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Perceptions of drinking water access and quality in rural indigenous villages in Fiji

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ABSTRACT

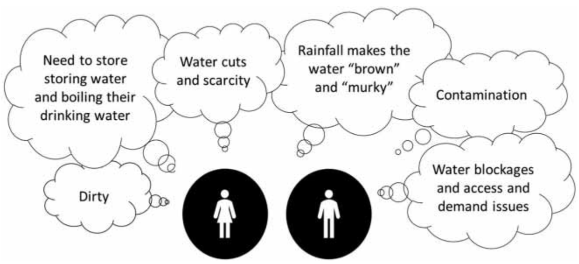
Poor rural water quality is a health challenge in Fiji. A mixed-methods study in six *iTaukei* (Indigenous Fijian) villages was conducted to understand local perceptions of drinking water access and quality, how this changes drinking water source choices, and impacts of age and gender. Seventy-two household surveys, 30 key informant interviews (KIIs) and 12 focus group discussions (FGDs) were conducted. Household surveys revealed 41.7% of community members perceived their water as dirty and 76.4% perceived their water as clean. Two-thirds of households reported that they always or usually had enough water. FGDs and KIIs revealed water access and quality was influenced by population size, seasonality, and rainfall. Perceptions of water quality caused villages to shift to alternative water sources. Alignment of the qualitative and quantitative data identified four themes: sources and infrastructure, access, quality and contamination. There was mixed alignment of perceptions between access and quality between the household surveys, and KIIs and FGDs with partial agreement sources and infrastructure, and quality. Gender was found to influence perceptions of dirty water, contamination, and supply and demand. Perceptions of water quality and access shape decisions and choices for water sources and can be used to inform resilience and inclusive water strategies.

Key words: contamination, gender, mixed-methods, risk perception, seasonality

HIGHLIGHTS

- Seasonality impacts drinking water access and quality perceptions in Fijian villages.
- Limited drinking water supply and quality issues result in people needing to switch to alternative water sources.
- Grazing livestock and plantations near drinking water sources are perceived as sources of contamination.
- Perceptions of water quality highlight the importance of a participatory approach to the development of water safety plans.

GRAPHICAL ABSTRACT



1. INTRODUCTION

In 2017, only 71% (5.3 billion people) of the world's population had access to safely managed drinking water, which was free of contamination (United Nations Children's Fund & World Health Organization 2019). Globally, drinking unsafe water is the second largest risk factor for diarrheal diseases in children under five (Troeger *et al.* 2018). Levels of water-related diseases are predicted to increase due to climate (Smith *et al.* 2014).

Controlling water-related diseases is one of the highest priorities for health security in the Western Pacific Region (World Health Organization 2017), where only 55% of countries have access to basic drinking water, with water access ranging from 92% in urban areas to 44% in rural areas (United Nations Children's Fund & World Health Organization 2019). Access to household drinking water is a challenge because of remote location, as well as human and financial capacity (Mirti & Davies 2005; Hadwen *et al.* 2015). Extreme weather events, such as flooding and cyclones, can damage infrastructure, threatening access and quality of fresh drinking water resources (Hadwen *et al.* 2015; MacDonald *et al.* 2017).

Fiji exemplifies many of the issues present across Pacific small island developing states. As of 2015, 94% of Fijian's population had access to basic drinking water, comprising 89% rural and 98% urban (World Health Organization & United Nations Children's Fund 2017). However, due to limited technical and financial capacity, it can take months to restore water and sanitation services to remote and rural villages post-disaster (Mosley *et al.* 2004). Further, after extreme weather events, water sources can become contaminated from debris, impacting environmental and human health (Mosley *et al.* 2004; Srinivas & Nakagawa 2008). Flooding and rainfall levels are associated with increased transmission and incidence of leptospirosis and increased transmission of typhoid (Jenkins *et al.* 2016; Lau *et al.* 2016; McPherson *et al.* 2018; Jenkins *et al.* 2019). As it is predicted that regional climate impacts will increase the incidence of water-related diseases and water insecurity (McIver *et al.* 2016), it is important to understand and prepare for these risks.

Perceptions of drinking water are impacted by a variety of factors such as demographics, age, gender, associations to past experiences, education level, cultural practices and sensorial information such as odour, sight, taste, and colour (Jones *et al.* 2005; de França Doria *et al.* 2009; de França Doria 2010; Mirlohi *et al.* 2011; Wright *et al.* 2012; Larson et al. 2016; Kunwar & Bohara 2020). These are important as they also influence water quality perceptions because these can change what people perceive as clean and safe. Perceptions of drinking water quality can also impact behaviours regarding what water source to use and whether it is clean (Kelly *et al.* 2018; Anthonj *et al.* 2020). Positive perceptions of their drinking water can mean people are less likely to change their behaviours (Kunwar & Bohara 2020).

There are several studies examining quantitative or qualitative perceptions of drinking water quality in Fiji, but none with a mixed-methods approach nor examination of the influence of gender and age on perceptions. Kohlitz *et al.* (2013) examined perceptions of drinking water and safety, finding 59% of Fijian communities believed it was safe to drink water without the need for treatment, and 87% of communities agreeing with the statement that people can die from drinking dirty water. Further, Kohlitz & Smith (2015) found people felt safe to drink the rainwater they collected despite contamination concerns. This mixed-methods study aimed to determine a) perceptions of water access and quality, b) how these perceptions influence drinking water source choices, and c) what influence gender and age has on those perceptions. Understanding perceptions is important as they shape and guide choices and actions around water and can be used to inform resilience and sustainable strategies.

2. METHODS

This study is part of a larger Watershed Interventions for Systems Health in Fiji ('WISH Fiji') project that focuses on solutions to prevent, detect and respond to three water-related diseases (leptospirosis, typhoid, and dengue), while simultaneously preventing degradation of ecosystems and natural resources, including water. WISH Fiji takes a proactive, systems approach to integrated watershed management to achieve benefits for humans and the environment (McFarlane *et al.* 2019).

This study utilises a concurrent triangulation mixed-method approach (Creswell *et al.* 2003) to understand potential risks to primary drinking water supplies in rural Fijian villages. We present findings from an exploration of household survey data to provide an account of the perceptions of rural village residents about their household drinking water. We relate these perceptions to field measurements of drinking water quality indicators from six *iTaukei* (Indigenous Fijian) villages located in three river sub-catchments of Central Division: Waibula ($n=1$); Dawasamu ($n=2$) and Upper Navua rivers ($n=3$). Village key informant interviews (KIIs) and focus group discussions (FGDs) were conducted to understand perceptions of rural village residents about their household drinking water quality and access. These six villages were purposively selected because of their diverse geographic locations and higher incidences of leptospirosis, typhoid, and dengue. Survey data and semi-structured KIIs and FGDs were conducted in each village between August and October 2019 during the dry season.

Fiji has two seasons: wet (December to April) and dry (May to November). The wet season occurs especially over the larger islands, Viti Levu and Vanua Levu (Fiji Gov 2010; Brown *et al.* 2017; Pearce *et al.* 2018). Rain is more common in the higher windward, south-eastern areas, which experience around 4000–5000 mm/yr (Singh & Mosley 2003). While in the lower leeward, north-western areas rainfall is lower at <2000 mm/yr, because of the localised island rain shadow effects (Singh & Mosley 2003).

2.1. Survey data collection and analysis

To select households included in the survey, each was assigned a unique number. All numbers were placed in a bowl and were selected one by one until at least 15% of households per village were selected. Once a number was selected, it was removed from the bowl. An available adult member of the household was interviewed by trained interviewers in the *iTaukei* language. Participant information is available in Supplementary Appendix 1.

Survey respondents were asked questions about their primary drinking water source and access, alternative water source and access, their drinking water characteristics (such as visual appearance, smell, and taste), and change in water use (Supplementary Appendix 1). The drinking water characteristic of 'clear' in the questionnaire was translated to *iTaukei* as 'clean' and this descriptor was therefore used instead. The questionnaire to collect data on household perceptions of water quality is problematic as well. Participants were asked 'yes or no' questions, such as 'Is your primary drinking water clean?', but people's perceptions of water quality also change – some days the water appears clean and other days it does not (as the qualitative data from FGDs and interviews show). This led to the percentages of water characteristics adding up to more than 100% in Table 2. Frequency and proportion tables were produced to compare outcomes from the six villages. Chi-squared and post hoc tests were conducted to identify any differences between villages for access to their primary water sources and characteristics of their primary water sources. Chi-squared tests were conducted to identify any differences for access to primary water sources and characteristics of their primary water sources by gender and age. Monte Carlo simulations were applied to the Chi-squared tests to prevent errors in calculations caused by small sample sizes. All analyses were conducted in R (R Core Team 2013).

2.2. Drinking water source, water distribution and sanitation system types

In the household survey, participants were asked about their primary drinking source. Village 1 has its own dam, which supplies water to the whole village, and a secondary school nearby. Village 2 had treated drinking water from the Water Authority of Fiji (WAF) but uses other sources such as rainwater because of water shortage issues as the dam is not able to provide enough water for surrounding communities due to the increased number of households. As of July 2020, Village 2 is now accessing treated water from a dam. Village 3 has its own dam, which supplies water to the whole village and two settlements nearby. Villages 4, 5, and 6 all have their own dam connected to a reservoir, which then supplies a reticulated system for domestic users in their households. Water treatment is not present in any of the villages. Definitions of each type of source and distribution system, and images are available in Supplementary Appendix 2.

Village sanitation systems were recorded during a Water Safety and Sanitation Planning (WSSP) process. Of the villages surveyed, all used on-site (non-sewered) sanitation systems. Consistent with Fijian sanitation practices of using flushing latrines, the front-end of the latrines were either pedestal or squat plates. The back-end infrastructure present was either septic tanks, non-standard tanks or pit latrines. There was a range in the quality of sanitation infrastructure. Village 2 had more sanitation back-end infrastructure that would safely contain and treat faecal sludge, with the highest portion of septic tanks (built to standards) (47%). The remaining back-ends in Village 2 were non-standard tanks (53%), such as old plastic water tanks or metal drums. Village 4 had less sanitation infrastructure that would safely contain or treat, with the majority of systems consisting of pit latrines (90%) and some non-standard tanks (10%).

2.3. Land use

In Village 1, there are farms upstream with livestock freely roaming and contaminating the water catchment upstream. In Village 2, around the dam there is a 300-metre radius of native reserve, with no agriculture or forestry activities in the area. In Village 3, there is kava and taro crop production upstream. Animals roam near the village and are not a risk to the water source catchment. In Village 4, there is no human habitation upstream or farming upstream that may pollute the main water source. In Village 5, there are animals and farming near the water catchment area. In Village 6, around the primary water source the catchment is intact with no human habitation or farming or livestock within the area.

2.4. Interview and focus group data collection and analysis

Thirty semi-structured KIIs and 12 FGDs were conducted in the six villages. Purposeful sampling, as described by Etikan *et al.* (2016), was used in each village to recruit key informants including the chief, *Turaga ni koro* (appointed village government liaison), religious leader, and the village health worker. Convenience sampling, as described by Etikan *et al.* (2016), was used for the male and female FGDs, and purposeful sampling was used for the water committee FGD. In each village, three separate FGDs were conducted. The first with men, the second with women and the third with the water committee. In some cases, the water committee was small, and members had limited availability, so a single member was interviewed. Furthermore, in some cases multiple men and women were interviewed individually in the village. Participants were interviewed in English or *iTaukei* based on their language preference, in village settings such as the village hall or participants' homes. Questions covered included the characteristics of their drinking water, primary drinking water source type (Supplementary Appendix 1), causes of water contamination, and any behaviour changes and illness related to the water (Supplementary Appendix 3). In line with cultural practices, all participants provided verbal consent to be recorded and interviewed. The English interviews were transcribed verbatim. The *iTaukei* interviews were translated and transcribed into English by a member of the WISH Fiji project. Thematic analysis was conducted in NVIVO 12. An initial coding framework was developed based upon one village's transcripts and was discussed with co-authors (J.N., S.A. and A.J.). This acted as a preliminary framework that was applied to the remaining transcripts. After transcripts for each village were coded, the coding framework was reviewed and updated, as necessary. Once all the villages were coded, a proposed final framework was discussed with co-authors (S.A. and J.N.), until agreement was reached, and all transcripts were re-coded in line with the finalised framework.

2.5. Alignment of qualitative and quantitative

The qualitative and quantitative data were collected and analysed separately to produce two sets of findings before the data alignment (O'Cathain *et al.* 2010). The alignment protocol utilised was based upon Kuehl (2017). The key findings were identified based on the research questions of this paper. In line with Kuehl (2017), each theme was assigned a convergence code of agreement, partial agreement, silence and dissonance, with codes being allocated based on the level of agreement between the qualitative and quantitative data sources.

2.6. Ethics statement

Free and informed consent of the participants was obtained. The study was approved by the appropriate Committee for the Protection of Human Participants, The University of Sydney's Human Research Ethics Committee (2019/588), Fiji National Health Research and Ethics Review Committee (FNHRERC Number: 2018.231.CEN), and Fiji National University's College Health Research Ethics Committee (CHRED ID: 009.19). All human subjects' data were collected with free, prior, and informed consent in line with Fijian Ministry of *iTaukei* Affairs protocols.

3. RESULTS

3.1. Water source, distribution, and access

Three water source types were identified as the primary water source (Table 1). The most-reported primary water source type was from a dam (63.8%, n=46). Piped into the household and rainwater tanks were identified as the distribution systems. Approximately two-thirds of participants (65.3%, n=48) reported that they always or usually had enough water through their primary water source. Across the six villages there were differences in water source, distribution system, and sufficiency of access (Table 1). For example, Village 2 on rainwater supply the highest proportion of survey participants reported as only having water sometimes, which is markedly different

Table 1 | Water source, distribution system, and sufficiency of access all as reported by householders across 6 villages ($n=72$)

Village number	1	2	3	4	5	6	Total (%)
Primary water source							
Spring	10						10 (13.8%)
Rainwater		10	1				11 (15.2%)
Dam			9	11	14	17	51 (70.8%)
Primary water distribution system							
Piped into house	10		9	11	14	17	61 (84.7%)
Rainwater tanks		10					10 (13.8%)
Unknown			1				1 (1.4%)
Enough access to a primary water source							
Always	2	3	3	5	8	9	30 (41.7%)
Usually	1	2	2	4	5	3	17 (23.6%)
Sometimes	6	5	4	2	1	4	22 (30.6%)
Seasonally only	1	0	1	0	0	1	3 (4.2%)

to average result. Village 1 was similar with most reporting sometimes. Villages 5 and 6 both with dam access reported always or usually having enough access to their primary water source. Despite these differences, there were no significant differences reported amongst villages in access to their primary water sources (Chi square=16.8, $p>0.1$). Further, age (Chi square=1.0, $p>0.1$) and gender (Chi square=1.0, $p>0.1$) did not influence perceptions of access to primary water sources (Supplementary Appendix 1; Table 2).

3.2. Household water perceptions

Two water quality characteristics, both regarding the appearance of drinking source and household water, were dominant in village members' perceptions (dirty $n=30$ [41.7%], and clean $n=55$ [76.4%]). The remaining water quality descriptions were largely about taste and smell and were only mentioned a few times (Table 2). There was a significant difference between villages for householder perceptions of their water being dirty (Chi square=20.2, $p<0.001$) and clean (Chi square=13.2, $p<0.05$). Post-hoc analysis showed Villages 1 ($p<0.05$) and 3 ($p<0.05$) had significant differences from the other villages in their perception of dirty water, with them less likely to report dirty water, with no respondents perceiving dirty water. Almost one-quarter of respondents ($n=17$, 23.6%) reported more than one water characteristic. Respondents from Villages 5 and 6 reported more variety water characteristics than other villages, suggesting that only one descriptor was not sufficient to characterise the range that respondents experience.

Perceptions of water quality by age and gender are available in Supplementary Appendix 1; Table 3. Age did not significantly impact people's perceptions of their water being dirty (Chi square=4.9, $p>0.05$) and clean (Chi

Table 2 | Number of respondents reporting yes to water characteristics by village ($n=72$)

Water characteristics	1	2	3	4	5	6	Total (%)
Clean (*makare se savasava*)	9	10	10	6	10	10	55 (76.4%)
Dirty (*duka*)	0	5	0	7	8	10	30 (41.7%)
Smelly (*boi ca*)	0	0	0	0	1	3	4 (5.6%)
Stained (*roka*)	0	0	0	0	0	3	3 (4.2%)
Salty (*tuituina*)	0	0	0	0	1	0	1 (1.4%)
Cloudy (*vuvu*)	0	0	0	1	0	0	1 (1.4%)
Sweet taste (*kamikamica*)	1	0	0	0	0	0	1 (1.4%)
Poor taste (*gunu ca*)	0	0	0	0	0	0	0 (0.0%)
Milky (*vuvu*)	0	0	0	0	0	0	0 (0.0%)

The *iTaukei* translations of English descriptors that were used in interviews are in parentheses and italicized, and the percentage of respondent who selected yes for the water characteristic in brackets.

square=0.9, $p>0.1$). Women were more likely to perceive their water as dirty (Chi square=7.61, $p<0.05$). There were no differences by gender for clean water perceptions (Chi square=1.0, $p>0.1$).

3.3. Sources and infrastructure

Across the six villages, there was a variety of water infrastructure (Table 3). Respondents noted in some places that water sources and infrastructure has changed. For example, Village 2 used to rely on the well for their main water source, but '*just a few years ago, the Water Authority* [of Fiji] *came to introduce our* [rainwater] *tanks, one tank per house with drains*' (Village 2, male FGD participant). Different water sources were reported to have different uses: for example, '*the piped water is mainly for drinking*', while river water is mainly for '*washing*' (Village 5, chief).

Table 3 | Household water and distribution system reported by the six villages

Village	1	2	3	4	5	6
Water source						
Borehole		Yes				
Dams			Yes	Yes	Yes	Yes
Rainwater				Yes		
Reservoir		Yes		Yes		
River	Yes	Yes	Yes		Yes	Yes
Spring	Yes					
Stream			Yes			Yes
Well		Yes			Yes	
Distribution system						
Pipes		Yes			Yes	Yes
Tank	Yes	Yes	Yes	Yes		Yes
Tap	Yes	Yes	Yes		Yes	Yes

3.4. Water scarcity

Water scarcity was identified by five villages, and this was impacted by the drier season (April to September) and water cuts. '*Sometimes, there could be no water for 3 weeks*' (Village 2, male FGD participant) and '*sometimes there is no water especially during dry days and that's when we time the opening of taps … opens in the morning from 6–9 am then close…open from 12-1 during lunch hour, close again, and then we will open again at 5 pm*' (Village 6, *Turaga ni koro*). Village 5 participants did not report an issue with water scarcity. In the words of the Village 5 *Turaga ni koro*, '*The delivery of water in the village has no limits, everybody gets the same amount of water, nobody gets more, nobody gets less, everybody receives the same amount of water*'.

Residents perceived that population growth, changes in water usage, and demand from other sources contributed to water scarcity. As voiced by the Village 4 religious leader, '*The problem is there is a lot of houses now and also some are using this water in their plantations and some are using it to breed their fish* [tilapia] *and that's the problem we're facing*'. In Village 1, the addition of a secondary school using the same water supply led the village to experience increased water cuts. '*Both the primary and the secondary school…are now sourcing* [water] *from that same dam so that's what's causing the problem* [with water access]' (Village 1, *Turaga ni koro*).

To address the water scarcity issues, participants reported that they relied on alternative sources, such as a well or a river. '*The drinking water is usually fetched from the stream*' (Village 6, health worker). Participants also noted that they change their behaviours in response to the water scarcity; for instance, '*When people see that there is less water, they will keep the water in the tank to be used for cooking. Bathing and washing will be done in the river*' (Village 2, religious leader).

3.5. Water quality

It was perceived that water quality issues were aggravated by rain, as participants reported after rainfall the water was 'brown', 'dirty' and 'murky'. After heavy rain, respondents said the pipes would get blocked by mud, sand, sticks and leaves, and this, in turn, resulted in overflow from the dam. A Village 2 health worker explained, '*Sometimes the water turns brown after heavy rain. When we open the tap, the brown water comes out first then clear water. But we just use it. We can't close it* [tap] *because that's the only source of water we have*'.

In response to a deterioration in water quality after rain, some villagers said that they change their behaviour by storing water and boiling their drinking water before consumption. As described by the *Turaga ni koro* in Village 1, '*When there's rain the water surely gets dirty. So, when that happens, they* [the water committee] *usually advise the village especially the mothers to boil their drinking water and that's as far as water is concerned*'. Another respondent said that people, '*store the water in bottles and buckets and let the dirt settle but others use the filter and fill up their buckets before drinking or using*' (Village 4, male FGD participant). These measures were viewed as helping to ensure the water they are consuming is safe. Respondents perceived that poor water quality is linked to illness experienced in the villages. Respondents noted: '*when we collect the water is always dirty…that's when we have sicknesses caused by drinking dirty water*' (Village 5 female FGD participant); and '*during the cyclone or during a long period of rainy days and it causes a lot of headaches and, diarrhoea and stomach aches*' (Village 6, chief).

Potential sources of water contamination identified by participants included: livestock grazing; plantations near the dam; farming; and chemicals. Some respondents noted that water sources not presently being used for drinking water have been made undrinkable through human activity: '*Since it's* [the borehole] *not being used, when the children play, they throw dirty things into it so now we don't use it*' (Village 2, village health worker). Contamination was perceived as too bad in Village 6 that it led to one of the village's dams being closed.

3.6. Alignment of qualitative and quantitative

There were mixed relationships between the qualitative and quantitative data on the perceptions of water access and quality (Table 4). Responses on water access were grouped into two themes: source and infrastructure, and availability. There was partial agreement across the two datasets for source and infrastructure. Between the qualitative and quantitative data villages reported eight water sources, with the qualitative data capturing a greater diversity. There was dissonance across the qualitative and quantitative data for water availability. Around two-thirds (65.3%) of households reported they had enough water from their primary source; in comparison, five out of six villages reported water access issues. Seasonality was not an issue influencing water access in the quantitative data, but the qualitative revealed it was a common issue during the drier season. Differences by gender were found in the qualitative data with men focusing more on blockages and supply and demand issues compared to women.

Responses linked to water quality were grouped into two themes: quality and contamination. There was partial agreement across both data sources for quality, with overlaps in the perception that the water was 'dirty'. The qualitative data was able to capture the implications of villages perceiving their water as dirty, which resulted in changes to behaviour, such as storing water and boiling water before consumption. These changes are more likely to be made by women, and women were more likely to perceive their water as dirty (Chi square=7.61, $p<0.05$). There was dissonance of the water contamination theme. According to the quantitative data, 76.4% ($n=55$) reported their household water was clean and thus no contamination, with no differences across gender. The qualitative data respondents revealed a variety of contaminants including plantations and farming. There were also gendered differences present with men discussing contamination more than women.

4. DISCUSSION

This study examined perceptions of drinking water access and quality in six *iTaukei* villages, how this influences water source choices, and whether there are age and gender differences in perceptions. Five out of six villages reported issues with water quality and scarcity, and this finding was consistent with previous studies in Fiji (Kohlitz *et al.* 2013; Kohlitz & Smith 2015). These issues were detectable (and therefore perceived), and sufficient to cause a change in behaviour for domestic purposes in villages, by introducing household water treatment and/or switching to alternative sources. Increased use of varied water sources is associated with an increased risk of water-related diseases (Ercumen *et al.* 2015; Prasad *et al.* 2018; Trudeau *et al.* 2018). This is specifically important in the Fijian context where there are high per capita incidences of water-related diseases such as leptospirosis, typhoid and dengue, predicted to increase with climate change (McIver *et al.* 2016).

Water intermittency was also highlighted as an issue in the study villages. String *et al.* (2020) found that pipe breakages were one of the main hazards being monitored and mitigated in Fijian villages. It is also a major issue

Table 4 | Convergence coding matrix

Themes	Quantitative results	Qualitative results	Convergence coding
Water access			
Sources and infrastructure	Three water source types were identified (dam, spring and rainwater). Dam was reported as a water source by 63.8% ($n = 46$). Piped into the household and rainwater tanks were identified as the most common distribution systems	Eight water sources were identified (borehole, dam, rainwater, reservoir, river, spring, stream, well) Dam was reported as a water source by 5 out of 6 villages Taps and tanks were identified as the most common distribution systems.	Partial agreement
Water access	65.3% ($n = 48$) reported that they always or usually had enough water through their primary water source. 4.2% ($n = 3$) reported issues to water access only occurred seasonally Age and gender did not influence access to primary water sources.	5 village reported issues with water access. Water access was impacted by the drier season (April to September) and water cuts Men more likely to share blockages and access and demand issues	Dissonance
Water quality			
Water quality	41.7% ($n = 30$) reported their household water was dirty Women were more likely to perceive their water as dirty (Chi square = 7.61, $p < 0.05$).	Water quality issues were aggravated by rainfall, and it was seen as 'brown', 'dirty' and 'murky' Poor water quality led to changes in behaviour such as storing water and boiling their drinking water before consumption, with women reporting these more	Agreement
Contamination	76.4% ($n = 55$) reported their household water was clean Gender does not impact perceptions of clean water.	Contamination was caused by plantations near the dam; farming; livestock grazing, chemicals and mud, sand, sticks and leaves after rainfall, which are reported more by men	Dissonance

in many low-income countries as it leads to changing pressure in the pipes, causing pipes to break and this can lead to contamination and cause water-borne diseases (Lee & Schwab 2005; Ercumen *et al.* 2015; Prasad *et al.* 2018). With rising pressures on water supply, these issues of water intermittency and interrupted access are important to address as the villages will continue to be put at risk of water-related diseases.

Our results of water source contamination are matched by others reported from rural Fiji (Mosley *et al.* 2004; Kohlitz *et al.* 2013; Byrne *et al.* 2021). The sources of possible drinking water contamination that villagers identified were chemicals, livestock, plantations near pipes or dams, and mud and dirt after the heavy rains. Kumar (2010) also reported perceived sources of contamination in Fiji to be agricultural and livestock activity, although this was not reported by participants in this study. There is little evidence in Fiji of water quality being affected by metals (Singh & Mosley 2003). A review from Sclar *et al.* (2016) show latrines near drinking water sources result in increased faecal indicator counts. Given that the majority of drinking water sources were damned streams uphill of the communities, the most likely mechanism for contamination is the ingress of contaminated water from latrines in close proximity to buried or sub-merged drinking water distribution systems in the villages. It is important to address this, as sanitation-related pollution in drinking water poses risks for human health. Steps that can be implemented to prevent this can include regular gutter cleaning, removing sanitation systems near drinking water sources or piped distribution systems, and building fences to prevent animals grazing near water sources.

Inadequate chlorination, intermittent water access, and agriculture-related pollution are also sources of contamination identified in the wider literature from low-and-middle income countries (Bain *et al.* 2014; Carrard *et al.* 2019). Sediment and bacterial contamination of water are important to consider as they influence water quality and can disrupt eco-systems. Suspended matter such as clay, silt, organic or inorganic matter, plankton, and other microscopic organisms are common sources of turbidity in water, and influence water quality (Lechevallier *et al.* 1981). Understanding the source of water contamination is critical, as, without this knowledge, villages cannot make appropriate decisions about risk or determine appropriate actions to reduce their risk.

While the study is focused on village-level risk factors, it is possible that contamination sources are originating from higher-order scales (Jenkins *et al.* 2020) – and this needs to be investigated in order to plan appropriate action.

Another study in Fiji villages reported water was safe to drink if it was 'clean' and not safe if 'dirty' (String *et al.* 2020). The differences in the perceptions of clean and dirty may link to the choice of words and wider connotations of the words. Clean may be a neutral word and does not necessarily have wider connotations. In comparison, dirty could be a negative word, associated with being unhealthy, and may promote an emotive response (Robinson & Howland 2021), so fewer village members may choose to associate their water as 'dirty'. Translation of words could also cause different understandings and interpretations. The questionnaire may not have truly captured an accurate picture of variability in water quality, as it only allowed participants to answer 'yes or no'. More than one water characteristic can be present in a village as descriptions can be dependent on the weather (i.e., on rainy days the water is dirty, whereas on a good/clear day they say it is mostly clean). People also become accustomed to the drinking water taste, smell, and visual appearance from where they grew up, so that can influence their perception. Piriou *et al.* (2014) and Turgeon *et al.* (2004) both show location impacts perceptions of drinking water taste.

Gender was found to influence perceptions of dirty water, contamination and access and demand. These differences could reflect gender roles in the maintenance of water infrastructure. Women may be more likely than men to perceive water as dirty because they are the ones who care for family members who get sick because of poor water (Naiga *et al.* 2017), so therefore they try to avoid water that can cause illness. Men may be more aware of the contamination, access and demand issues because they play a larger role in operation and maintenance of water supply systems, and are responsible for fixing issues when they arise (Nelson *et al.* 2021). The difference in perceptions highlights the importance of gender inclusivity in decision-making processes for water in Fijian villages in order to ensure different perspectives and issues are captured.

We found that perceptions were not impacted by age. Other literature shows older people can have different sensory perceptions of drinking water compared with younger generations (Mirlohi *et al.* 2011). The impact of age on water perceptions can be explained through the loss of sensory perceptions, for example, older people are more likely to have lost some taste and smell senses (Boyce & Shone 2006; Mirlohi *et al.* 2011). This highlights that differing age perceptions are important to consider as some populations are more at risk of water-related diseases than others.

Risk perceptions for drinking water quality have been found to impact behaviour. Exposure to dirty water sources led villagers to change their behaviour, such as boiling their water and relying on alternative sources (which may or may not meet WHO standards). In other evidence from Fiji, it was found that despite concerns from physical contamination of rainwater, it was assessed as still safe to drink as there was no perceived risk of illness from it (Kohlitz & Smith 2015). The impact of perceptions is clear in Singapore where views of recycled water were changed (Po *et al.* 2003; Leong & Lebel 2020). Previously it was perceived 'yuck' and 'disgusting', but perceptions were changed through a multi-step approach, such as the name choice of NEWater, government support, and awareness and education programmes (Po *et al.* 2003; Leong & Lebel 2020). Participatory village water safety planning is a potential mechanism that can be introduced into villages to increase knowledge and understanding of their drinking water and actions that can be proactively taken to reduce risk (String *et al.* 2020).

In line with our study, seasonality has been shown to impact water behaviours in Kenya, Ghana, and Zambia (Kelly *et al.* 2018). In the dry season, people brought water from water kiosks, as there was limited supply because wells and dams dried up, but during the wet season there was excess water available and people did not need to buy it (Kelly *et al.* 2018). Understanding the impact of seasonality is important for water choices, is important as it can be used help design sustainability and resilience strategies for villages.

5. CONCLUSION

Our study provides information about how villages in Fiji perceive their drinking water, and how this shapes their behaviours with drinking water. Population growth in villages puts pressure on water access. After heavy rains, water was often perceived to be contaminated and dirty, leading villages to rely on alternative sources and change their behaviour. The data suggest that it is critical to take a participatory approach to include villages as this allows them to advocate for action that can appropriately target contamination sources. Improving villagers' knowledge of pathways to ill health from water-related disease will empower them to advocate for and action improvements in water quality. Water access and supply was common during the dry season, and lead to water cuts and dependence on alternative drinking water sources. Future investment and improvement need focus on strengthening water supply and treatment infrastructure in villages. Future work needs to be conducted on combining household water perceptions with water quality monitoring and water-related disease data.

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CONFLICT OF INTEREST STATEMENT

The authors are not affiliated with or involved with any organisation or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this paper

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

REFERENCES

Anthonj, C., Tracy, J. W., Fleming, L., Shields, K. F., Tikoisuva, W. M., Kelly, E., Thakkar, M. B., Cronk, R., Overmars, M. & Bartram, J. 2020 Geographical inequalities in drinking water in the Solomon Islands. *Science of The Total Environment* **712**, 135–241. https://doi.org/10.1016/j.scitotenv.2019.135241.

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T. & Bartram, J. 2014 Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. *PLoS Medicine* **11**(5), e1001644. https://doi.org/10.1371/journal.pmed.1001644.

Boyce, J. M. & Shone, G. R. 2006 Effects of ageing on smell and taste. *Postgraduate Medical Journal* **82**(966), 239–241. https://doi.org/10.1136/pgmj.2005.039453.

Brown, P., Daigneault, A. & Gawith, D. 2017 Climate change and the economic impacts of flooding on Fiji. *Climate and Development* **9**(6), 493–504. https://doi.org/10.1080/17565529.2016.1174656.

Byrne, H., Cassar, S., Humphrey, J., Lowe, N., Currell, M. & Brown, N. J. 2021 Enhancing access to safe drinking water in remote Fijian communities: modeling and implementing a pilot rain-rank disinfection program. *Environmental Engineering Science* **38**(5), 430–442. https://doi.org/10.1089/ees.2020.0270.

Carrard, N., Foster, T. & Willetts, J. 2019 Groundwater as a source of drinking water in Southeast Asia and the Pacific: a multi-country review of current reliance and resource concerns. *Water* **11**(8), 1605. https://doi.org/10.3390/w11081605.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L. & Hanson, W. E. 2003 An expanded typology for classifying mixed methods research into designs. In: *Handbook of Mixed Methods in Social and Behavioral Research* (Tashakkori, A. & Teddlie, C. eds.). Sage, Thousand Oaks, CA, pp. 209–240.

de França Doria, M. 2010 Factors influencing public perception of drinking water quality. *Water Policy* **12**(1), 1–19. https://doi.org/10.2166/wp.2009.051.

de França Doria, M., Pidgeon, N. & Hunter, P. R. 2009 Perceptions of drinking water quality and risk and its effect on behaviour: a cross-national study. *Science of The Total Environment* **407**(21), 5455–5464. https://doi.org/10.1016/j.scitotenv.2009.06.031.

Ercumen, A., Arnold, B. F., Kumpel, E., Burt, Z., Ray, I., Nelson, K. & Colford Jr., J. M. 2015 Upgrading a piped water supply from intermittent to continuous delivery and association with waterborne illness: a matched cohort study in urban India. *PLOS Medicine* **12**(10), e1001892. https://doi.org/10.1371/journal.pmed.1001892.

Etikan, I., Musa, S. A. & Alkassim, R. S. 2016 Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics* **5**(1), 1. https://doi.org/10.11648/j.ajtas.20160501.11.

Fiji Gov 2010 March 23 Our Country. Available from: https://web.archive.org/web/20100323104147/http://www.fiji.gov.fj/index.php?option=com_content&view=article&id=645&Itemid=196#t1 (accessed 1 March 2021).

Hadwen, W. L., Powell, B., MacDonald, M. C., Elliott, M., Chan, T., Gernjak, W. & Aalbersberg, W. G. L. 2015 Putting WASH in the water cycle: climate change, water resources and the future of water, sanitation and hygiene challenges in Pacific Island Countries. *Journal of Water, Sanitation and Hygiene for Development* **5**(2), 183–191. https://doi.org/10.2166/washdev.2015.133.

Jenkins, A. P., Jupiter, S., Mueller, U., Jenney, A., Vosaki, G., Rosa, V., Naucukidi, A., Mulholland, K., Strugnell, R., Kama, M. & Horwitz, P. 2016 Health at the sub-catchment scale: typhoid and its environmental determinants in Central Division, Fiji. *EcoHealth* **13**(4), 633–651. https://doi.org/10.1007/s10393-016-1152-6.

Jenkins, A. P., Jupiter, S. D., Jenney, A., Rosa, V., Naucukidi, A., Prasad, N., Vosaki, G., Mulholland, K., Strugnell, R. & Kama, M. 2019 Environmental foundations of typhoid fever in the Fijian residential setting. *International Journal of Environmental Research and Public Health* **16**(13), 2407. https://doi.org/10.3390/ijerph16132407.

Jenkins, A., Jupiter, S. D., Capon, A., Horwitz, P. & Negin, J. 2020 Nested ecology and emergence in pandemics. *The Lancet Planetary Health* **4**(8), e302–e303. https://doi.org/10.1016/S2542-5196(20)30165-0.

Jones, A. Q., Dewey, C. E., Doré, K., Majowicz, S. E., McEwen, S. A., Waltner-Toews, D., Henson, S. J. & Mathews, E. 2005 Public perception of drinking water from private water supplies: focus group analyses. *BMC Public Health* **5**(1), 129. https://doi.org/10.1186/1471-2458-5-129.

Kelly, E., Shields, K. F., Cronk, R., Lee, K., Behnke, N., Klug, T. & Bartram, J. 2018 Seasonality, water use and community management of water systems in rural settings: qualitative evidence from Ghana, Kenya, and Zambia. *Science of The Total Environment* **628–629**, 715–721. https://doi.org/10.1016/j.scitotenv.2018.02.045.

Kohlitz, J. P. & Smith, M. D. 2015 Water quality management for domestic rainwater harvesting systems in Fiji. *Water Science & Technology: Water Supply; London* **15**(1), 134–141. http://dx.doi.org/10.2166/ws.2014.093.

Kohlitz, J., Hasan, T., Khatri, K., Sokota, A., Iddings, S., Bera, U. & Psutka, R. 2013 Assessing reported use and microbiological performance of a point-of-use household water filter in rural Fiji. *Journal of Water, Sanitation and Hygiene for Development; London* **3**(2), 207–215. http://dx.doi.org/10.2166/washdev.2013.061.

Kuehl, S. 2017 *Coping has Limits: 'Mixed Presenters' Emergency Department Presentations for Self-Harm and Other Reasons*. University of Otago, Wellington, New Zealand. Available from: https://ourarchive.otago.ac.nz/handle/10523/7568.

Kumar, V. 2010 Water management in Fiji. *International Journal of Water Resources Development* **26**(1), 81–96. https://doi.org/10.1080/07900620903392216.

Kunwar, S. B. & Bohara, A. K. 2020 Water quality avoidance behavior: bridging the Gap between perception and reality. *Water Economics and Policy* **06**(02), 1950012. https://doi.org/10.1142/S2382624X19500127.

Larson, K. L., Stotts, R., Wutich, A., Brewis, A. & White, D. 2016 Cross-cultural perceptions of water risks and solutions across select sites. *Society & Natural Resources* **29**(9), 1049–1064. https://doi.org/10.1080/08941920.2015.1122132.

Lau, C. L., Watson, C. H., Lowry, J. H., David, M. C., Craig, S. B., Wynwood, S. J., Kama, M. & Nilles, E. J. 2016 Human leptospirosis infection in Fiji: an eco-epidemiological approach to identifying risk factors and environmental drivers for transmission. *PLOS Neglected Tropical Diseases* **10**(1), e0004405. https://doi.org/10.1371/journal.pntd.0004405.

Lechevallier, M. W., Evans, T. M. & Seidler, R. J. 1981 Effect of turbidity on chlorination efficiency and bacterial persistence in drinking water. *Appl. Environ. Microbiol.* **42**, 9. https://doi.org/0099-2240/81/070159-09$02.00/0.

Lee, E. J. & Schwab, K. J. 2005 Deficiencies in drinking water distribution systems in developing countries. *Journal of Water and Health* **3**(2), 109–127. https://doi.org/10.2166/wh.2005.0012.

Leong, C. & Lebel, L. 2020 Can conformity overcome the yuck factor? explaining the choice for recycled drinking water. *Journal of Cleaner Production* **242**, 118196. https://doi.org/10.1016/j.jclepro.2019.118196.

MacDonald, M. C., Chan, T., Elliott, M., Kearton, A., Shields, K. F., Barrington, D. J., Souter, R. T., Powell, B. R., Bartram, J. & Hadwen, W. L. 2017 Temporal and thematic trends in water, sanitation and hygiene (WaSH) research in Pacific Island Countries: a systematic review. *Journal of Water, Sanitation and Hygiene for Development* **7**(3), 352–368. https://doi.org/10.2166/washdev.2017.021.

McFarlane, R. A., Horwitz, P., Arabena, K., Capon, A., Jenkins, A., Jupiter, S., Negin, J., Parkes Margot, W. & Saketa, S. 2019 Ecosystem services for human health in Oceania. *Ecosystem Services* **39**, 100976. https://doi.org/10.1016/j.ecoser.2019.100976.

McIver, L., Kim, R., Woodward, A., Hales, S., Spickett, J., Katscherian, D., Hashizume, M., Honda, Y., Kim, H., Iddings, S., Naicker, J., Bambrick, H., McMichael, A. J. & Ebi, K. L. 2016 Health impacts of climate change in Pacific Island Countries: a regional assessment of vulnerabilities and adaptation priorities. *Environmental Health Perspectives* **124**(11), 1707–1714. https://doi.org/10.1289/ehp.1509756.

McPherson, A., Hill, P. S., Kama, M. & Reid, S. 2018 Exploring governance for a One Health collaboration for leptospirosis prevention and control in Fiji: stakeholder perceptions, evidence, and processes. *The International Journal of Health Planning and Management* **33**(3), 677–689. https://doi.org/10.1002/hpm.2521.

Mirlohi, S., Dietrich, A. M. & Duncan, S. E. 2011 Age-associated variation in sensory perception of iron in drinking water and the potential for overexposure in the human population. *Environmental Science & Technology* **45**(15), 6575–6583. https://doi.org/10.1021/es200633p.

Mirti, A. V. & Davies, S. 2005 *Drinking Water Quality in the Pacific Island Countries: Situation Analysis and Needs Assessment (No. SOPAC Joint Contribution Report 181)*. Pacific Data Hub, Noumea, New Caledonia.

Mosley, L. M., Sharp, D. S. & Singh, S. 2004 Effects of a tropical cyclone on the drinking-water quality of a remote Pacific Island. *Disasters* **28**(4), 405–417. https://doi.org/10.1111/j.0361-3666.2004.00266.x.

Naiga, R., Penker, M. & Hogl, K. 2017 Women's crucial role in collective operation and maintenance of drinking water infrastructure in rural Uganda. *Society & Natural Resources* **30**(4), 506–520. https://doi.org/10.1080/08941920.2016.1274460.

Nelson, S., Abimbola, S., Mangubhai, S., Jenkins, A., Jupiter, S., Naivalu, K., Naivalulevu, V. & Negin, J. 2021 Understanding the decision-making structures, roles and actions of village-level water committees in Fiji. *International Journal of Water Resources Development* 1–18. https://doi.org/10.1080/07900627.2021.1916449.

O'Cathain, A., Murphy, E. & Nicholl, J. 2010 Three techniques for integrating data in mixed methods studies. *BMJ* **341**, c4587.

Pearce, T., Currenti, R., Mateiwai, A. & Doran, B. 2018 Adaptation to climate change and freshwater resources in Vusama village, Viti Levu, Fiji. *Regional Environmental Change* **18**(2), 501–510. https://doi.org/10.1007/s10113-017-1222-5.

Piriou, P., Devesa, R., Puget, S., Thomas-Danguin, T. & Zraick, F. 2014 Evidence of regional differences in chlorine perception by consumers: sensitivity differences or habituation? *Journal of Water Supply: Research and Technology-Aqua* **64**(7), 783–792. https://doi.org/10.2166/aqua.2014.097.

Po, M., Nancarrow, B. E. & Kaercher, J. D. 2003 *Literature Review of Factors Influencing Public Perceptions of Water Reuse (Technical Report 54/03)*. CSIRO Land and Water.

Prasad, N., Jenkins, A. P., Naucukidi, L., Rosa, V., Sahu-Khan, A., Kama, M., Jenkins, K. M., Jenney, A. W. J., Jack, S. J., Saha, D., Horwitz, P., Jupiter, S. D., Strugnell, R. A., Mulholland, E. K. & Crump, J. A. 2018 Epidemiology and risk factors for typhoid fever in Central Division, Fiji, 2014–2017: a case-control study. *PLOS Neglected Tropical Diseases* **12**(6), e0006571. https://doi.org/10.1371/journal.pntd.0006571.

R Core Team. 2013 *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. Available from: https://www.r-project.org/.

Robinson, J. & Howland, O. 2021 Visible and invisible risks: exploring washing and hygiene practices with women living on low income in Kenya. *Global Public Health* **0**, 1–14. https://doi.org/10.1080/17441692.2021.1887314.

Sclar, G. D., Penakalapati, G., Amato, H. K., Garn, J. V., Alexander, K., Freeman, M. C., Boisson, S., Medlicott, K. O. & Clasen, T. 2016 Assessing the impact of sanitation on indicators of fecal exposure along principal transmission pathways: a systematic review. *International Journal of Hygiene and Environmental Health* **219**(8), 709–723.

Singh, S. & Mosley, L. M. 2003 Trace metal levels in drinking water on Viti Levu, Fiji Islands. *The South Pacific Journal of Natural and Applied Sciences* **21**(1), 31. https://doi.org/10.1071/SP03006.

Smith, K., Woodward, A., Campbell-Lendrum, D., Chadee, D., Honda, Y., Liu, Q., Olwoch, J., Revich, B., Sauerborn, R. & Aranda, C. 2014 *Human health: Impacts, adaptation, and co-benefits* (Climate Change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change) In: (pp. 709–754). Cambridge University Press, Cambridge.

Srinivas, H. & Nakagawa, Y. 2008 Environmental implications for disaster preparedness: lessons learnt from the Indian Ocean Tsunami. *Journal of Environmental Management* **89**(1), 4–13. https://doi.org/10.1016/j.jenvman.2007.01.054.

String, G. M., Singleton, R. I., Mirindi, P. N. & Lantagne, D. S. 2020 Operational research on rural, community-managed water safety plans: case study results from implementations in India, DRC, Fiji, and Vanuatu. *Water Research* **170**, 115288. https://doi.org/10.1016/j.watres.2019.115288.

Troeger, C., Blacker, B. F., Khalil, I. K., Rao, P. C., Cao, S., Zimsen, S. R. M., Albertson, S. B., Stanaway, J. D., Aniruddha Deshpande, A., Abebe, Z., Alvis-Guzman, N., T Amare, A. T., Alamrew Anteneh, Z., Antonio, C. A. T., Aremu, O., Asfaw, E. T., Atey, T. M., Atique, S., Avokpaho, E. F. F. G., Awasthi, A., Ayele, H. T., Barac, A., Barreto, M. L., Bassa, Q., Belay, S. A, Bensenor, I. M, Bhutta, Z. A, Bijani, A., Bizuneh, H, Castañeda-Orjuela, C. A, Dadi, A. F, Dandona, L, Dandona, R, Phuc Do, H., Dubey, M, Dubljanin, E, Edessa, D, Endries, A. Y., Eshrati, B., Farag, T., Feyissa, G T., Foreman, K. J., Forouzanfar, M H., Fullman, N, Gething, P. W, Gishu, M. D, Godwin, W. W, Gugnani, H. C., Gupta, R., Hailu, G. B, Hassen, H. Y., Hibstu, D. T, Ilesanmi, O. S., Jonas, J. B, Kahsay, A, Kang, G, Kasaeian, A, Khader, Y. S, Khalil, I. A., Khan, E. A., Khan, M A., Khang, Y-H, Kissoon, N, Kochhar, S., Kotloff, K. L, Koyanagi, A., Kumar, G. A., Razek, H., Malekzadeh, R., Malta, D. C., Mehata, S., Mendoza, W, Mengistu, D. T., Menota, B. G., Mezgebe, H. B., Mlashu, F. W., Murthy, A., Naik, G. A., Nguyen, C. T., Nguyen, T. H., Ningrum, D. N. A, Ogbo, F. A., Olagunju, A. T., Paudel, D., Platts-Mills, J. A., Qorbani, M., Rafay, A., Rai, R. K., Rana, S. M., Ranabhat, C. L., Rasella, D., Ray, S. E., Reis, C., Renzaho, A. M. N., Rezai, M. S., Ruhago, G. M., Safiri, A., Salomon, J. A., Sanabria, J. R., Sartorius, B., Mawhney, M., Sepanlou, S. G., Shigematsu, M., Sisay, M., Somayaji, R., Sreeramareddy, C. T, Sykes, B. L., Taffere, G. R., Topor-Madry, R., Tran, B. X., Tuem, K. B., Ukwaja, K., Vollset, S. E., Walson, J. L., Weaver, M. R., Weldegwergs, K. G., Werdecker, A., Workicho, A., Yenesew, M., Yirsaw, B. D., Yonemoto, N., Zaki, M. E. S., Vos, T., Lim, S. S., Naghavi, M., Murray, C. J. L., Mokdad, A. J, Hay, S. I. & Reiner Jr, R.C. 2018 Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet Infectious Diseases* **18**(11), 1211–1228. https://doi.org/10.1016/S1473-3099(18)30362-1.

Trudeau, J., Aksan, A.-M. & Vásquez, W. F. 2018 Water system unreliability and diarrhea incidence among children in Guatemala. *International Journal of Public Health* **63**(2), 241–250. https://doi.org/10.1007/s00038-017-1054-6.

Turgeon, S. 2004 Perception of drinking water in the Quebec City region (Canada): the influence of water quality and consumer location in the distribution system. *Journal of Environmental Management* **70**(4), 363–373. https://doi.org/10.1016/j.jenvman.2003.12.014.

United Nations Children's Fund, World Health Organization. 2019 *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2017: Special Focus on Inequalities*. United Nations Children's Fund (UNICEF) and World Health Organization, New York.

World Health Organization. 2017 *Western Pacific Regional Framework for Action on Health and Environment on A Changing Planet*. WHO Regional Office for the Western Pacific, Manila, Philippines.

World Health Organization, United Nations Children's Fund. 2017 *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines*. World Health Organization, Geneva.

Wright, J. A., Yang, H., Rivett, U. & Gundry, S. W. 2012 Public perception of drinking water safety in South Africa 2002–2009: a repeated cross-sectional study. *BMC Public Health* **12**(1), 556. https://doi.org/10.1186/1471-2458-12-556.

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