'You can't blame people for risky choices if there are no better options': Household water safety in the Dominican Republic

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Introduction

Around a quarter of the population worldwide is reported to lack safely managed drinking water services, meaning inadequate water availability, accessibility and/or quality, according to the WHO/UNICEF Joint Monitoring Programme (JMP), the custodian of global data on water supply, sanitation and hygiene (JMP, 2021). This figure is likely to be an underestimate, however, as it relates to water that is free from contamination. Levels of contamination can differ between a water source and the point of its consumption due to contamination during collection, transport or storage (Shields et al., 2015) and the underreporting of high-risk behaviours (Vedachalam et al., 2017). Microbial contamination of water at the point of use is a dynamic phenomenon, which can be temporally affected by weather and rainfall patterns (Howard et al., 2003; Guo et al., 2019; Dongzagla et al., 2021), intermittent supply and system outages (Kumpel & Nelson, 2016), household water storage (Slavik et al., 2020; Staddon & Brewis, 2024), and the use of high-risk unimproved sources to supplement safer water sources (Cronk et al., 2024). Moreover, as water safety indicators can change as often as daily (Price et al., 2021), contamination levels can vary greatly over time and true levels of microbial contamination may not be captured due to the timing of sampling (Harris et al., 2023).

This uncertainty in assessing water safety is of particular concern for households in low- and middle-income countries (LMICs) that rely on multiple sources of water to fulfil their everyday water needs (Elliot et al., 2017; Daly et al., 2021; Cronk et al., 2024)). When households are forced to rely on water sources not covered by mainstream regulatory systems, the water they use can fall into a regulatory vacuum (Majuru et al., 2016). This places the responsibility of water safety on household members who have to rely on their knowledge and perceptions to ensure water quality is appropriate for its intended use. There are many low-cost technologies available to improve water quality at the point of use or consumption, such as chlorination (Arnold & Colford, 2007), flocculation-disinfection sachets (Crump et al., 2005), filtration and solar disinfection (García-Gil et al., 2021). In places where water supply is unsafe or inconsistent, such options can improve the safety of drinking water, reducing diarrhoeal disease by up to 61% when used consistently and correctly (WHO, 2016). However, these techniques rely on consistent, long-term use for the promised health benefits to be realised (Brown & Clasen, 2012). Intermittent or inconsistent use undermines their effectiveness (Sobsey et al., 2008). Relying on household water treatment to fulfil the goal of universal access to safe water requires long-term, sustained behaviour change, which places an additional burden on people already suffering the cognitive stress of resource scarcity (Ray & Smith, 2021).

This paper presents the findings of a mixed-methods study, which considers household perceptions of water safety in the Dominican Republic and how these influence water storage, treatment and source selection. It uses water quality testing, using *E. coli* as an indicator of water quality, to assess whether these perceptions of water safety are supported by objective evidence of water contamination. We argue that without adequate resources and reliable information, households' safety strategies are not effective to ensure water safety. Faulty perceptions lead to overconfidence in water that is often contaminated by the processor, vendor, or consumer. Household water treatment and storage strategies should not be prioritised over systemic changes to public health communication and access to water services.

The next section presents the context of the case study and the various methods employed. The quantitative data is then presented and analysed in conjunction with data from the household survey to assess the suitability of water quality for its uses. Subsequently, the influences of household storage and treatment on water quality are assessed, and user perceptions and behaviours are analysed alongside the water quality findings. The influences and vested interests of the wider regulatory and commercial context in the Dominican Republic is considered, and the implications of this case study for JMP estimates of water access are discussed. The conclusion summarises why many households have no option but to engage in risky choices.

Methodology

Case study location

This research focusses Malpaez, which is located in the municipality of San Gregorio de Nigua, 25 km west of the capital of Santo Domingo. Malpaez was selected as the case study location because of the variety of water sources used by its residents, its relative proximity to Santo Domingo, and the interest of its community leaders in the project. The research was undertaken in partnership with the Dominican country office of Habitat for Humanity, building on their existing relationships with communities.[1] Malpaez consists of three communities: one, also called Malpaez, has approximately 250 houses; Los Caguiles which also has around 250

[1] The study design and tools were approved by Loughborough University Ethics Review Sub-Committee (ref 2023-13507-12754 and 2022-11010-11451

houses; and La Canela with approximately 200 houses. All three communities experienced an intermittent and often unreliable water supply and employed a variety of coping strategies to meet their water needs. These strategies included use of multiple water sources, household water storage and treatment, and collaborative social coping strategies (Brown et al., 2024). The most common water sources included rural piped water systems, water tankers, and rainwater harvesting.

As in most of the Dominican Republic, households also purchase drinking water separately from water for other uses. This water is usually treated by reverse osmosis (RO), which is a water treatment technology that uses hydrostatic pressure to push water, against the osmotic gradient, through a polymer membrane with a layered, web-like structure, filtering out even the smallest contaminants which are retained and concentrated on the influent surface of the membrane (Greenlee et al., 2009). RO is traditionally associated with desalination of seawater for potable use, but in the Dominican Republic most of the water intended for drinking is municipal piped water or groundwater that has been treated by RO, for which distinct technology has been developed. This water is usually purchased in 20l bottles from local vendors or directly from the production facility, with the plastic bottles being returned and refilled by the producer. Many households also purchase RO-treated water from small water tankers, which are referred to here as ‘RO water tankers’. To avoid confusion, the large tankers which provide water for general domestic use are referred to as ‘domestic water tankers’ to differentiate them from the smaller RO water tankers.

Methods

A household survey was conducted between February and March, 2023. A sample size of 200 households was calculated a sample of the approximately 700 households in the study communities, which provides a confidence level of 90% that the real value is within ±5% of the measured/surveyed value. As there was greater diversity of water sources in Malpaez, compared to the relative homogeneity of water access in La Canela and Los Caguiles, the sample was adjusted proportionally so that the variety of household experiences could be captured. Therefore, half of participating households were resident in Malpaez and 50 in each of La Canela and Los Caguiles. To select participating households in Malpaez and Los Caguiles, every fourth house was approached, beginning with the western boundary of the community and walking in a straight line. Permanently empty houses were disregarded. If a household was unavailable, they were approached twice more, at least once on a weekend or in the evening, before being substituted by the house to the left. Since La Canela has fewer households, every third house was contacted. The first author conducted the surveys in Spanish, accompanied by a trusted member of each community. The survey data were collected using the Kobo Toolbox app and analysed using R-studio (version 4.3.2).

In addition to the survey, 10 semi-structured interviews lasting 30-60 minutes were conducted with community residents between November 2022 and March 3023. Interview respondents were selected using a snowball sampling method, ensuring that respondents were selected from a wide range of locations within the communities, relied on a range of water sources, and represented different income brackets. Key informant interviews were held with the national water utility, *Instituto Nacional de Agua Potable y Alcantarillados* (INAPA), and the government environmental health department; these interviews lasted between 60 and 90 minutes. All interviews were conducted in Spanish and recorded on a Dictaphone, with verbal informed consent recorded before initiating the interview. The recordings were transcribed using an automatic transcription service and then edited first by two local interns familiar with the local dialect and accent, followed by a final edit by the interviewer. The interviewees' names were pseudonymised before transcripts were thematically analysed in Spanish using NVIVO 20. The topic guides for these interviews were formulated based on the finding from a period of formative research in the community. During this period the first author stayed for six nights in the home of a community leader in Malpaez, which enabled her to visit and participate in informal discussions, observe and participate in daily activities, and build constructive relationships with the study communities. One focus group discussion, lasting 45 minutes, was held with seven female residents from Malpaez which also contributed to the formative part of this study.

In April 2024, water samples were taken from households that participated in the survey to be analysed for the four 'critical parameters': *E. coli*, chlorine, turbidity and pH (WHO, 2022), though pH measurements were discontinued due to technical problems with the probe. A fifth parameter, Total Dissolved Solids (TDS), was also considered integral to this study, since RO treatment relates to the removal of dissolved solids. A minimum of 12 samples for each of the four principal water sources - reverse osmosis (RO) water tankers, 20l bottles, piped network, and domestic water tankers - was the target. To achieve this, a proportional sample of surveyed households was selected, and then adjusted to ensure that these water sources were represented. In total, 80 water samples were collected from 37 households. Households were asked to confirm the intended purposes for each water source and a photograph was taken to facilitate discussion about the impact of water storage or retrieval practices on the results. All available water sources in each household were tested. In four households, two piped water samples were taken because the households stored water differently according to the intended use. In one household, samples were taken from the cistern and the water flowing from the pipe that was filling it to test whether there was a difference in contamination levels between the water as it arrived to the household and the water stored in the cistern. In another household, samples were taken from two barrels; one of the barrels had been refilled from empty that morning, and the other had been half-full of water stored for more than a day before refilling.

Eleven more samples were collected directly from water tankers, bottles purchased directly from a local vendor, or water from these sources which had been decanted into empty bottles that a household habitually used. These samples were processed in the same way as the household samples, except for an opportunistic sample from an RO water tanker at the side of the road where it was not possible to ensure the required conditions for microbiological testing. To validate the method, nine samples were repeated by the INAPA's water quality laboratory following their sampling guidelines. These samples were taken at the same time and place as their counterparts and stored in a cool bag. They were delivered to the lab within three hours of sampling and analysed the same day.

Turbidity was measured using a Hach meter 2100p. Electrical conductivity and temperature readings were taken using the Hanna Instruments 98129 probe, which displays the derived estimate of Total Dissolved Solids (TDS). The sample was tested for residual and total chlorine using diethyl-p-phenylene diamine (DPD) reagent tablets and a colour comparator. If residual chlorine was not detected, a further sample was taken for microbiological testing, which was processed onsite and incubated at a temperature of 25-30° C for 48 hours using Aquagenx's compartment bag test (CBT) kits that provide a Most Probable Number (MPN) of *E. coli* per 100ml (Stauber et al., 2014).

E. coli count is the most common indicator of potential faecal contamination. While no *E. coli* is a good indicator of the absence of other pathogens in untreated water, the same is not necessarily true of treated water, where bacteria may be successfully eliminated more readily than other pathogens (Charles et al., 2020). The *E. coli* results were interpreted according to the Aquagenx Most Probable Number Table for Drinking-Water, which identifies the MPN and upper 95% confidence level per 100ml of water (reproduced in (JMP, 2022).

Insert Table 1 here

The Aquagenx categories are used to discuss the results of the water testing. 'Safe' indicates that *E. coli* was not detected in the sample, or was detected at a MPN of less than 1/100ml, and is therefore likely to be free of associated disease-causing bacteria. Values between 1-3.2 MPN/100ml and 3.7 MPN/100ml are categorised as 'probably safe', 3.1-9.6 MPN/100ml as 'possibly safe', 13.6 and 17.1 MPN/100ml as 'possibly unsafe', 32.6 and 48.3 MPN/100ml and 'probably unsafe', and >100 MPN/100ml as 'unsafe'. The highest value detectable by the CBT is >100 MPN/100ml. These risk categories are used throughout the paper to discuss the CBT results.

A laboratory evaluation of the Aquagenx CBT EC+TC MPN Kit by the JMP found that, with incubation at 25˚ C, in 73% of paired samples the semi-quantitative risk class matched the expected value. Using a presence-absence test, the kit correctly identified the presence or absence of E. coli in 90% of cases with a threshold of 1 CFU/100 mL (JMP, 2022). This method was selected for its ease of use in the field and its semi-quantitative risk categories, which suited the approach of this study.

Results and Discussion

This section presents and discusses the findings of the study. It first summarises the results of the water quality testing, breaking down the results by source, intended use, and the implications of household storage on water safety. Household perceptions of drinking-water safety, and the ways households evaluate whether water is suitable to drink are discussed, followed by the factors that influence households' engagement in risky practices, and the contextual influences on their perceptions and knowledge of water safety.

E. coli testing results

Table 3 presents the test results of the 80 household water samples. Since very few samples contained residual chlorine, the recorded values of turbidity, which influences the effectiveness of chlorination, are shown for completeness but not discussed. Residual chlorine was detected in five samples, one was lost in transit, hence 74 were tested for *E. coli*. Of these, 42 tested positive for *E. coli* with 21 showing the highest possible result of 100+ MPN/100ml ('unsafe'). Samples taken from all water sources tested positive for *E. coli* which suggests that the safety of all sources was inconsistent, and therefore none present a reliable option for safe water at point of use.

Insert Table 2 around here

Of the 80 household samples, 48 were from water used for drinking or cooking. Of these, 32 were samples taken from 20l bottles and RO tankers. Of the 37 households sampled, 21 used the same water source for cooking and drinking; the remainder used used piped water (9), water tankers (2), rain (3), piped water and rainwater (1), and a different brand of 20l bottles (1) for cooking, in addition to using 20l bottles or RO tankers for drinking (see table 2).

Insert Table 3 around here

Around two-thirds (64%) of samples used for drinking and cooking were ‘safe’ (>1 MPN/100ml). The remaining 36% tested positive for E. coli, with a third of these testing positive for a high concentration (>100 MPN/100ml) indicating ‘unsafe’ water. Contrary to perceptions that the RO water tankers are less safe than sealed bottles, the RO water tankers had the highest proportion of ‘safe’ samples (>1 MPN/100ml) at 76%, compared to 56% of sealed 20l RO bottles. There were lower proportions of ‘safe’ water from domestic water tankers (53%), pipes (13%), and harvested rainwater (29%), which is to be expected from water sources not intended for drinking. Overall, water intended for cooking had a higher proportion of ‘unsafe’ water (26%) than water for drinking (10%), although it did present less E. coli contamination than water intended for other uses, as shown in Figure 1.

Insert Figure 1 around here

Household water storage

All households in the study communities use water storage to cope with the intermittent water supply. Interviews and surveys showed that households appeared to understand the importance of cleaning storage containers regularly and covering stored water, and were vigilant about these practices for water intended for cooking. However, household members were observed touching water with their hands when retrieving it from barrels, using vessels without handles to scoop water, and using the same vessels to drink and scoop water. These practices have been shown to contribute to contamination of household water in the home between the point of delivery and the point of use (Clasen & Bastable, 2003; Usman et al., 2018; Staddon & Brewis, 2024). Additionally, some studies show that long-term storage leads to loss of disinfectant residual due to insufficient mixing, periods of stagnation and temperature changes, which increase microbial growth, particularly if water is stored for multiple days (Baker et al., 2013; Nnaji et al., 2019; Slavik et al., 2020).

These previous findings appear to be confirmed by testing that showed how water that has been stored by households is more contaminated than water they take directly from the piped network. For example, a sample from a container that contained a mix of old and freshly stored water had a higher concentration of *E. coli* (<100 MPN/100ml, ‘unsafe’) than water in a barrel that was empty before refilling (2 MPN/100ml, ‘probably safe’). Another house had an underground cistern; the water flowing from the pipe was ‘probably safe’ (3.2 MPN/100ml), while the water in the cistern it was filling was ‘unsafe’ (<100 MPN/100ml).

To further investigate the potential impact of storage on water quality, multiple samples were taken from four households: one from the container used to store water for cooking, and one from a container that was used for other domestic uses but not for cooking. Table 4 shows the results of these tests. Water for personal hygiene and household cleanliness was stored outside and considered unsuitable to cook with. In each case, water for cooking had a higher concentration of *E. coli* than water stored outdoors. This is concerning because this risky water is consumed by households in salads, cooked foods, and when brushing teeth. This surprising result is possibly due to water stored inside being used more often, hence experiencing more frequent encounters with hands and contaminated retrieval vessels.

The results from these four households are consistent with the wider sample of piped water sources. Of the samples of water from pipes, domestic water tankers and rainwater, 37% were from water containers that households used to store water for cooking. These samples were more contaminated than those from the same sources that were intended for other household purposes. This indicates that safe storage practices cannot always be relied on to protect against contamination and waterborne diseases. If these techniques are practised incompletely, inconsistently, or without understanding what they are protecting against, they may even exacerbate the risks they are intended to mitigate.

Insert Table 4 around here

Household water treatment

Household water treatment techniques, such as chlorination, are often proposed as solutions to the risk presented by water storage. Chlorination was the only treatment option reported by the households in the study communities: 85% reported using chlorine, none reported using filters or boiling their water. To be effective, ongoing chlorination of stagnant or stored water is important to prevent growth of microorganisms. The use of chlorine as a healthy practice appears to be a common understanding in the study communities; 85% of households reported chlorinating at least one of their storage containers, and all households put chlorine in water that is used for cooking from the piped network or domestic water tankers. This was most commonly in the form of household bleach purchased from supermarkets, which is a sodium hypochlorite solution. Households reported adding one teaspoon (15ml) to a 208l barrel.

While standard doses are easy to promote in public health messaging, the effective dose changes according to the physio-chemical and microbial quality of the water (Nielsen et al., 2022). Official guidance disseminated by the *Secretaria de Estado de Salud Pública y Asistencia Social* (SESPAS), the government's public health department, followed the Organisation of American States recommended dose of five drops of bleach per gallon of water, and that the treated water should be left for 30 minutes before drinking (OAS & SESPAS, 2010). Residual chlorine testing is not a common practice in the study communities, so households have no means of assessing whether the dose is correct. Although chlorination may be perceived as a desirable behaviour, households lack sufficient information about correct dosages or sufficient motivation for continual implementation. Consequently, even if chlorination is practised consistently, it may have unreliable effects.

Attrition and inconsistent usage of household water treatment techniques, such as chlorine, are well-documented problems with household water treatment interventions (Crider et al., 2023). Compliance with best practice tends to reduce over time because people overestimate the safety of their water (Orgill et al., 2013). Moreover, households bear the cost of disinfection products so may be unwilling or unable to buy chlorine, particularly if they are unconvinced of the need for or the effectiveness of the practice. Relying on techniques, such as chlorination, to respond to chronic shortages or insufficient water access is not an effective way to ensure positive public health outcomes and may limit their effectiveness if needed in an acute crisis. As the Dominican Republic is vulnerable to hurricanes, earthquakes and serious flooding events (GFDRR, 2022), the limited effectiveness of measures to ensure water safety in such crises presents a risk to the country's resilience.

Perceptions of quality

All surveyed households purchased drinking water separately to their domestic water, either in sealed 20l bottles (52%) or from an RO water tanker (46%). Other sources included refilling their own bottles from the treatment plant, buying bottled water cooperatively with neighbours, or family members purchasing water for them. Just under half (46%) of respondents had a specific brand or provider that they preferred. Around one-third (34%) of these cited concerns that other sources would make them sick and mentioned previous experience as a factor in their decision making. They indicated that they avoid a brand if it has made them sick previously and stay loyal to one if they have drunk it for a long time without getting sick. A further 12% said that the method of treatment was the most important factor in assessing whether water was of good enough quality to drink, with specific responses including purification, filtration, membrane osmosis and RO. For one in 10 households, convenience was the primary factor in their decisions when selecting a water provider, whether it was a convenient delivery schedule, convenience of access, or proximity. A common comment from households that used RO water tankers related to the hygiene or trustworthiness of the vendors. The hygiene and cleanliness of the hoses, general personal hygiene of the vendor, and their moral character were factors influencing which RO tankers households chose to buy from.

The most common reason respondents gave for their choice of drinking-water was taste, with 37% describing it as the primary consideration. This was highlighted by Claudia, a teacher from La Canela who buys drinking water from RO water tankers:

> The water from the pipe isn't fresh. The only drinkable water comes in the small tankers … There is one [RO water tanker] that has lighter, better water than the others. Sometimes when you drink water it feels heavy … it feels like it is out of the tap and the tap is metallic. But when you buy a good one, it goes down well.

In Claudia's account, there is an association between the hardness or softness of water and its quality, which is used to determine whether water is safe to drink. Many interviewees used the word 'heavy' to depict water they would not trust to drink, and described good quality water as 'smooth', 'fresh', 'natural' or 'light'. Iris, a domestic worker from Malpaez, recounted how inconsistent her experiences of buying drinking-water from RO tankers are: 'It will taste fresh one day, then another it's so heavy you can't drink it and I have to throw it out.' When an RO tanker came to community leader Amalia's home during her interview, she introduced the vendor saying: 'I trust him. Jorge knows if he brings me bad water, we will have problems.' She explained that she only buys from this vendor, as she suspects others fill their tankers up from taps. Speculation about this type of practice was common. Marianela, a seamstress who worked from her home in Malpaez, explained: 'A guy used to pass in the mornings [but] I stopped buying from him. I thought the water was good because the tanker said [Brand Name] on it, but someone told me he fills it from his cistern at home'. A local mechanic from Los Caguiles stated that he had seen an RO tanker being filled from the river. The validity of these claims is unknown, but it affects water purchasing practices.

The descriptors associated with water quality appear to align with the physical qualities of RO water, which would be expected to have low total dissolved solids and electrical conductivity. These are measures of the dissolved ions present in the water, with higher values indicating water that consumers might describe as 'heavy' or with high salinity. As Table 1 shows, the piped water networks and tankers have much higher electrical conductivity and total dissolved solid values than the RO water sources. This difference would be perceptible by tasting, which makes distinguishing RO water from other types of water relatively simple. It is likely that consumers' evaluation of the 'heavy' or 'smooth' water is related to higher or lower total dissolved solids, which reassures them that the water they are drinking is actually RO water. Associations between taste and safety may arise from lack of trust in the regulation of water vendors. A sample taken from an RO tanker that advertised itself as a provider of drinking water had an electrical conductivity measurement of 1822 μS/cm and total dissolved solids of 904 ppm. These results are inconsistent with RO water, which had maximum values of 98 μS/cm and 51 ppm (see Table 1). While this is only one sample, hence not representative of all water providers, it indicates there is at least one RO tanker regularly servicing the case study area which sells water that is not treated in the way advertised to consumers.

Associating the taste of RO water with quality is a rational choice for consumers given the unreliable information and lack of confidence in regulatory standards. The drinking water supply network of 12 national companies and 180 local vendors (Severino, 2022) presents enormous logistical challenges for regular testing and enforcement, hence regulatory standards are not universally enforced (MAPAS-RD, 2016). Gloria, a single mother from Los Caguiles, indicated that she knew water was safe if it was RO-treated. She said that while the *Instituto Domincana de Calidad* (INDOCAL), issues water providers with a seal that approves their treatment process, some companies falsify the seal, so its presence is a less reliable measure of quality than the water's taste and appearance. However, this association between taste and safety may lead consumers to drink unsafe water, which is supported by the water sampling undertaken. The safety of RO water is inconsistent, with 36% of samples testing positive for *E. coli* at a level above the national standard for drinking water of 1 MPN/100ml.

The unreliability of drinking-water safety is reflected nationally. A study of microbial contamination in similar communities in Puerto Plata, Dominican Republic found that only 2% of bottled water samples presented little to no risk, while 35% displayed high or very high risk. Despite this, bottled water was still perceived as the safest to drink (Baum et al., 2014). Preliminary results released by the Institute of Microbiology and Parasitology at the Universidad Autónoma de Santo Domingo show that 30% of water samples sold in 0.5l sealed bottles (16 oz.) failed to comply with at least one of the microbiological indicators of the national standards for water quality NORDOM 1 (El Nuevo Diario, 2019). Water that meets consumers' taste expectations can lead to overconfidence in the safety of the water being drunk. After the 2010 earthquake in neighbouring Haiti and ensuing cholera outbreak, the Dominican Republic experienced isolated outbreaks of cholera. During this time, reliance on bottled water may have reduced the perceived need for additional hygiene measures, increasing the risk of transmission (McLennan, 2016).

While point-of-use technologies, such as chlorination or home filtration, might improve water safety, effective implementation of these practices would require households to undergo intensive perception and behaviour change. Interviews and surveys demonstrated that there is a strong association between taste and the perception of quality and safety, and the taste of chlorine was associated with poor quality water, rather than with safety. Therefore, disinfection practices may appear to consumers as indicators of poor quality. For example, one survey respondent had tried many brands of drinking-water, claiming that their chosen brand tastes 'natural' but 'many of the others taste of chlorine'. This suggests the taste of chlorine is considered 'unnatural' and, therefore, unsuitable to drink.

Influences on behaviour

The economics of water access leads many people into risky strategies. The deposit for 20l bottles ranges from RD$240 to RD$600 (USD $4-10), compared with the cost of water, which is RD$35-90. The high cost of the deposit disincentivises households from having adequate storage for their needs. In addition, the bottles are the same shape as those commonly used for water dispensers, which is awkward with no handles. As full bottle of water weighs 20kg, they are difficult to carry and pour from. For some households, this is a barrier to storing enough drinking-water in the home to meet their needs. For example, Maria Carmen, an elderly resident of Malpaez who lives alone, used two different brands of 20l bottles to drink and to cook. She relied on a neighbour's support to refill her bottles in town because she could not travel or lift the bottles. Needing to take advantage of the neighbour's availability, she always asked him to decant a bottle into a bucket and take it for refilling, even if it was nearly full. At the time of sampling, Bottle A (used for drinking) was decanted into a 25l plastic bucket, while Bottle B (used for cooking) was in its original container. Bottle A (sampled from the bucket) had an *E. coli* concentration of >100 MPN/100ml ('unsafe'), while Bottle B was 'safe' (0 MPN/100ml). This is an example of a person's vulnerabilities (age and lack of mobility) compounding their experience of water insecurity, increasing their overall vulnerability. As others have also found, residents with disabilities and mobility limitations experience worse water access (Mactaggart et al., 2018) and elevated risks from the strategies they employ to manage their limitations (Groce et al., 2011).

The ergonomics and economics of the bottles prompted other households to employ convenience measures. Of the 14 households that bought sealed 20l RO bottles, four decanted them into other containers for ease of use or because of the bottle deposit cost. Three households had a mechanical pump tap instead of a lid on the bottle; two of these had an *E. coli* concentration of >100 MPN/100ml. The high levels of contamination in these samples are partly due to the use of the devices without appropriate sterilisation. The pump and tubing are difficult to clean; bacteria from contaminated water can accumulate inside and contaminate other bottles when the pump is transferred. Other solutions included having small bowls or basins of water in the kitchen for easy access while cooking, or storing bottles on the floor to avoid the need for lifting. Both provide opportunities for contamination.

However, the most influential factor on households' risky behaviour is inconsistent or insufficient access to water. Prohibitive costs motivate households to choose cheaper or unregistered water providers, even if the quality is less reliable. Households store water for prolonged periods of time because of the intermittent supply. This is a rational reaction to ensure there is enough water on hand, even if it means water is stored for longer than is considered safe. Households experience a high user burden, especially those with higher levels of water insecurity, who focus on the tangible water requirements to keep daily life running smoothly, such as laundry, cooking, bathing and drinking, rather than on the less tangible risk of microbial contamination. This is especially the case if there are few reliable sources of information or strategies to evaluate water safety. A representative from SESPAS noted that increasing access was the first step in improving household water quality: ‘You can’t blame people for risky choices’, she said, ‘if there are no better options available to them.’

Public health information and private interest marketing

Bottled and RO water in the Dominican Republic are supplied by several multinational, national and local private companies. These companies require certification from the institute of quality, the *Instituto Domincana de Calidad* (INDOCAL), to prove that they comply with NORDOM 64, the regulation for packaged drinking water. Consumers in the Dominican Republic are increasingly reliant on the private sector to supply their drinking water. This is partly attributed to declining confidence in municipal water supplies; pipes are old and in poor repair, so even if the disinfection and treatment process is operating at the treatment plant, contamination can easily enter the distribution network. Public confidence has been lost ‘little by little’ according to Alba, the manager responsible for domestic water quality at the *Secretaria se Salud Publica y Assistencia Social* (SESPAS).

Private water companies and their associated lobbying groups have also engaged in promotion and advertising. During informal conversations, a television campaign was often mentioned when introducing the topic of water safety. Although the campaign could no longer be traced from online sources, it was consistently considered influential. The campaign reportedly featured a young child who was gravely ill in bed, with his mother crying and wishing she had bought bottled water instead of using piped water. Alba described the context of the video:

> There was a campaign called: “Why did I give you that water?”… It plays on the maternal instinct, which is always to protect the child … And when the sales fall, they return to those campaigns to create a need for people to feel safe.

There were multiple videos with a similar theme, some promoting sealed bottled water over RO water tankers, and some undermining confidence in tap water. Several people recalled the videos from when they were children, explaining how it caused their parents to change from using water tankers to sealed 20l bottles. Such campaigns, delivered in the interests of commercial water bottling companies, appear to have played a pivotal role in shaping consumers' perceptions of what water is safe to drink.

This type of private interest communication has also had a legislative effect. Alba explained that private water companies lobbied against the introduction of water quality guidelines. When that failed, they did not want the word 'potable' associated with tap water: 'They were clear that this was the way they were going to be able to sell'. There are two sets of national water quality guidelines. NORDOM1 is the set of parameters for 'potable water', and NORDOM 64 refers to 'packaged water'. Water for human consumption must comply with NORDOM 64. Consequently, the word 'potable' is culturally disassociated from drinkability and is generally understood to refer to domestic water that is not drunk.

JMP indicators of water access

Households' lack of capacity to ensure water quality is reflected in the national Joint Monitoring Program (JMP) statistics on water quality. To be classified as 'safely managed', water must be from an improved source, accessible on the premises, available when needed, and free from contamination. Official JMP statistics show the coverage of 'safely managed' drinking water services in the Dominican Republic as 45%. If water is from an improved source but one of these criteria are not met, they are categorised as 'basic' services. The Dominican Republic has a further 52% 'basic' service coverage. The main reason for services being downgraded to 'basic' appears to be the 'free from contamination criteria', which is at 45% nationally compared to 96% and 90% for the accessibility and availability criteria respectively (JMP, 2023).

According to the 2022 census, the water sources used in the study communities are similar to those used in other rural communities in the same region and nationwide (ONE, 2022). The JMP states that the Dominican Republic has 35% rural coverage of safely managed water services, and a further 57% of basic service coverage. Based on these statistics, an approximately equivalent proportion of households with safely managed drinking water services would be expected in the study communities. Sampled households were evaluated using the criteria of availability, accessibility, and safety in relation to the water sources they used for drinking. Of these, 52% qualified as safely managed, however, as previously discussed, the JMP drinking water services refer to the water households use for 'drinking, cooking, personal hygiene and other domestic uses' (JMP, 2017). Consequently, the water households use for drinking and cooking should both be free from contamination. Due to the higher levels of *E. coli* detected in water intended for cooking, only 20% of household water would qualify as safely managed under this definition.

The issue of reliability complicates the assessment of availability. In the study communities, 23 piped households (11.5%) received water every day, but of these 15 received water for less than three hours a day. Despite efforts to define reliability indicators (Mokssit et al., 2018; Meyer et al., 2023), there are no widely accepted thresholds for availability. Therefore, these estimates assume water is available when needed as it was present in the home at the time of sampling. The 20% estimate of safely managed water in the study communities is probably too high due to availability being overestimated. This illustrates how using the JMP water services ladder can overestimate access to water due to multiple sources and intermittent services. This is not a phenomenon that is unique to the study communities or to the Dominican Republic. An estimated 1 billion people globally experience intermittent water supply, although this may be an underestimate as experiences and degrees of intermittency can vary greatly (Bivins et al., 2017). Intermittent water supply causes inconvenience to consumers and requires high coping costs to mitigate its effects (Vairavamoorthy et al., 2007; Erickson et al., 2020). When interruption to water supply is predictable, the negative impacts are reduced, although this reduction becomes less pronounced the more frequently a household experiences interruptions (Thomson et al., 2024). Reliability is not a specific key objective of the UN Sustainable Development Goal 6 for water and sanitation (UN, 2015), and the JMP indicator of 'available when needed' does not capture experiences of unreliability. Consequently, reliability is an 'underutilised or missing metric', which has consequences for the accuracy of assessing the availability of water services for communities around the world that have intermittent access to water supplies (Galaitsi et al., 2016:14).

Drinking water services are the primary source of water households use to drink, cook, for personal hygiene and for other domestic uses. Nationally, the most common reported drinking water source in the JMP MICS survey (2019) was bottled water, by 79% of consumers. A further 8% used water from processed tankers, indicating that these consumers purchased water to drink from RO tankers. This is supplemented by water for other domestic uses; a 2021 survey by the Dominican Office of National Statistics, which excludes bottled water, estimates piped water coverage at 81%. Although there is the functionality to record a secondary water source in the JMP methodology, it is not easily available nor communicated in the high-level results. The multiplicity of household water needs, and the sources they use to meet them, create gaps in monitoring capability and knowledge (Daly et al., 2021), reinforcing the view that there is a primary source of water that can meet all needs. This assumption undermines understandings of what water access is and how successful the aim of achieving widespread access has been. A narrow focus on water for drinking has led to an overinflated sense of progress (Crow & Goff, 2014) and has propagated the conceptualisation of water access as a means for survival, rather than promoting equity and wellbeing (Gimelli et al., 2017; Jepsen et al., 2017).

Conclusions

Households in Malpaez employ multiple strategies in their attempts to ensure that the quality of water is appropriate for its use. In the case of water for drinking, the most prevalent strategy is to purchase RO-treated water from a trusted source and be vigilant to changes in taste that indicate the water is not RO-treated. In the case of water for other uses, households procure and store water in the way they perceive to be most appropriate for the intended use. These strategies, however, do not eliminate the danger of contamination.

The fact that households do not have access to consistent and reliable water means that their ability to ensure the water they use is safe is compromised. Intermittent water systems require water to be stored for several days, which increases the risk of contamination from within the home. The high cost of drinking-water and bottle deposits prompt households to reduce these costs by storing water in alternative containers, or buying from cheaper, less reliable suppliers. Safe storage techniques and household water treatment are thus undermined by inconsistent application. In the absence of robust regulation, consumers are left relying on their own perceptions of water safety to select appropriate water sources. These perceptions, which are influenced by political and cultural lobbying on behalf of commercial bottled water providers, lead to overconfidence in water that may be contaminated by the processor, vendor, or consumer. Household safety strategies increase the risk of illness if they introduce opportunities for contamination and reduce the perceived need for other strategies, such as chlorination and adequate hygiene practices. Improved household water treatment and safe storage education may be a low-cost, rapidly deployed solution to some of the water safety risks to health, however, cannot be relied upon to produce long-term improvements. Implementing household water treatment and safe storage strategies consistently requires considerable effort from households, who already experience a high user burden in obtaining the water they need. They are effective in the contexts and environments for which they are intended, and can provide a rapid, low-cost solution for acute system failures or shortages, but cannot be relied on to resolve chronic system failures.

The responsibility for ensuring water safety at the point of consumption is delegated to households in the Dominican Republic. However, the available information and resources do not facilitate effective evaluation and decision-making. Households do not have the equipment, knowledge or capacity to assess the safety of their water, and even if they did there are few reliable options available to them to improve it. Confidence in regulatory structures is low and, as this study shows, lack of confidence is justified. Without adequate regulation and enforcement, households have no way of knowing which water sources are trustworthy. This lack of trust creates an information vacuum; when this vacuum is filled by information that serves private interests, it hampers the effective dissemination of effective public health information. This paper has shown that public health communication needs to improve to ensure consumers are adequately informed and equipped to avoid health risks associated with contaminated water. However, interventions focusing solely on public health communication and influencing consumer behaviour will be ineffective at improving public health outcomes if the systemic causes of misinformation and lack of information are not addressed. Efforts must be focused on expanding access to water services, so households can meet their needs without relying on mitigating strategies. A robust system of regulation that responds to the ways in which suppliers deliver and consumers procure water must be established and enforced. Only then can consumer confidence in public water services, regulatory structures and public health information be rebuilt and household water insecurity reduced.

This paper has also shown that the indicators used to evaluate water access can lead to overestimates of safely managed drinking water services coverage, due to underestimates of contamination in water, a lack of acknowledgment of multiple source use, or a lack of emphasis on reliability when assessing the availability of water services. Systematic failures were identified in how water safety and access are monitored, which are not unique to these communities. An estimated 1 billion people globally experience intermittent water supply (Bivins et al., 2017) and are at greater risk of water-borne disease, as water can be contaminated in the distribution network (Kumpel & Nelson, 2013; Ercumen et al., 2014; Guragai et al., 2017) or through storage techniques (Staddon & Brewis, 2024). It has been shown worldwide that household water treatment options are too inconvenient, not effective enough, or too costly for households to be able to rely on fully to ensure their water safety (Chaúque et al., 2023). There are also many voices claiming that JMP statistics underestimate the scale of deficiencies in water service provision worldwide (Wutich et al., 2017; Yu et al., 2016; Weststrate et al., 2019). Contextual knowledge at a range of scales, from neighbourhood to city to country, illustrates that statistics provide a false or incomplete picture of the realities of water access (Satterthwaite, 2003). Such statistics lead to an overinflated impression of the adequacy of water services. The perceived lack of urgency for action and investment in water provision (Crow & Goff, 2014; Galaitsi et al., 2016), as this paper has highlighted, results in many households having no option but to engage in risky choices.

References

1. Achore M, Bisung E, Kuusaana ED. Coping with water insecurity at the household level: A synthesis of qualitative evidence. *Int J Hyg Environ Health*. 2020;230:113598. doi:10.1016/j.ijheh.2020.113598.

2. Aguilera B, Carracedo S, Saenz C. Research ethics systems in Latin America and the Caribbean: a systemic assessment using indicators. *Lancet Glob Health*. 2022;10(8):e1204-e1208.

3. Arnold BF, Colford JM. Treating water with chlorine at point-of-use to improve water quality and reduce child diarrhoea in developing countries: A systematic review and meta-analysis. *Am J Trop Med Hyg*. 2007;76(2):354-364.

4. Baker KK, et al. Quality of piped and stored water in households with children under five years of age enrolled in the Mali site of the Global Enteric Multi-Center Study (GEMS). *Am J Trop Med Hyg*. 2013;89(2):214-222.

5. Baum R, et al. Assessing the microbial quality of improved drinking water sources: Results. *Am J Trop Med Hyg*. 2014;90(1):121–123. doi:10.4269/ajtmh.13-0380.

6. Berhanu L, et al. Effect of microbial quality of washing water on hand hygiene status of food handlers in Jimma Town: Implications for food hygiene and safety. *J Multidiscip Healthc*. 2021;14:1129-1134. doi:10.2147/JMDH.S306359.

7. Brick T, et al. Water contamination in urban south India: household storage practices and their implications for water safety and enteric infections. *Int J Hyg Environ Health*. 2004;207(5):473-480. doi:10.1078/1438-4639-00318.

8. Brown J, Clasen T. High adherence is necessary to realize health gains from water quality interventions. *PLoS One*. 2012;7(5):e36735. doi:10.1371/journal.pone.0036735.

9. Charles KJ, Nowicki S, Bartram JK. A framework for monitoring the safety of water services: from measurements to security. *NPJ Clean Water*. 2020;3:36. doi:10.1038/s41545-020-00083-1.

10. Clasen TF, Bastable A. Faecal contamination of drinking water during collection and household storage: the need to extend protection to the point of use. *J Water Health*. 2003;1(3):109-114. doi:10.2166/wh.2003.0013.

11. Crider YS, et al. Adoption of point-of-use chlorination for household drinking water treatment: a systematic review. *Environ Health Perspect*. 2023;131(1). doi:10.1289/EHP10839.

12. Crow B, Goff M. What is water equity? The unfortunate consequences of a global focus on 'drinking water'. *Water Int*. 2014;39(2).

13. Crump JA, et al. Household-based treatment of drinking water with flocculant-disinfectant for preventing diarrhoea in areas with turbid source water in rural western Kenya: cluster randomised controlled trial. *BMJ*. 2005;331:478. doi:10.1136/bmj.38512.618681.E0.

14. Daly SW, et al. Multiple water source use in low- and middle-income countries: a systematic review. *J Water Health*. 2021;19(3):370-392. doi:10.2166/wh.2021.205.

15. Doria MF, Pidgeon N, Hunter PR. Perceptions of drinking water quality and risk and its effect on behaviour: a cross-national study. *Sci Total Environ*. 2009;407(21):5455-5464. doi:10.1016/j.scitotenv.2009.06.031.

16. Dupont D, Adamowicz WL, Krupnick A. Differences in water consumption choices in Canada: the role of socio-demographics, experiences, and perceptions of health risks. *J Water Health*. 2010;8(4):671-686. doi:10.2166/wh.2010.143.

17. El Nuevo Diario. Estudio de la UASD establece 30 % de agua embotellada no está apta para consumo. *El Nuevo Diario*. 2019 May 22. Available from: https://elnuevodiario.com.do/estudio-de-la-uasd-establece-30-de-agua-embotellada-no-esta-apta-para-consumo/. Accessed 19 May 2024.

18. Elliot M, et al. Multiple household water sources and their use in remote communities with evidence from Pacific Island countries. *Water Resour Res*. 2017;53:9106-9117. doi:10.1002/2017WR021047.

19. García-Gil Á, et al. Solar water disinfection to produce safe drinking water: a review of parameters, enhancements, and modelling approaches to make SODIS faster and safer. *Molecules*. 2021;26(11):3431. doi:10.3390/molecules26113431.

20. Global Facility for Disaster Risk and Recovery (GFDRR). République Dominicaine. *GFDRR*. 2022. Available from: https://www.gfdrr.org/fr/republique-dominicaine. Accessed 16 July 2024.

21. Gorelick MH, et al. Perceptions about water and increased use of bottled water in minority children. *Arch Pediatr Adolesc Med*. 2011;165(10). doi:10.1001/archpediatrics.2011.83.

22. Groce N, et al. Water and sanitation issues for persons with disabilities in low- and middle-income countries: a literature review and discussion of implications for global health and international development. *J Water Health*. 2011;9(4):617-627. doi:10.2166/wh.2011.198.

23. Harris AR, Davis J, Boehm AB. Mechanisms of post-supply contamination of drinking water in Bagamoyo, Tanzania. *J Water Health*. 2013;11(3):543-554. doi:10.2166/wh.2013.023.

24. JMP. Progress on household drinking water, sanitation and hygiene 2000–2020: Five years into the SDGs. *WHO, UNICEF, JMP*; 2021.

25. JMP. Downloads index. *WHO/UNICEF JMP*; 2023. Available from: https://washdata.org/data/downloads#DOM. Accessed 10 Oct 2024.

26. Kumpel E, Nelson KL. Intermittent water supply: prevalence, practice, and microbial water quality. *Environ Sci Technol*. 2016;50(2):542-553. doi:10.1021/acs.est.5b03973.

27. Lee GO, et al. Household coping strategies associated with unreliable water supplies and diarrhea in Ecuador, an upper-middle-income country. *Water Res*. 2020;170:115269. doi:10.1016/j.watres.2019.115269.

28. Levy K, et al. Following the water: a controlled study of drinking water storage in northern coastal Ecuador. *Environ Health Perspect*. 2008;116(11):1533-1540. doi:10.1289/ehp.11296.

29. Mactaggart I, et al. Access to water and sanitation among people with disabilities: results from cross-sectional surveys in Bangladesh, Cameroon, India and Malawi. *BMJ Open*. 2018;8:e020077. doi:10.1136/bmjopen-2017-020077.

30. Majuru B, Suhrcke M, Hunter P. How do households respond to unreliable water supplies? A systematic review. *Int J Environ Res Public Health*. 2016;13(12):1222. doi:10.3390/ijerph13121222.

31. McLennan J. Did point-of-use drinking water strategies for children change in the Dominican Republic during a cholera epidemic? *Public Health*. 2016;138:57-62. doi:10.1016/j.puhe.2016.03.012.

32. Nielsen AM, et al. Chlorination for low-cost household water disinfection – a critical review and status in three Latin American countries. *Int J Hyg Environ Health*. 2022;244:114004.

33. Nnaji CC, Nnaji IV, Ekwule RO. Storage-induced deterioration of domestic water quality. *J Water Sanit Hyg Dev*. 2019;9(2):329-337. doi:10.2166/washdev.2019.151.

34. Orgill J, et al. Water quality perceptions and willingness to pay for clean water in peri-urban Cambodian communities. *J Water Health*. 2013;11(3). doi:10.2166/wh.2013.212.

35. Puspita T, et al. Packaged drinking water in Indonesia: the determinants of household in the selection and management process. *J Water Sanit Hyg Dev*. 2023;13(7):508-519. doi:10.2166/washdev.2023.050.

36. Ray I, Smith KR. Towards safe drinking water and clean cooking for all. *Lancet Glob Health*. 2021;9:e361–e365. doi:10.1016/S2214-109X(20)30476-9.

37. Severino J. Agua procesada: Un mercado líquido dominado por pocos y compartido por muchos. *El Dinero*. 2022 Oct 6. Available from: https://eldinero.com.do/210144/agua-procesada-un-mercado-liquido-dominado-por-pocos-y-compartido-por-muchos/. Accessed 22 Jan 2023.

38. Shaheed A, et al. Why "improved" water sources are not always safe. *Bull World Health Organ*. 2014;92(4).

39. Skinner B. Small-scale water supply: a review of technologies. Rugby: Practical Action; 2003.

40. Slavik S, et al. Water quality aspects related to domestic drinking water storage tanks and consideration in current standards and guidelines throughout the world – a review. *J Water Health*. 2020;18(4):439-463. doi:10.2166/wh.2020.052.

41. Sobsey MD, et al. Point of use household drinking water filtration: a practical, effective solution for providing sustained access to safe drinking water in the developing world. *Environ Sci Technol*. 2008;42(12):4261-4267. doi:10.1021/es702746n.

42. Ssemugabo C, et al. Knowledge and practices of households on safe water chain maintenance in a slum community in Kampala City, Uganda. *Environ Health Prev Med*. 2019;24:45. doi:10.1186/s12199-019-0799-3.

43. Staddon C, Brewis A. Household water containers: mitigating risks for improved Modular, Adaptive, and Decentralized (MAD) water systems. *Water Secur*. 2024;21:100163. doi:10.1016/j.wasec.2023.100163.

44. Usman MA, Gerber N, Pangaribowo EH. Drivers of microbiological quality of household drinking water – a case study in rural Ethiopia. *J Water Health*. 2018;16(2):275-288. doi:10.2166/wh.2017.069.

45. Vedachalam S, et al. The role of packaged water in meeting global targets on improved water access. *J Water Sanit Hyg Dev*. 2017;7(3):369-377. doi:10.2166/washdev.2017.155.

46. World Health Organization (WHO). Results of Round II of the WHO Household Water Treatment Evaluation Scheme. Geneva: WHO; 2016.

47. World Bank Water and Sanitation Program (WSP). Segundo informe de Monitoreo de los Avances de País en Agua Potable y Saneamiento - República Dominicana. WSP; 2016. Available from: https://www.sica.int/documentos/segundo-informe-de-monitoreo-de-los-avances-de-pais-en-agua-potable-y-saneamiento-mapas-ii-republica-dominicana_1_114348.html. Accessed 27 Feb 2024.

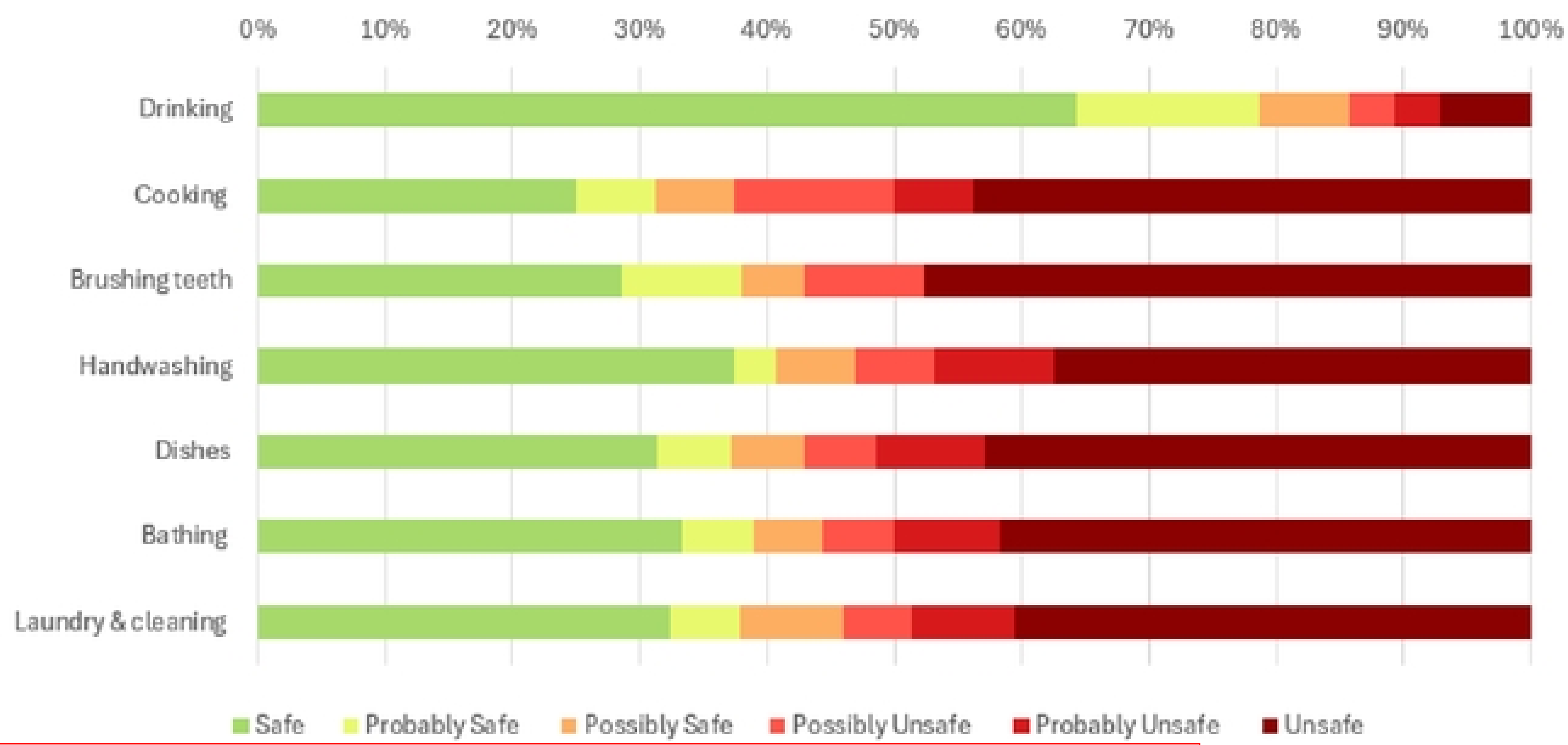


Figure 1Water safety by intended use

Source: Household bacteriological water testing, n=80

Figure 1

Table 1 Aquagenx MPN results categories, adapted from JMP, 2022

MPN/100ml	Aquagenx Category
>1	Safe
1-3.2 and 3.7	Probably safe
3.1-9.6	Possibly safe
13.6 and 17.1	Possibly unsafe
32.6 and 48.3	Probably unsafe
>100	Unsafe

Table 1

Table 1 Intended use of sampled water by source, n=48

Intended use of sampled water	Number of samples				
	20l bottles	RO water tanker	Pipes	Tanker	Rain
Drinking only	9	3	0	0	0
Drinking and Cooking	8	13	0	0	0
Cooking only	1	0	9	2	3

Table 2

Table 3 Physiochemical and microbiological results. n=80[1].

		Sample count		Electrical conductivity (µS/cm)	Total Dissolved Solids (ppm)	Turbidity (NTU)	Temperature (°C)	Chlorine residual (no. samples)	E. coli test count	MPN/ 100ml	Upper 95% confidence level	Aquagenx safety category	Result count
Water sold as treated by reverse osmosis (RO) n=32	20l bottles	17	Mean	21.6	44	0.94	26.4	0	17	0	2.87	Safe	10
										3.2	11.82	Probably Safe	1
			Max	98	51	2.1	29			3.7	9.7	Probably Safe	1
										4.7	22.75	Possibly Safe	2
			Min	10	8	0.3	11.3			13.6	83.06	Possibly Unsafe	1
										100+	9435.1	Unsafe	2
	RO water tanker	15	Mean	53.5	17.5	1.08	28.4	0	15	0	2.87	Safe	13
			Max	311	42	3.11	30.7			1.5	7.81	Probably Safe	1
			Min	24	1	0.49	26.3			48.3	351.91	Probably Unsafe	1
	Piped water	24	Mean	921.7	461.5	1.12	28.2	0	19	0	2.87	Safe	1
										[illegible]	6.32	Probably Safe	1
			Max	1491	745	4.09	32.4			3.2	11.82	Probably Safe	1
										3.4	12.53	Possibly Safe	1
										8.4	21.19	Possibly Safe	1
			Min	635	319	0.34	24.3			13.6	83.06	Possibly Unsafe	1
										48.3	351.91	Probably Unsafe	1
										100+	9435.1	Unsafe	12
	Domestic water tanker	16	Mean	622.5	311.9	2.9	28.3	4(safe)	12	0	2.87	Safe	5
										8.4	21.19	Possibly Safe	1
			Max	781	390	10.9	32.6			13.6	83.06	Possibly Unsafe	1
										17.1	56.35	Possibly Unsafe	1
			Min	287	143	0.83	24.8			48.3	351.91	Probably Unsafe	1
										100+	9435.1	Unsafe	3
	Rainwater harvesting	7	Mean	108.3	54.6	3.39	27.1	0	7	0	2.87	Safe	2
			Max	417	213	11.5	28.3			1.5	7.81	Probably Safe	1
			Min	29	15	0.99	25			13.6	83.06	Possibly Unsafe	1
										100+	9435.1	Unsafe	3
	Borehole	1		879	435	1.56	29.5	0	1	0	2.87	Safe	1
	Total	80											

[1] To avoid skewing the results, duplicate samples from the same home have been removed if they were intended for similar uses and had the same level of *E. coli*

Table 1 Piped water stored for cooking and other uses

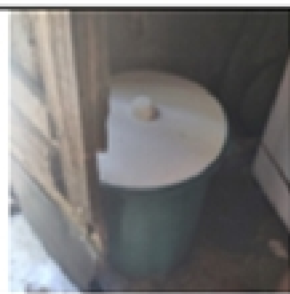
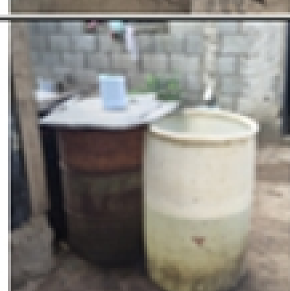
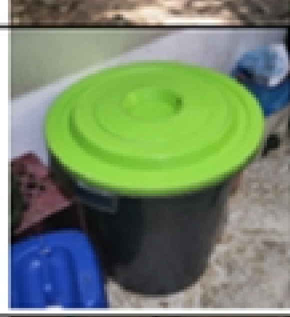
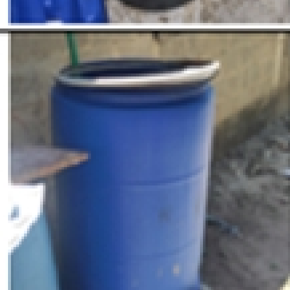
1a		Piped water 30l plastic barrel Fitted lid Stored in kitchen by back door	Yes	Washing dishes Bathing Handwashing Brushing teeth Cleaning Laundry	100+ MPN/100ml Unsafe
1b		Piped water 55-gallon(204l) plastic barrel Improvised soft plastic lid Stored outside in garden	No	Washing dishes Bathing Handwashing Cleaning Laundry	32.6 MPN/100ml Probably unsafe
2a		Piped water 30l plastic barrel Fitted lid Stored in hallway between front entrance and kitchen	Yes	Washing raw food Washing dishes Bathing Handwashing Brushing teeth Cleaning	100+ MPN/100ml Unsafe
2c		Piped water 55 -gallon plastic barrel Covered with sheet metal Stored outside in garden	No	Cleaning Laundry	3.4 MPN/100ml Possibly safe
3a		Piped water 55-gallon plastic barrel Stored outside by back door to kitchen Covered with plastic and metal	Yes	Washing raw food	13.6 MPN/100ml Possibly unsafe
3b		Piped water 100-gallon plastic tank Hole cut in top, covered with metal Stored in garden	No	Washing dishes Bathing Handwashing Cleaning Laundry	0 MPN/100ml Safe
4a		Piped water 30l plastic barrel Fitted lid Stored in kitchen	Yes	Washing raw food Brushing teeth	100+ MPN/100ml Unsafe
4b		Piped water 55-gallon plastic tank No cover Stored in open air patio with roof	No	Washing dishes Bathing Handwashing Cleaning Laundry	1.5 MPN/100ml Probably safe

Table 4