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Risk perception from the consumption of untreated drinking water in a small island community

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ABSTRACT

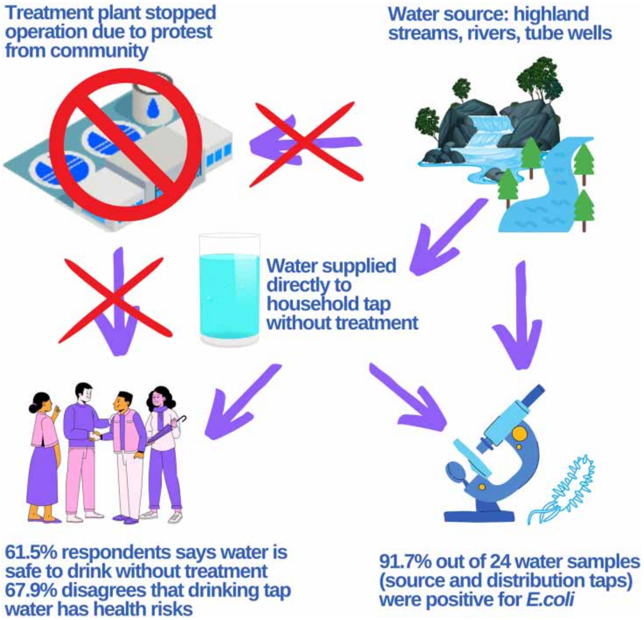
A small island community in Malaysia uses gravity-fed drinking water, and rejected water treatment by the authorities. This study was conducted to evaluate the community's risk perception towards their untreated water supply by interviewing one adult per household in four out of eight villages on the island. The survey asked questions on risk perception, socioeconomic characteristics, and perception of water supply quality. Water samples were collected from a total of 24 sampling locations across the four villages, and 91.7% of them were positive for *E.coli*. The study surveyed 218 households and found that 61.5% of respondents agreed to some degree that the water is safe to drink without treatment, while 67.9% of respondents disagreed to some degree that drinking tap water is associated with health risks, and 73.3% of respondents agreed to some degree that it is safe to drink directly from taps that are fitted with water filters. Using factor analysis to group the risk perception questions and multivariable GLM to explore relationships with underlying factors, the study found that older respondents, lower income level, positive water odour perception and positive water supply reliability perception lowers risk perception. The village of residence also significantly affects the risk perception level in the model.

Key words: drinking water, health risk, remote community, risk perception, rural water supply, water safety

HIGHLIGHTS

- Currently there is very little research in Malaysia on drinking water risk perception.
- This study is looking at remote community risk perception to help shape water resource management.
- This study looks at risk perception of water source and the actual level of faecal indicator.
- Finding from this study can be applied to other small and remote community water supplies in the region.

GRAPHICAL ABSTRACT



INTRODUCTION

Malaysia is committed to ensuring universal access to a safe water supply in order to protect the health of its population and is working towards 99% treated drinking water coverage. Monitoring data revealed that the country has achieved 96% overall treated drinking water coverage, with 99% coverage in urban areas and 89% coverage in rural areas (KeTTHA 2016; WHO 2018). Despite these achievements, the figures reflect the disparity that remains globally between urban and rural areas, as highlighted by the WHO/UNICEF joint monitoring programme (JMP) for water supply, sanitation, and hygiene in their 2017 sustainable development goal (SDG) update report (WHO & UNICEF 2017). Finance, governance and cultural practices are among the main challenges surrounding drinking water supply management and coverage, especially in the rural areas and among small community water supplies. For example, some communities consider it their tradition to find their own water source, without depending on others, and some believe that water, which comes from nature, should be free for everyone to use (Saimy & Yusof 2013; Nelson-Nuñez *et al.* 2019).

Such challenges are reflected in a local community on an island with a population of less than 4,000, who are still using untreated drinking water sources for their daily use. This tropical island with an area of 137 square kilometres is located some 50 kilometres off the west coast of Malaysia (Latitude: 2.790249, Longitude: 104.169846). It receives around 3,000 mm of rain yearly, experiencing a wet season (October to February) and a dry season (March to September), where water shortages occasionally occur. The community lives in coastal villages and sources its water from central highland stream dams, rivers, and tube wells (wells with mechanized pumps constructed around the vicinity of the villages). Households manage their own piping, though working together as a community when necessary is common. In 2008, a drinking water treatment plant was built by the authorities to supply clean water to the island's population. This plant included all the main components of potable water treatment (coagulation and flocculation, sedimentation, filtration, and disinfection with chlorine) but on a smaller scale and lower cost compared with conventional treatment plants in Malaysia for larger communities in non-remote areas. Treated water is supplied to every house via a network of pipes, and a water meter is installed to calculate usage for monthly billing by the public utility department, which fully owns and manages the plant. This follows a national blueprint for drinking water management, with minimal community participation or involvement (DOE 2011; TDA 2012).

The treatment plant had, however, ceased operations due to protest from the community who were not only apprehensive towards chlorinated water but also vouched for the safety of the (untreated) raw water source which had provided water to them for many generations. The authorities, however, believe that the cause of the apprehension in the community was mostly related to the fact that households would be billed for treated water. Limited access to clean water and consumption of water that is contaminated is a major cause of acute diarrheal illness, and studies have shown the presence of disease risk even from untreated pristine surface water, spring water, and ground water (Machdar *et al.* 2013; Barragán *et al.* 2021; Mchiouer *et al.* 2021).

According to Dupont *et al.* (2014), understanding a community's risk perception is useful for implementing an effective drinking water management strategy. Drinking water consumption and behaviour have been shown to be related to the perception of risk (Delpla *et al.* 2020). A study in Sri Lanka by Nauges & Van Den Berg (2009) revealed that the probability of a household treating water by boiling or filtering water before drinking is higher if the perception of safety risk, such as from waterborne illnesses, is higher. Meanwhile, risk perception can be influenced by perception of chemicals in water, information received from outside sources, and the level of trust in water suppliers (Doria *et al.* 2009; Doria 2010). Identification of the different risk perceptions that are relevant to the community and establishing the different issues that influence the risk perception can assist the relevant authorities to develop a more targeted strategy in terms of risk communication and to implement policies and programmes that are more effective in drinking water management (Doria 2010; Brouwer *et al.* 2020).

The problem of drinking water supply resource and management on the island has been longstanding, and various reports and plans have been laid out in the past, and more are planned for the future at local and national level (DOE 2011). However, the success of these intervention programmes at the local level can be hindered by issues such as miscommunication or a lack of understanding of the community (Spicer *et al.* 2020). No previous research had looked at the issue from the community's perspective, or looked at the community's perception of new drinking water supplies. The aim of this study is to assess the risk perception of the island community toward their untreated drinking water source and discover the factors that influence their perception. The findings could assist the authorities in developing a better intervention strategy. This approach might also be introduced to other remote small communities facing similar issues.

METHODOLOGY

Study design

This was a cross-sectional study to discover the risk perception of the community towards the untreated drinking water and underlying factors. The study was conducted from 2014 to 2016, using a survey questionnaire which was administered via face-to-face interview to all the households in the four villages selected for the study. At the same time, water samples on the island were collected and tested for the presence of indicator organisms to assess the level of fecal contamination of the water.

Study site and study population

The study site is an island 50 kilometers off the east coast of west Malaysia with a reported local population of around 3,300 people living in eight different villages.

Sampling methods

Four out of the eight villages on the island were selected to be included in the study. This included the main village with the largest population and three other villages that had the most reliable access from the main village. The selected villages were labelled as: (i) Village A; the main village located on the western side of the island with the largest number of households, (ii) Village B; a smaller village to the north of Village A, (iii) Village C; a village on the east side of the island connected centrally by road to Village A, and (iv) Village D; a village near the northern side of the island accessible via a short boat ride from Village A. Every household in these villages that has access to the main water supply of their respective villages was included in the study once they consented to the interview. Water samples were also collected from all the main water sources in the four selected villages, as well as any holding tanks they supply and the connected point of use (household tap water).

Data collection

A survey questionnaire was used to collect information on risk perception in relation to the currently consumed untreated tap water, chlorine perception, and willingness to pay among the villagers for treated drinking water and their demographics. The questionnaire (Supplementary material, S1; Drinking water consumption, perception, and practice questionnaire) has been modified from a previous study that looked into an individual's perception of their drinking water supply (Doria *et al.* 2005). Only one adult per household was interviewed. For the risk perception variable, the respondents were asked whether they agree that: (i) tap water is safe to be consumed without treatment (ii) there are associated health risks with drinking tap water, and (iii) it is safe to drink directly from a tap fitted with a water filter. The respondents would then give a score based on a Likert scale of one for 'completely disagree' to seven for 'completely agree' to each of these items.

A pilot survey was conducted in 10 households, which helped to identify any issues the interviewers might face on the ground. The data collected during the pilot survey was included in the overall analysis.

Water samples were collected over a five-day period at the beginning of the study from 24 sampling points (8 water source points, 2 storage tanks, and 14 distribution points), where 100 ml of water was collected from each site and tested for the presence of *E.coli* using the Colilert test.

Data analysis

SPSS statistical software version 23 was used for data analysis. From individual socio-demographic data collected from the interviews, composite household socioeconomic variables such as the highest education level in the household and the highest income level in the household were created. A descriptive analysis was conducted to describe the demographic and socioeconomic characteristics of the respondents.

Factor analysis using equamax rotation was applied using SPSS in order to reduce the number of dependent variables (the three risk perception statements described earlier) for analysis, producing one composite dependent variable. Univariate analysis of factors that may influence the new composite variable was then conducted. Factors with a significance level of $p < 0.1$ were then included for multiple linear regression analysis. Factors that remained significant at $p < 0.05$ were selected for the stepwise backward elimination method to identify the best model to explain the relationship between factors and risk perception. Factors that were not significant but had a considerable role in the model were also retained.

RESULTS

Out of 351 households, one respondent from 218 households was available and agreed to be interviewed, giving a 62% response rate. Reasons for non-respondents included no adult occupants present at the household (even after a second visit), and households that did not agree to answer the questionnaire. Refusal reasons included having no time for the interview, households that refuse to answer since they follow the opinion of the head of the larger family, such as the grandfather (though he lives in a different household), and not seeing the research as worthwhile (despite attempts to explain the possible benefits).

There were almost an equal number of female and male respondents, with about an equal distribution of age, except for the lower number of respondents from the oldest age group. Among the respondents, 35% had primary level or no formal education, and 64% had secondary or tertiary level education. The income level was also quite evenly distributed among the respondents, with a percentage of between 16 and 24% at each income level. With regard to the source of drinking water consumption, the large majority of the households interviewed consumed untreated piped tap water from the main dam or river, with only 9% of them either consuming water from tube wells, from spring water, or purchasing bottled water for their drinking water use (Table 1).

From the 24 water samples collected, 22 were positive for *E.coli*. The samples were tested using the Colilert test, which quantified bacterial count using the Most Probable Number (MPN) model (Blodgett 2010). All five main water sources (labelled as 'Intake') were positive, ranging from 3.1 to 304.4 MPN per 100 mL, two water storage tanks (located in Village D) sampled were also both positive at a level of 5.2 and 316.9 MPN per 100 mL, while 13 out of 14 distribution point samples were positive, ranging from 29.5 to 829.7 MPN per 100 mL, and 2 out of 3 samples from tube well collection were positive at 8 and 70.8 MPN per 100 mL (Table 2). More parameters are detailed in supplementary material S2.

There were three statements used to assess risk perception, the descriptive analysis showed that 61.5% of respondents 'agreed to some degree that the water supply is safe to drink without any treatment, giving a score from 5 to 7. The majority also disagreed that drinking tap water was associated with health risks, with 67.9% giving a score of 1 to 3. 73.3% of the respondents also agreed to some degree that it is safe to drink directly from the tap with a water filter, giving a score from 5 to 7 (Table 3).

Factorial analysis of the three risk perception statements produced one new component (Table 4). The new component has strong correlations with the three risk perception variables or statements, showing positive correlations with the two low-risk perception statements and a negative correlation with the high-risk perception statement. Therefore, the new component

Table 1 | Demographics of study participants

Variable	Respondent (%)
Gender:	
Female	113 (51.8)
Male	105 (48.2)
Age (Years):	
13–30	46 (21.1)
31–40	57 (26.1)
41–50	45 (20.6)
51–60	46 (21.1)
61 or >	24 (11.0)
Education level:	
No formal education	10 (4.6)
Primary level	68 (31.2)
Secondary level	91 (41.7)
Tertiary level	49 (22.5)
Income level:	
< RM 1,000	46 (21.5)
RM 1,000–1,999	51 (23.8)
RM 2,000–2,999	47 (22.0)
RM 3,000–3,999	35 (16.4)
RM 4,000 or >	35 (16.4)
Village:	
Village A	141 (64.7)
Village B	21 (9.6)
Village C	38 (17.4)
Village D	18 (8.3)
Main drinking water source:	
Piped from dam/river	192 (88.1)
Piped from tube well	7 (3.2)
Piped from spring	5 (2.3)
Bottled water	7 (3.2)

derived from factorial analysis is defined as 'low-risk perception', since the higher the score means the lower the risk perception.

ANOVA and simple linear regression analysis were then conducted on the new component variable with the independent variables to explore the factors affecting the low-risk perception of untreated drinking water.

This initial analysis revealed that low-risk perception was significantly associated with respondents' age group ($p < 0.001$), education level ($p < 0.001$), income level ($p = 0.009$), village ($p < 0.001$), born in the same village ($p = 0.004$), 'I am happy with colour' ($p < 0.001$), 'I am happy with odour' ($p < 0.001$), 'water supply is reliable' ($p < 0.001$), and years the respondents had lived in the house ($p < 0.001$).

Following the univariate analysis, multiple linear regression using generalized linear model in SPSS was conducted to identify the best fit model that can explain the main factors that influence low-risk perception score. Using a stepwise backward elimination procedure, it was possible to identify a best-fit model that included respondents' age group, income level, village, 'I am happy with odour' and 'water supply is reliable' (Table 5). The model produced a likelihood ratio chi-square of 116.465 ($p < 0.001$).

Table 2 | *E.coli* levels of 24 water samples in the four villages using the Colilert test

Sampling points	*E. coli* (MPN index per 100 mL)	95% confidence limit[a]		DOE Standard[b] (count per 100 mL)	WHO Guideline[c] (count per 100 mL)
		Lower	Upper		
Village A					
Intake	106.7	78.2	140.4	10	0
Point 1	68.9	50.5	93.8	10	0
Point 2	53.7	41.4	67.8	10	0
Point 3	37.9	27	51.2	10	0
Village B					
Intake	304.4	217	401.8	10	0
Point 1	37.3	27.3	49.5	10	0
Point 2	29.5	19.9	41.6	10	0
Point 3	48.8	33.9	67.5	10	0
Village C					
Intake	18.1	11.5	26.9	10	0
Point 1	93.4	70.3	121.9	10	0
Point 2	74.3	53	98.8	10	0
Point 3	49.6	35.4	67.8	10	0
Village D					
Tube 1	8	3.7	15.3	10	0
Tube 2	0	0	0	10	0
Tube 3	70.8	53.2	91.6	10	0
Intake 1	3.1	0.7	8.9	10	0
Intake 2	313	217	439.5	10	0
Point 1	0	0	0	10	0
Point 2	344.1	245.3	472.5	10	0
Point 3	436	310.9	586.6	10	0
Point 4	98.5	72.2	132.1	10	0
Point 5	829.7	623.9	1,108.7	10	0
Tank 1	316.9	232.1	423	10	0
Tank 2	5.2	1.8	10.8	10	0

[a]95% confidence limit based on the MPN table (Blodgett 2010).
[b]DOE standard is for Class I water bodies which requires no treatment (DOE 2021).
[c]WHO guideline for water used for drinking (WHO 2017).

In this model, younger respondents were significantly associated with higher risk perception (negative correlation with low-risk perception). This was shown for those below 50 age groups, compared with those above 60 age groups. While lower income was significantly associated with lower risk perception. There was also a significant difference between the different villages of the respondents. Risk perception was highest in Village A and lowest in Village B. Also, those most unhappy with the odour of the water supply were significantly shown to have higher risk perceptions compared with those most happy with the odour. It also appeared that the happier the respondents were with the water supply, the lower the risk perception, but the difference was not significant.

DISCUSSION

The water sources and their distribution points were tested to assess the drinking water quality and provide some context towards the villagers' perception of the risk of the water to their health. All three highland streams and both rivers sampled

Table 3 | Score for the three risk perception statements

Likert scale	Water supply is safe to drink without treatment (Median = 6; Mode = 7) N (%)	There are health risks associated with drinking tap water (Median = 1; Mode = 1) N (%)	It is safe to drink directly from tap fitted with water filter (Median = 6; Mode = 7) N (%)
1 (Completely disagree)	43 (19.7)	119 (54.6)	30 (13.8)
2	9 (4.1)	15 (6.9)	5 (2.3)
3	14 (6.4)	14 (6.4)	10 (4.6)
4	18 (8.3)	19 (8.7)	13 (6.0)
5	21 (9.6)	19 (8.7)	21 (9.6)
6	35 (16.1)	15 (6.9)	57 (26.1)
7 (Completely agree)	78 (35.8)	17 (7.8)	82 (37.6)

Table 4 | Factorial analysis component matrix (one component extracted) on risk perception

Risk perception variable	Correlation with component 1
Low-risk perception statements	
• Water supply is safe to drink without treatment	0.787
• It is safe to drink directly from tap with water filter	0.761
High-risk perception statement	
• There are health risks associated with drinking tap water	−0.662

Extraction Method: Principal Component Analysis.

in the study were positive for *E. coli* (Table 2, S2). The central part of the island, where the highland streams are located, consists mostly of secondary forest, and common wild animals include mouse deer, macaques, pythons, monitor lizards, and flying foxes. Small-scale cattle farming and feral cattle can also be found in some parts of the island, including where the river sources are located (TDA 2012).

The island does not have an integrated sewage system, and villagers relied on individual septic tanks that weren't regularly maintained. During the dry seasons, the main water source can run low, and villagers will look for alternative spring water or get their water from available tube wells (TDA 2012). This study was conducted in September, which coincided with the end of the dry season. A more detailed study with repeated sampling would give a more accurate picture of the quality of the various water sources on the island.

From the overall response to the three risk perception statements of drinking water variables, most villagers felt that their untreated drinking water source is safe for consumption. Based on the low-risk perception component (from factorial analysis of three risk perception statements), the older the age group, and the lower the income level, the safer they felt with untreated drinking water. The more satisfied the respondents were with the odour and the reliability of the water supply, the more they believed the untreated water to be lower risk. Also, the risk perception level was different between different villages in the study.

Previous studies have shown contrasting results regarding the relationship between age and risk perception. The findings of this study agreed with the study by Park (Park *et al.* 2001), which showed that younger people perceived tap water as less safe. A more recent study linked young people's higher perception of health risk to access to information on water quality from the media (Crampton & Ragusa 2016). However, other studies have shown different results, where older people are more sensitive to health risk (Kim *et al.* 2018).

In this study, there is a suggestion that the older generation was more trusting of their drinking water source and believed that the natural water was pure and safe without the need for treatment, especially with chemicals. Data from the survey showed that the median age of respondents who claimed that water treated with chlorine contained chemicals dangerous

Table 5 | Multiple linear regression of dependent variables with low risk perception

Variables/factors		B	95% Confidence Interval Lower	Upper	Sig.
Age group	13–30	**−0.921**	**−1.371**	**−0.471**	**< 0.001**
	31–40	**−0.603**	**−1.033**	**−0.173**	**0.006**
	41–50	**−0.603**	**−1.027**	**−0.179**	**0.005**
	51–60	−0.166	−0.595	0.262	0.447
	>60	0			
Income	< 1,000	**0.510**	**0.111**	**0.909**	**0.012**
	1,000–1,999	**0.477**	**0.085**	**0.868**	**0.017**
	2,000–2,999	**0.419**	**0.054**	**0.783**	**0.024**
	3,000–3,999	0.216	−0.180	0.613	0.285
	≥4,000	0			
Village	Village D	**0.628**	**0.137**	**1.120**	**0.012**
	Village C	**0.582**	**0.258**	**0.906**	**< 0.001**
	Village B	**0.801**	**0.394**	**1.208**	**< 0.001**
	Village A	0			
Happy with odour	1 Completely disagree	**−1.511**	**−2.226**	**−0.797**	**< 0.001**
	2	**−1.583**	**−2.292**	**−0.875**	**< 0.001**
	3	−0.142	−0.770	0.485	0.657
	4	−0.359	−0.786	0.068	0.099
	5	**−0.459**	**−0.839**	**−0.080**	**0.018**
	6	**−0.562**	**−0.908**	**−0.216**	**0.001**
	7 Completely agree	0			
Water supply reliable	1 Completely disagree	−0.217	−0.601	0.167	0.267
	2	0.095	−0.445	0.635	0.730
	3	0.164	−0.326	0.655	0.511
	4	0.303	−0.096	0.702	0.137
	5	0.407	−0.007	0.821	0.054
	6	0.212	−0.153	0.576	0.255
	7 Completely agree	0			

Significant findings ($p < 0.05$) in bold.

to health was 45 years, compared with 39 years among those who claimed otherwise ($p < 0.05$). The median age of respondents who didn't treat water before drinking was 46, compared with 41 years for those that did, but that finding was not statistically significant. A study in Ireland on private well owners had a similar finding where they underestimated the risk of contamination to their well and had a strong positive perception of their well water, as well as thinking that the well water is natural and free from chemicals (Hooks *et al.* 2019).

Findings from previous studies by Hooks *et al.* (2019) and Doria (2010) showed that trust in the water supplier and a sense of control or ownership of the water supply can influence drinking water risk perception and behaviour. Since the households and the community were used to managing their water supply on their own, they may not trust the new management, and this may influence how much they feel that the water supplied to them is safe. However, this study did not explore trust in water suppliers, only water supply reliability, which we demonstrated significantly influenced risk perception.

Previous studies looking at the relationship between income and perception of risk from drinking water have been mixed (Doria 2010). The finding from this study could be related to the ability to consider alternatives to the established drinking water supply, which is less for those with low income, who are more likely to tolerate issues with their drinking water (Doria *et al.* 2005; Majuru *et al.* 2016).

The finding on the perception of drinking water odour and water supply reliability is similar to previous studies on risk perception, which showed that organoleptics and trust in water supply play an important role in influencing drinking water choice (Triplett *et al.* 2019) and influencing the perception of the safety of the water supply (Doria *et al.* 2009; Nauges & Van Den Berg 2009). The 2009, Nauges and Van Den Berg study in Sri Lanka also revealed that a household's perception of risk depended not only on the water's characteristics of taste, smell, and colour (organoleptics), but also on their level of education and their awareness of proper hygiene practices.

Happiness with water odour is related to a lower perception of health risk. This suggests that a properly treated water supply that is not thought to have a bad smell can lead to an improved risk perception among the community. However, it may also mean that a water supply that smells familiar is more trusted and considered safe by the user. This may explain why some of the study population prefers untreated natural water, which tastes or smells familiar to them compared with chlorinated treated water.

The final significant independent variable was the village of the respondent. Village A has the highest perception of risk. It is the main village on the island with a school, a health clinic, and many other administrative offices. It has the highest percentage of residents migrating from the mainland. During initial univariate analysis, factors related to where the person was born and house ownership were significant. Those born on the island and those who own houses believe the health risk from untreated water is lower compared with people migrating from outside and people who are staying in staff living quarters. These factors, however, did not appear in the best fit model.

This can be compared with studies by Spicer *et al.* (2020) and Dupont *et al.* (2014), that looked at health risk perceptions and practices in first nations communities in Canada. Spicer found that some water sources had significant cultural value to the community, while Dupont suggested that differences in risk perception could be attributed to culture. Culture shapes people's views on the significance and meaning of water, which will affect their perception of water treatment.

There were two limitations to this survey. First, we had to select villages that were the most accessible to be included in the study, and this could lead to sampling bias. Sampling bias could skew the result of a study and produce a result that does not represent the study population. We do know, however, that the other villages that were not included had similar water supply systems to those included in the study, and that the four selected villages represented more than half of the population of the whole island. Second, the study also faced respondent bias, as the local community could have a negative perception of outsiders doing a study on drinking water, as this has been a long-standing issue in their community. They could be more likely to give what can be seen as 'positive' replies. As much as possible, we explained to the respondents that the study team did not represent any group, especially not the local government or health authorities, before doing the survey. However, this bias would only make the result more conservative, meaning that the risk perception could possibly be lower than our estimates.

CONCLUSION

This research showed that risk perception is an important issue in the community that influences their acceptance of drinking water intervention programmes. There was also evidence that an individual's risk perception of untreated drinking water was related to the respondent's age, perception of odour (organoleptic) and which village they were from. Older people on the island believe the health risk from untreated water is lower, while those with a negative perception of odour believe the health risk to be higher. There are also certain characteristics of the villages, such as the different backgrounds of the respondents in each village, that also differentiate the risk perception level between the villages, though this needs to be explored further in another study. We recommend that local authorities involved in health promotion and health intervention programmes provide more information on health risk to the community and get the community involved. This could include sharing information about water source contamination with community leaders or integrating it into health education programmes for the younger generations and using community participation strategies in drinking water management. A more detailed study on the water quality and safety of the drinking water sources could also provide stronger evidence of health risk. The study approach can also be applied to other small or remote communities in Malaysia that face similar issues.

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ETHICAL APPROVAL

This research was registered under National Medical Research Register (NMRR 14-608-20003) and has obtained ethical approval from the Malaysian Medical Research & Ethics Committee (KKM/NIHSEC/P14-782) and from the General Research Ethics Committee University of East Anglia.

DATA AVAILABILITY STATEMENT

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

CONFLICT OF INTEREST

The authors declare there is no conflict.

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