottle with a membrane filter inside, 12% (4/34) preferred the large membrane filter with four taps, and 6% (2/34) preferred the membrane filter with single bucket and pitcher. Comments on posters indicated that preferences were often driven by durability of the water housing container, rather than operation or maintenance of the filtration unit. This could be because most attendees had no experience using a filter but had multiple experiences with poor quality water containers. When asked approximate market value of the filters, the mean attendee estimated price was less than the market value online in Australia or the US. The online price doesn't take into account shipping or storefront profit, which often at least doubles the cost of a product. For the one product available in Vanuatu, WASH stakeholders were willing to pay less than half the cost for which it is currently advertised in the store. When attendees were then told the estimated Vanuatu market price and told that one of the filter options would be on sale for the listed price the following day, 16 signed up to buy one if it was available for the estimated Vanuatu market price. Nine attendees wrote their name and email address down stating they would be interested in buying a single ceramic filter alone without a container for 500 Vatu (US\$4.46), one signed up to buy the four ceramic candles option for 8,000 Vatu (\$71.36), and six signed up to buy the personal water bottle for 4,500 Vatu (\$40.14). On the final day of the workshop, a local vendor brought the one filter that was actually sold by the private sector: the water bottle filter. Only one individual who had signed up to buy the water bottle followed through on the commitment from the previous day and purchased the filter.

Survey participant demographics

The survey questionnaire captured responses from 689 participants among 22 different communities from at least four different islands. The largest group, 346 people, were from Tanna island, 305 from Malekula, 16 from Efate, 17 from Moso, and 5 answered the survey in Efate but were originally from other islands. More females than males were surveyed, with 61% (420/689) of those surveyed identifying as female and 39% (269/689) male. Most participants were aged between 30 and 59 (54%, 373/689) but 13% (86/689) were over the age of 60 and the remainder below 60. Most participants were categorized as unpaid family workers 55% (382/689), 24% (166/689) produced goods which they sold for cash, 13% (87/689) stated they were currently inactive, 7% (51/689) were employed, and 1% (3/689)

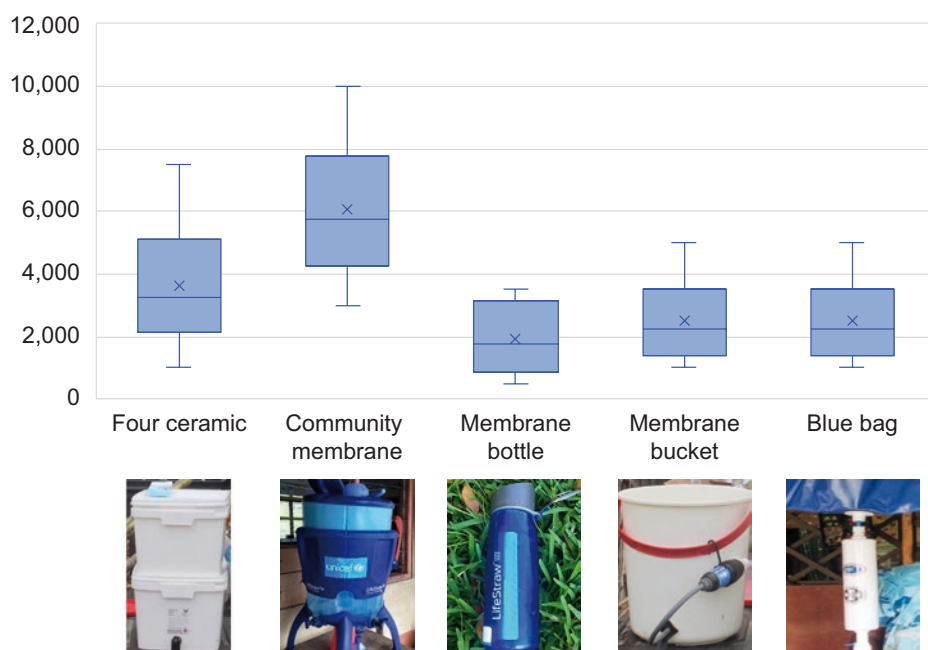


Figure 4 WASH sector stakeholders estimated prices of various filter options
Photo credit: author and ADRA, 2015

stated they were volunteers. These demographics are quite different from that found in the 2016 Mini-Census for rural households, with 52% (31,371/50,584) selling fish/crops/handicrafts, 17% (10,209/60,684) earning wages, 17% (10,104/60,684) owning business or leasing land, and 15% (9,000/60,684) living off remittances or stating other or none. While the categories were different and the Mini-Census did not include unpaid family workers as a category, the large difference in producers could be a sign that the survey did not reach a representative sample of the population. Those surveyed were often those who did not attend the community meeting and were at home during the day when the survey was conducted.

Reported water issues

Most participants reported getting their water from groundwater sources (55%, 381/689), while 46% (316/689) used rainwater, 29% (316/689) used a stream or surface water, 0.3% (2/689) replied 'I don't know', and 31% (182/689) stated other. Most stating other clarified that the source came from a pipeline, which in most cases in Vanuatu means it is groundwater. Participants often selected more than one water source; thus the total is more than 100%. The survey revealed that 62% (430/689) of the individuals surveyed stated water challenges affected their daily life. Quantity was the issue stated by most people, with 47% (324/689) of respondents stating there is not enough water. While water contamination is often not easily visible, 27% (186/689) stated that water quality is an issue. Seven per cent

(49/689) felt the distance from their house to the water access was an issue. For the respondents who stated water quality is an issue in their daily life, there were three main issues cited. (Again, multiple responses were accepted, thus the total does not add up to 100%.) Most (77%, 143/186) reported bad taste as one of their issues, poor colour was mentioned by 50% (93/186), and 33% (87/186) stated the water made them ill. Salty water was frequently mentioned and marked as 'bad taste' by the enumerators. Bad taste also frequently came up during product demonstrations. One male participant in Malekula stated, 'Some older people of the community prefer drinking water from the river compared to rainwater because river water has better taste than rainwater.' The feelings were so strong that even if a rainwater collection tank was installed near someone's home, they would still travel to the river for their water. However, in other parts of the country, the perception of taste is different and rainwater is preferred. For example, in 2017 and again in 2018, 11,000 residents from the island of Ambae evacuated after increased volcanic activity. Community members who were used to drinking rainwater on Ambae installed a tarp to collect rainwater in their temporary home on Maewo rather than use a piped spring water tap. This same community had brought two Sawyer water filters with them from Ambae and some community members treated the rainwater prior to consumption.

Water-related health knowledge

In Vanuatu, there is already a lot of existing knowledge about the impact of poor quality water. In this survey, 89% (612/689) of respondents stated that poor water quality can make them sick. When asked about the possible consequences on their health if poor quality water is consumed, individuals correctly named multiple items such as: diarrhoea (60%, 418/689), abdominal pain (43%, 293/689), headache (37%, 257/689), vomiting (25%, 176/689), and skin rash or other issues (8%, 57/689). Interestingly, 29% (199/689) of survey participants stated flu or cough, and 1% (9/689) stated kidney stones. While handwashing can reduce flu and cough transmission (Wong, 2014) these are not typically considered waterborne, washed, based or related diseases. Kidney stones are more frequently impacted by a lack of adequate water intake rather than water quality (Mitra et al., 2018; Willis et al., 2019).

Over half (54%, 374/689) of those who participated in the individual survey thought the people of their village are aware of the importance of good quality water, while the remaining 46% think the opposite. After the product demonstrations and open discussions about the importance of good water quality, it was noted in several communities that people think they do not know enough about water quality and many expressed interest to learn more. One individual stated that, 'There has never been an awareness made to us about the importance of water quality.' After the product demonstration, one of the enumerators noted, 'The community members determination of water quality is from general knowledge and observation.'

There are a few government programmes aimed at sharing water quality information, but they are currently under-resourced (Rand and Sammy, 2018). Most communities have a volunteer, mostly unpaid, Village Health Worker. Village Health Workers should be supported by one paid Village Health Worker Coordinator at the

provincial level, but currently not all six provinces have a coordinator. Many of the Village Health Workers act as Nurse Aids or run village level aid posts and have little time for outreach activities. Sometimes the volunteers receive funds or gifts from villagers, such as chickens and taro, in exchange for services. Some of these Village Health Workers have been trained on environmental health topics during a one-time MoH national pre-service training, an annual provincial in-service training, or from an NGO. However, these trainings do not always occur. When they do occur, the trainers use 'Healthy Island materials' (Figure 5). These materials include one sentence about water quality: 'Use safe water or treat to make it safe to use' (MoH, 2011). The Red Cross currently also teaches about safe water in its promotional materials used in emergencies and UNICEF is also helping MoET to get water quality information into the school curriculum.

Survey participant water treatment current practice

Most participants (84%, 580/689) shared at least one way they felt could treat water. The most mentioned solution for water treatment was boiling the water 78% (534/689). After boiling, the numbers dropped significantly for other appropriate water treatment methods with only 2% (16/689) stating UV filtration, and less than 1% (4/689) mentioning filters or chlorine (3/689). Many of the methods mentioned, if done in isolation, may not actually ensure water reaches WHO or national standards (WHO, 2019). For example, 10% (71/689) of respondents mentioned cloth filtration, 6% (43/689) natural filtration, 1% (10/689) tank cleaning, and 1% sedimentation (5/689). Unfortunately, 23% (157/689) stated they did not treat their water in any way, but an impressive 67% (462/689) stated they boiled once a week. A few others reported using natural filtration (5%, 23/689), UV filtration (2%, 13/689), chlorine (<1%, 1/689), and other (<1%, 58/689). These results are similar to what both the MICS 2007 and DHS 2013 studies found.

Community perceptions related to boiling water

As stated at the beginning of the article, traditionally in Vanuatu the government has advocated for communities to mitigate the harmful effects of poor quality water consumption by boiling water (Figure 6). It is therefore not surprising that

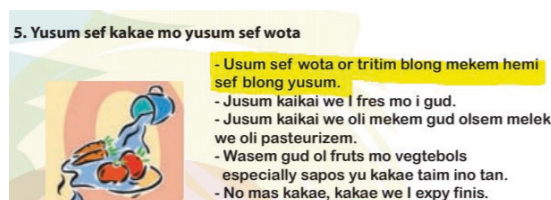


Figure 5 The only section of the Healthy Island material for Village Health Workers that mentions treating water. It states 'Use safe water or treat water to make it safe for use'



Figure 6 Vanuatu Emergency WASH Cluster visual with the message to 'Boil water all the time before you drink' in Bislama

Source: DoWR, 2016

boiling was the most frequently mentioned water treatment method by WASH Sector Workshop attendees, in the MICS, DHS, and this survey. However, multiple survey participants stated that they do not like boiled water because the water tastes 'smoked'. Others expressed concern if boiling water was worth the effort given the labour required. Given that 91% (50,050/55,285) of households in Vanuatu stated a preference for firewood as the first choice for cooking fuel in the 2016 Mini-Census (VNSO, 2017), time is needed to gather wood, make a fire, and maintain the fire during boiling. Boiling water can contribute to the degradation of forests and air pollution. While many people in Vanuatu cook outdoors, globally cooking fires are a large problem. It is estimated that indoor air pollution related to cooking leads to approximately 4 million premature deaths per year from pneumonia and other noncommunicable diseases (WHO, 2018). After all that, in Indonesia where water is commonly boiled, water is sometimes still found to be bacterially contaminated, perhaps due to unhygienic handling and storage (Sodha et al., 2011).

Some studies in other countries have also found that boiling water every time before consumption is difficult, due to time, fuel, and financial requirements (Workman, 2019). In Vanuatu, individuals also discussed inconvenience and boiling water was not a routine habit for many people. During the product demonstrations in Tanna and Malekula, people stated the same idea multiple times, with one participant summarizing the idea as, 'the community is aware of boiling as a means of purifying water, but we do not practice it'. Demonstration participants also shared that they boil water when children are sick but stop boiling water as soon as the child becomes well again.

Community perceptions related to chlorination

In many locations around the world, water is safely managed through chlorination (National Academy of Sciences, 1977). Chlorine can eliminate contamination at the treatment point but also during transport and storage if residual chlorine remains in the water. In Port Vila, the capital of Vanuatu, operation and maintenance of a chlorination treatment system is effectively done by a concession with Vanuatu Services ENGIE. In Luganville, the second largest city in Vanuatu, operation and maintenance is currently done by eight paid DoWR urban staff members managed by a Foreman under the Provincial Water Supervisor with frequent support from Port Vila DoWR leaders. Unfortunately, even with this level of investment, the Luganville water system does not currently have a properly functioning drip chlorinator. In other countries, chlorination has been tried with success even in rural settings, sometimes at the community level or as a household treatment option (Arnold and Colford, 2007). However, in Vanuatu, this has not been successfully implemented. As stated above, chlorine tablets were previously distributed as part of UNICEF hygiene kits during emergencies, but DoWR requested they be removed from the kits as they were not being used, required significant explanation to prevent misuse, and people complained of the taste. This dislike of the taste was revealed again during the product demonstrations. When asked if they would consider chlorine as a way to treat water, many

participants said no. As one participant in Malekula, put it, 'No. It tastes different'. There is also frequently misinformation about chlorine not just in Vanuatu, but in the greater Pacific region. For example, in some locations there are protests against its use (RNZ, 2019). Product demonstration participants stated that they thought chlorine is harmful to the body, even though chlorine can safely treat drinking water (Nieuwenhuijsen et al., 2009; Backer, 2019).

Community perceptions related to manufactured filters

During the community meetings in Tanna and Malekula, individuals selected which of the options they most preferred. Of the options presented most people (38%, 192/510) preferred the clear ceramic pot filter, 30% preferred the clear single ceramic filter (151/510), only 7% liked the four ceramic filters in a white container (34/510), and 26% (133/510) preferred the membrane filter in buckets. No community members selected any form of chlorination, solar disinfection, or boiled water as their preferred option. Instead, they all preferred filters. The product displays could have been biased in favour of the filters as only filters were physically demonstrated. Votes were also based purely on display, not use, as individuals weren't able to use the filters for long periods before determining preferences.

Discussion facilitators reported that most of the community participants had never heard about the filtration station technology before the survey and product demonstration. They said it was first presented and explained to them during the survey and product demonstrations. During the product demonstration, people often reacted positively to the water filtering home stations. The visual effect of seeing clear transparent water come from muddy water left an impression. 'I can see the quality of the water before and after filtration' stated one woman in Malekula. Many household members were surprised at the small size of this compact device home water filtration system. The same woman said, 'It will take up less space in my little home'.

Of the filters shared, communities preferred the clear single ceramic candle filter options or the 'clay pot' filter. Even though both had similar features and filtering capacity, the 'clay pot' filter was preferred by some to the single clear ceramic candle filter as it was bigger and offered more storage volume. However, the clay pot's main drawback is its fragility; the slightest shock during transport to the islands or even an earthquake at home can be enough to break it. Some preferred the single ceramic filter because, as stated by a female participant in Malekula, 'One filter will be easier to clean and less expensive when it comes to replacing'. This was based on information presented during the demonstration when facilitators shared that the life expectancy of the ceramic filters was 7,000 litres. During the demonstration, it was estimated that under normal use, an annual replacement of the filter for a family of five people would be required so that each family member could have 4 litres per day for 350 days.

Nearly all the individuals surveyed (97%, 667/689) stated that they would consider buying a water filtration station for their family. However, few were willing to pay the market price for the filters in one lump sum. As was found with the WASH sector

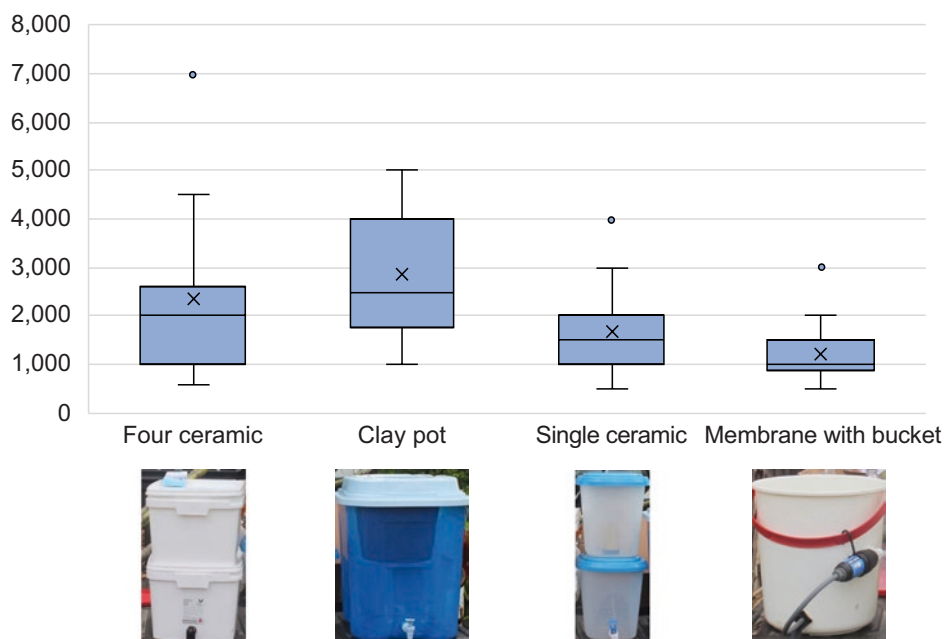


Figure 7 Community product demonstration willingness to pay

stakeholders, community members undervalued the cost of the filters (see Figure 7). On average, community members in the product demonstration were willing to pay 2,013 Vatu (\$17.96) for a filter.

At the start of the research, there was just one supplier selling household water filter options in Vanuatu that addressed bacterial contamination. Now there are at least three. Wilco Hardware has an 8,275 Vatu (\$73.81) ceramic candle filter available in Santo and Port Vila. PSC Limited sells membrane filtration inside individual water bottles for 4,800 Vatu (\$42.82). After the research was completed, the Vanuatu Red Cross Society and Vanuatu Services ENGIE started selling ceramic candle filters for 4,000 Vatu (\$35.68) each in three provincial headquarters.

Community perceptions related to other water treatment options

Several other water treatment options were discussed in the product demonstrations including: community treatment options, solar disinfection (SODIS), cloth filtration, and biosand filtration. Although *Ni-Vanuatu* people are considered communal, preliminary discussions revealed there was limited trust in community level water treatment options and individuals repeatedly stated they preferred household level options. While SODIS has worked in other locations (CDC, 2012), SODIS faced scepticism and community members were unconvinced even after learning that its efficiency was demonstrated globally by WHO. Participants stated that cloth filtration is sometimes promoted by nurses in the islands. While it improves water turbidity, and there some examples of its effective use against cholera, it is usually

ineffective against bacteria and viruses and not encouraged. Most community members were not very interested in the biosand filtration method. They stated it seemed complicated to put in place when compared to some of the other lower maintenance options displayed.

Community operation, maintenance, and gender and gender perceptions

When asked who would oversee the water treatment system operation and maintenance, and allowed to choose multiple options, most people felt it would be the mother who was in charge of the water filtration station at home (75%, 519/689). However, 37% (255/689) of the time the role was considered the father's, 3% (19/689) the children's, and 7% (48/689) everyone's responsibility. Currently, the Government of Vanuatu mandates that village water committees include at least 40% women to be registered. Given this finding, training could go beyond the water committee and ensure women are involved in operation and maintenance training for any household water treatment systems.

Conclusion

The Government of Vanuatu is committed to achieving the SDGs and ensuring 'Safe and affordable drinking water' for all by 2030. The Vanuatu People's Plan aims to, 'Ensure all people have reliable access to safe drinking water'. However, currently in Vanuatu, many households report issues related to water quantity and water quality. The National Implementation Plan for Safe and Secure Water Capital Assistance Program aims to address these issues but needs more options to assist the many households that are consuming bacterially contaminated water.

There is a public health need for safe water. Consumption of poor quality water can cause diarrhoea and waterborne diseases and may contribute to child stunting (Dangour et al., 2013; Lauer et al., 2018; Joseph et al., 2019). The 2013 DHS revealed that 12% of children under the age of 5 years in Vanuatu had diarrhoea within the two weeks prior to the survey. In addition, 29% of children in Vanuatu under the age of 5 years are stunted. In Vanuatu, there is a current practice of boiling water when there is a perceived need, but the practice is not a daily routine in most households. There is little knowledge among many households about other water quality treatment technologies.

This article summarizes research designed to explore how government can best support households to consume safe water. Based on the results of the compilation of water quality results, key informant interviews, WASH sector stakeholder participatory activity, individual surveys, product demonstrations, and government workshops, it is clear different options are appropriate for different settings. In the capital and small towns, chlorine dosing and cost recovery through routine bill collection is working well in some locations and there are plans to improve the system in others. In emergency settings, shock chlorination of rainwater tanks at relocation centres might be most appropriate. For rural and untreated urban household daily use, point of use water treatment seems most promising.

There are some myths and misinformation about water treatment options that may make them harder to promote. Of the options explored in this research, household water filtration systems, sold by the private sector, seemed to be the most viable option. While consumers in Vanuatu stated interest in buying a water filter after exposure to the idea, WASH sector stakeholders and community members underestimated the market cost. Community members indicated a willingness to pay around 2,000 Vatu (\$17.84) per year for point of use water treatment, but the lowest price filter available on the market costs twice that amount. Of the different filtration systems, consumers stated a preference for easy to use, large, and transparent water storage containers. Filters are, however, currently only available on two of Vanuatu's 66 inhabited islands.

There is a need for more sharing of water quality information, correction of misconceptions, and promotion of improved behaviours. This could include raising public awareness on safe water issues, collaborating with private sector actors, adjusting policies and standards, designing large campaigns to spread awareness, improving the DWSSP process to trigger behaviour change, changing social norms, and motivating new habit formation. Further exploration could also be done to see if subsidies or payment plans could be supported by donors or the private sector to ensure consumption of safe drinking water for all households in Vanuatu.

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