

RESEARCH ARTICLE

A COMPARATIVE INVESTIGATION OF PERCEIVED QUALITY, TRUST, AND SUSTAINABILITY IN POTABLE AND BOTTLED WATER CONSUMPTION

Mohammad A. Tabieh^a, Chiraz Zidi^b, Ahmad Jamrah^c, Tharaa Al-Zghoul^{d*}, Emad Al-Karablieh^a

^aDepartment of Agricultural Economics and Agribusiness, School of Agriculture, The University of Jordan, Amman 11942, Jordan

^bDepartment of Civil Engineering, Muscat University, Sultanate of Oman

^cDepartment of Civil Engineering, School of Engineering, The University of Jordan, Amman 11942, Jordan

^dDepartment of Civil Engineering, Faculty of Engineering, Tafila Technical University, Tafila 66110, Jordan

*Corresponding Author Email : jamrah@ju.edu.jo, tharaaalzghoul@gmail.com

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ABSTRACT

The growing global demand for bottled water (BW) as a freshwater source persists, despite the availability of various potable water alternatives. This study aimed to investigate the reasons behind the public's preference for BW over other accessible potable water sources. The research approach involved evaluating the quality of selected water parameters across different potable water sources, including commercial BW types. The study concluded that all types of BW used in the study are compatible with the prevailing BW standards; with the exception of one type that violated the "fluoride" requirement and three types that violated the "nitrate" requirement. The study also concluded that all types of potable water used in the study are compatible with the prevailing drinking water standards; with the exception of one type (groundwater) that violated the "fluoride" and "chloride" requirements, and all types violated the "nitrate" requirement. Concurrently, a social survey of 97 households revealed that 81% identified tap water as their primary freshwater source, used for cooking (80%), cleaning (88%), drinking (38%), and irrigation (65%). Despite generally positive perceptions of tap water quality, 86% of respondents believed BW has better quality. Furthermore, 53% used only BW for drinking, and 68% expressed distrust in alternative supplies. Results of the social survey indicated that 81% of the respondents stated that tap water is their primary source of household freshwater.

KEYWORDS

Bottled water, Drinking water standards, Potable water, Social survey, Water quality.

1. INTRODUCTION

The world's freshwater resources are increasingly threatened by anthropogenic pollution, which can negatively impact the physical, chemical, and microbiological quality of water at the source (Aliyu et al., 2023; Jamrah et al., 2023; Hamaideh et al., 2024). This may necessitate additional treatment costs to render the water compliant with prevailing potable water (PW) standards (Abolli et al., 2023). The use of potable freshwater sources by households is becoming more dependent on the water quality at the point of use. Concurrently, the consumption of bottled water (BW) for potable purposes has grown remarkably in recent years. It is noteworthy that the drinking water quality standards governing PW and BW differ significantly (Abolli et al., 2023; Teymoorian et al., 2023). The study has reported that health concerns associated with PW consumption have driven the growth of the BW industry. Other factors contributing to the increased demand for BW include lifestyle changes, the ease of handling and portability of BW, and consumer preferences for water rich in vitamins and minerals (Mordor Intelligence, 2018). These factors have led to a more dynamic and expanding BW industry. This rapid growth highlights the evolving role of BW in the water consumption landscape, as consumers seek alternatives to traditional PW sources.

However, it is important to note that the drinking water quality standards governing PW and BW differ significantly. Several recent studies have investigated the quality of both PW and BW, providing insights into the comparative assessments of water sources. The analysis investigated the

physical, chemical, and microbiological quality of different BW brands commercially available in Lahore, Pakistan (Nazir et al., 2022). They selected five locally produced and four national brands, and analyzed parameters, major cations and anions, as well as the presence of arsenic, total coliforms, and fecal coliforms/*Escherichia coli*. The results revealed remarkable differences in the water quality among the brands. While most brands met the national and international standards, one brand had sodium and arsenic levels exceeding the permissible limits. Additionally, some brands were found to be deficient in essential minerals like magnesium and calcium. Microbiological analysis showed the presence of total coliforms in several brands, indicating potential contamination issues. The researchers also assessed the efficiency of the treatment plants by comparing the quality of raw and processed water, finding that plants using low-TDS raw water or a 50% blending technique were more cost-effective (Nazir et al., 2022).

The researchers investigated the exposure of BW to sunlight and its impact on the leaching of heavy metals into the water, thereby deteriorating its quality (Umoafia et al., 2023). Three plastic bottle brands (n = 100 per brand) were exposed to sunlight for different durations. The leaching of contaminants was exposure duration dependent. Health risk evaluation revealed possible Cr, Cd, Pb, As, and Ni toxicity, with Cr, As, and Ni posing potential carcinogenic risks. Arsenic posed the highest non-carcinogenic risk, while Ni posed the highest carcinogenic risk in all brands after 42 days of exposure. The microbial parameters also failed to meet the WHO safety limits. The findings suggest that the exposure of bottled water to sunlight

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should be avoided to ensure a healthy population (Umoafia et al., 2023). Similarly, investigated the chemical quality of PW in Thailand, including water from rivers, taps, BW, groundwater, and commercial ice cubes, and found minor pollution with a range of organic and inorganic contaminants (Kruawal et al., 2005).

The analysis investigated revealed that despite the availability of cheap and safe tap water in Flanders, Belgium, the consumption of BW remains widespread, driven primarily by negative perceptions about tap water's health, safety, and taste (Geerts et al., 2020). However, the researchers also highlighted the importance of broader social factors, including infrastructural issues that limit access to potable tap water and social norms that favor BW. Additionally, demographic characteristics like gender, age, and education level were found to influence BW usage, with men, older individuals, and those with lower education levels more likely to be heavy consumers. To address this challenge, the study recommends an integrated approach encompassing advertising campaigns to change perceptions, ensuring universal tap water access, and targeted interventions for high-consumption groups, all of which consider the product (type of water), the consumer, and the broader social context.

In contrast, reported that BW, rainwater, and tap water samples in Cairo, Egypt, were within the acceptable limits set by the World Health Organization (WHO) and below the EPA's maximum contaminant levels for drinking water (Saleh et al., 2001). Further, investigated the presence of metals in the freshwater of 101 households in Riyadh, Saudi Arabia, and compared it to 21 commercially available BW brands, finding that the levels of several metals, including Cd, Fe, Hg, Ni, and Zn, exceeded the guideline limits recommended by European and WHO standards (Al Saleh and Al Doush, 1998). examined the physical and chemical quality of PW produced from various sources in Kuwait and compared it to 20 commercially available BW brands, reporting that all samples complied with World Health Organization standards (Al Fraij et al., 1999). In contrast, analyzed the chemical quality of 25 BW brands available in Alabama, United States, and found that most samples did not comply with U.S. Environmental Protection Agency (EPA) or European drinking water standards for total organic carbon and a variety of metals, including As, Cd, Hg, Zn, Se, and Ti, violated both the American and European standards (Ikem et al., 2002).

These studies highlight the complex and sometimes contradictory nature of water quality assessments, emphasizing the need for a comprehensive and comparative analysis of the social, analytical, and sustainability aspects of PW and BW consumption. This will help inform policies and interventions aimed at ensuring safe and sustainable water supplies for all. An understanding of the motives behind the extensive use of BW for potable purposes is essential. These motives could be based on knowledge of the quality of available sources of household freshwater. They can also be based on freshwater use, economic conditions and social constraints. As a result, this study aims at understanding the reasons that encourage the public to consume BW as a freshwater source rather than other available potable freshwater sources. To achieve this objective, this research will provide an attempt to: 1) investigate the quality of available potable

freshwater sources and compare that to the governing drinking water standards, 2) investigate the quality of market-available BW and compare that to the governing BW standards, 3) conduct a social study for the purpose of profiling the participating households in terms of family size, economic status, source of household freshwater, perception of water quality, possible water use, and reasons for preferring certain types of water over others.

2. METHODS

A study was conducted to assess the water quality of five household freshwater sources and 11 commercially available BW brands. Water samples were collected on a weekly basis for three weeks from the following freshwater sources: two groundwater sources, one filtered water source, one tanker water source, and tap water. The collected freshwater and BW samples were analyzed for key physical and chemical water quality parameters, including pH, electrical conductivity, total dissolved solids (TDS), turbidity, chloride, fluoride, alkalinity, hardness, nitrite, nitrate, sulfate, and phosphate. All analyses were performed in duplicate and compared to drinking water and BW quality standards, following the Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

Additionally, a social survey was conducted using a questionnaire to profile the participating households in terms of family size, economic status, freshwater source, perception of water quality, water usage patterns, and reasons for preferring certain water

types. The survey covered a total of 97 households, comprising 727 people. The collected data included the number of household members, freshwater source, presence of color/taste/odor in

the freshwater, different uses of freshwater, use of BW, and motivations for BW consumption. Statistical analyses were then performed to present the findings from the social survey.

3. RESULTS AND DISCUSSIONS

Table 1 presents the results of the physical and chemical water quality parameters measured for the five produced water sources selected for this study. The measured values are compared against the prevailing drinking water standards as well as the standards for BW.

Table 1 includes information on the measured values for various physical and chemical water quality parameters. For each parameter, Table 1 shows the measured concentration or value from the produced water sources, and indicates whether these fall within the acceptable limits defined by the drinking water standards and BW standards. This provides a comprehensive overview of the water quality characteristics of the selected produced water sources compared to the relevant benchmarks, allowing an assessment of the suitability of the produced water for different potential uses or treatment requirements, whether for potable consumption or other industrial/agricultural applications.

Table 1: Results of selected quality parameters for the various types of water used in the study along with the adopted quality standards.

Parameter	Groundwater 1	Groundwater 2	Filtered Water	Tap Water	Tanker Water	BW	Drinking Water Standards	BW Standards
T (°C)	19.6	23	22.6	19.7	19.7	20.6	Acceptable	
EC (µS/cm)	15.87	10950	258.95	355	423.5	252.2		
TDS (mg/L)							120 - 600	100 - 600
pH	8.05	7.1	7.92	8.39	8.4	7.63	6.5 - 8.0	6.5 - 8.0
Turbidity (NTU)	0.08	0.27	0.44	0.64	0.64	0.19	1 - 5	5
Fluoride (mg/L)	0.6	2	0.09	0.15	0.2	0.08	< 1.5	0.8 - 1.5
Chloride (mg/L)	238.43	3068.7	1.93	3.57	4.24	3.16	< 250	
P-Alkalinity (mg/L)	0.48	0	0	0.34	0.16	0		
M-Alkalinity (mg/L)	11.57	6.75	3.78	5.51	5.7	3.43		
T-Hardness (mg/L)	4.6	109.8	7.53	6.73	6.48	5.82	200 - 500	< 200
Ca Hardness (mg/L)	2.34	84.9	3.29	1.88	2.64	3.47		
NO ₃ ⁻ (mg/L)	2.7	6.1	3.2	1.6	3.9	3.9	< 50	50
NO ₂ ⁻ (mg/L)	2	4	12.5	9	1.5	11	0.2 - 3.0	0.2
SO ₄ ²⁻ (mg/L)	101	30	48	47.5	61	18.5	< 250	250
PO ₄ ³⁻ (mg/L)	1.5	1.85	10.01	17.96	2.95	1.67		

The water quality parameters for the five produced water sources examined in this study are presented in Table 1, alongside the applicable drinking water standards and BW quality standards. Analysis of the data in Table 1 reveals that the produced water samples generally met the drinking water quality criteria, with a few exceptions. Specifically, the groundwater-derived produced water source exceeded the regulatory limits for fluoride and chloride concentrations. Additionally, all five produced water sources failed to comply with the nitrate standard for

drinking water.

Similarly, Table 2 shows the physical and chemical characteristics of 11 commercially available brands of BW ((noted in the table as BW)) that were also evaluated in this study. These BW quality parameters are likewise compared against both drinking water standards and typical BW standards.

Table 2: Comparative analysis of selected quality parameters for the various types of BW consumed in Oman used in the study along with the adopted quality standards.

Parameter	Type of BW											Standards	
	BW 1	BW2	BW 3	BW 4	BW 5	BW 6	BW 7	BW 8	BW 9	BW10	BW 11	BW	Drinking water
pH	7.8	7.8	7.7	7.1	7.5	7.6	6.8	7.8	7.4	7.9	7	6.5 – 8.0	6.5 – 8.0
TDS (mg/L)	120	120-180	115	120	120	135	120	120	150	120	110	120 – 600	100 - 600
T _{hardness} (mg/L)									50		53	200 - 500	< 200
Iron Fe (mg/L)									1			1	0.3
Bromate (mg/L)									<0.01			0.01	10 µg/L
Bicarbonate (mg/L)	23	27	22.5		26	16	38	18.4	70				
Sulfate (mg/L)	16	19	15	49	<5	<1	6	5	25	0.5	51	< 250	< 250
Sodium (mg/L)	11.9	10	11.6		12	10	8	11.5	15	15	16	< 200	
Calcium (mg/L)	7.9	3.4	7.5	1.2	18	24	19.5	5.2	15	13.9	<5		
Chloride (mg/L)	36	47	35		62	68	50	14	55	46.3		< 250	
Magnesium (mg/L)	9.7	19	9.2	12.48	8	8	6.5	3	10	13.9	13	30 – 150	150
Nitrate (mg/L)	1	0.4	1		<0.1	0.05			5		<0.1	0.2 – 3.0	50
Fluoride (mg/L)								0.06	1			1.5	0.8 – 1.5
Potassium (mg/L)	1	0.2	1	0.6	<0.1	<0.1	5	0.8	5	nd	1		

The comprehensive dataset presented in these two tables allows for a thorough evaluation of the suitability of the produced water and BW sources for various applications, whether for potable use, industrial processes, or other purposes. The identification of any water quality parameters that fall outside the accepted standards provides valuable information to guide the need for appropriate treatment or management strategies.

Investigation of Table 2 shows that all eleven types of BW used in the study are compatible with the prevailing BW standards; with the exception. One BW source exceeded the regulatory limit for fluoride concentration, while three BW sources failed to comply with the nitrate standard.

Complementing the water quality data, the study also included a social survey administered to a sample population of 727 individuals representing 97 households, with an average family size of 7.5 members. The survey results, as illustrated in Figure 1, indicate that 81% of the respondents identified tap water as their primary household freshwater source.

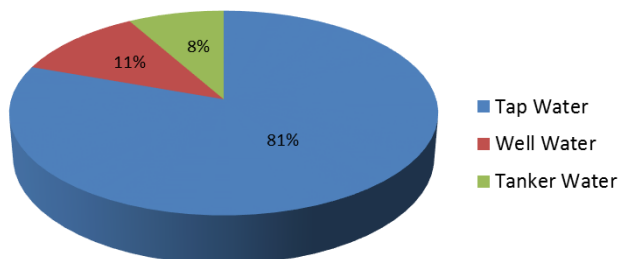


Figure 1: Source of household freshwater as reported by social survey respondents.

The integration of the quantitative water quality analysis and the qualitative social survey data provides a multifaceted understanding of the water resources and usage patterns within the study area. This holistic approach can inform the development of effective water management strategies to address the needs and preferences of the local community.

Based on the information provided in Figure 2, the social survey results reveal important insights into the household freshwater usage patterns within the study population.

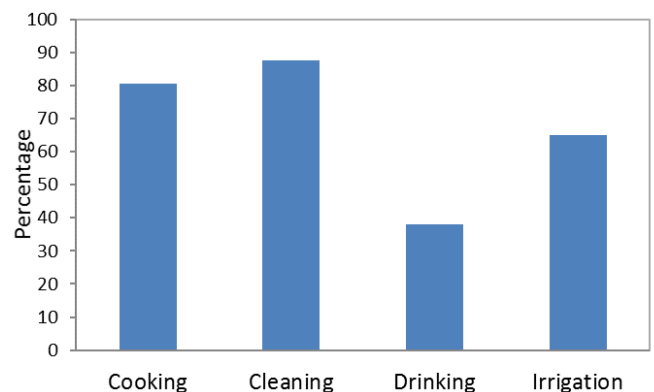


Figure 2: Distribution of social survey respondents when asked about the different uses of their source water in their households.

As presented in Figure 2; when asked about the different uses of household freshwater, the majority of respondents, at 80%, reported using freshwater for cooking purposes. An even larger proportion, 88%, indicated that they utilize freshwater for cleaning activities. These findings suggest that essential household tasks, such as food preparation and maintaining cleanliness, represent the primary drivers of domestic freshwater demand in the surveyed community.

In contrast, only 38% of households stated that they use freshwater for drinking purposes. This relatively lower percentage highlights the potential for improving access to safe and palatable drinking water sources, which could lead to increased consumption of freshwater for direct human consumption.

Additionally, 65% of respondents noted that they use freshwater for landscape irrigation, reflecting the importance of outdoor water use for activities such as gardening and lawn maintenance. This information can guide the development of targeted water conservation strategies, potentially including the promotion of drought-tolerant landscaping or the implementation of efficient irrigation systems.

The detailed understanding of these freshwater usage patterns, as

presented in Figure 2, can inform the design of holistic water management approaches that address the diverse needs and priorities of the local community. By identifying the primary areas of freshwater consumption, policymakers and water professionals can develop more effective and tailored solutions to promote sustainable water use practices.

The social survey also explored the respondents' perceptions of the water quality attributes associated with their freshwater source, as presented in Figures (3, 4, 5, 6, and 7). It is important to note that these responses are subjective in nature and should not be interpreted as definitive assessments of the actual freshwater quality. However, these perceptions are regarded as the primary drivers behind the respondents' preference for using BW for drinking, rather than the available potable (tap) water.

According to Figure 3, only 57% of the respondents reported that their household freshwater source does not have any noticeable color. This suggests that a significant proportion of the population perceives their tap water to have an undesirable color, which may influence their decision to seek alternative water sources for drinking.

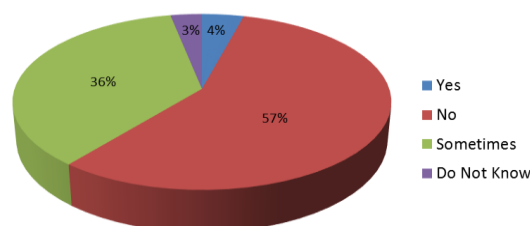


Figure 3: Distribution of social survey respondents when asked if their source water has a color.

The subsequent Figures provide further insights into the respondents' subjective assessments of other water quality parameters. While these perceptions do not necessarily reflect the true water quality, they nonetheless represent the community's lived experiences and concerns, which can shape their water usage behaviour and preferences.

Continuing the analysis of the respondents' subjective perceptions of their household freshwater quality, Figure 4 reveals that only 45% of the respondents reported that their freshwater source does not have any noticeable taste.

This finding suggests that a significant proportion of the population, 55%, perceive their tap water to have an undesirable taste. The perception of poor taste can be a major deterrent for the use of tap water for drinking purposes, as people often prefer water that is perceived to be clean, fresh, and palatable.

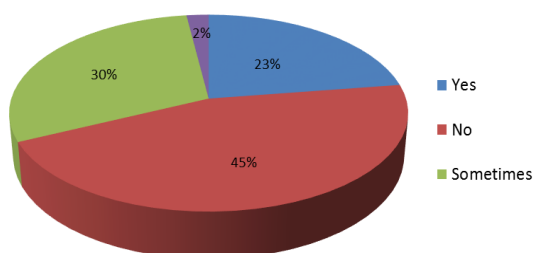


Figure 4: Distribution of social survey respondents when asked if their source water has a taste.

The prevalence of taste-related concerns, as indicated by the data in Figure 4, highlights the importance of addressing this issue from the community's perspective. Factors such as water treatment processes and source water characteristics can all contribute to the perceived taste of tap water.

By understanding the community's subjective assessment of taste, water management authorities can focus their efforts on improving the organoleptic properties of the potable water supply. This could involve optimizing treatment techniques, upgrading distribution infrastructure, or even better communicating the safety and quality of the tap water to build trust and confidence among the users. Addressing the perceived taste

issues can be a crucial step in promoting the acceptance and utilization of the available potable water sources, ultimately leading to more sustainable and equitable water use patterns within the community.

The survey data presented in Figure 5 indicates that 69% of respondents reported their household freshwater source does not have any noticeable odour. This suggests a generally positive perception of the odour-related characteristics of the available potable water supply among the community. Water management authorities can leverage this information to address any underlying issues and effectively communicate the quality of the tap water, thereby promoting its acceptance and utilization.

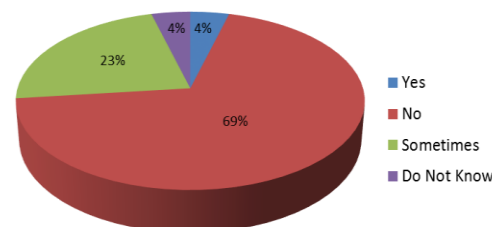


Figure 5: Distribution of social survey respondents when asked if their source water has an odor.

Additionally, according to Figure 6, 58% of respondents reported the formation of a calcareous layer in their household heating pots. This suggests the local tap water has elevated mineral content, particularly dissolved calcium and magnesium, leading to scale build up in water-based appliances. Water management authorities can use this information to assess water hardness levels and implement appropriate treatment measures to address the scale formation issue and improve the overall quality of the tap water for domestic use (Abolli et al., 2023).

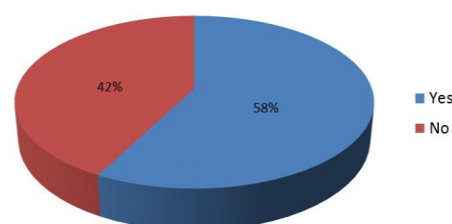


Figure 6: Distribution of social survey respondents when asked if their source water resulted in calcareous layer in their heating pots.

According to Figure 7, only 50% of respondents reported that their household freshwater source did not result in any sickness among their family members. This suggests a significant proportion of the population experienced health-related issues potentially linked to the local tap water supply. Water management authorities should investigate this issue further and implement appropriate interventions to ensure the safety and quality of the community's drinking water.

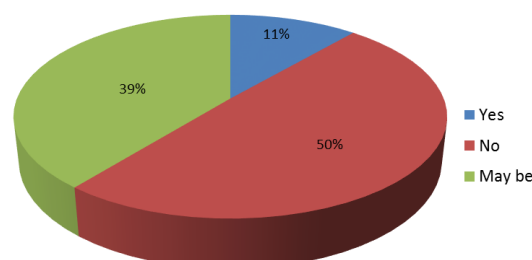


Figure 7: Distribution of social survey respondents when asked if their source water resulted in sickness of one of their family members.

Results of the social survey presented in Figures (8, 9 and 10) constitute an attempt to better understand the motives of survey sample population

for preferring BW for drinking when compared to their household freshwater source.

When asked how often do they use BW for drinking, as shown in Figure 8, 53% of the survey respondents reported using BW for drinking all the time, indicating a strong preference for BW over their household freshwater source.

This suggests the community perceives significant advantages in BW compared to the local tap water, which water management authorities should investigate further to understand the underlying concerns or perceptions driving this preference. Addressing the root causes could help improve public trust and reduce reliance on bottled water alternatives.

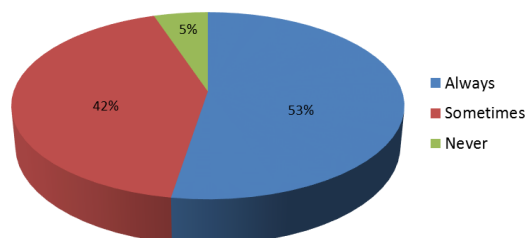


Figure 8: Distribution of social survey respondents when asked about how often they use BW for drinking in their households.

According to Figure 9, 68% of respondents cited the better quality of BW as the primary reason they use it instead of their household freshwater source. This suggests significant public concerns about the quality and characteristics of the local tap water, highlighting the need for water authorities to investigate and address these perceptions through water quality assessments, system improvements, and public education.

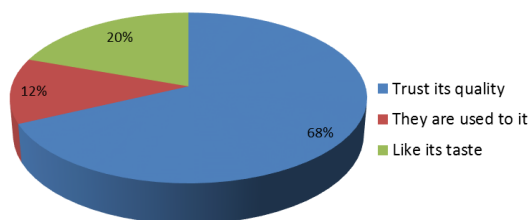


Figure 9: Distribution of social survey respondents when asked about why they use BW for drinking in their households.

Finally, according to the results presented in Figure 10, an overwhelming 86% of the survey respondents agreed that BW has better quality compared to their household freshwater source. This finding indicates a strong public perception that BW is a superior drinking water option over the local tap water supply. The high percentage of respondents who believe BW is of better quality suggests significant distrust in the quality and characteristics of the household water source.

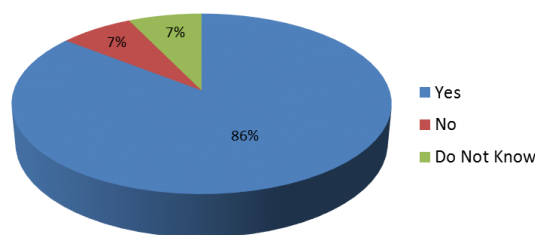


Figure 10: Distribution of social survey respondents when asked if BW has better quality when compared to tap water in their households.

Water authorities should investigate and address these concerns through comprehensive water quality assessments, system improvements, and effective public education campaigns. Addressing the root causes of this widespread preference for BW could help reduce reliance on the more expensive and less sustainable bottled water alternative.

4. CONCLUSIONS

The study evaluated the quality of eleven BW samples and five PW samples in relation to prevailing standards. The results showed that all eleven BW samples met the applicable BW standards, except for one sample that violated the fluoride requirement and three samples that violated the nitrate requirement. For the PW samples, all five met the drinking water standards, except for one groundwater sample that violated the fluoride and chloride requirements, and all five samples that violated the nitrate requirement.

The social survey findings indicated that 81% of respondents identified tap water as their primary household freshwater source. The reported uses of household freshwater were 80% for cooking, 88% for cleaning, 38% for drinking, and 65% for landscape irrigation. Regarding perceived freshwater quality, 57% of respondents reported no issues with color, 45% reported no taste concerns, and 69% reported no odour problems. Despite this, 53% of households used only BW for drinking, and 68% expressed a lack of trust in the quality of other household freshwater sources. Notably, 86% of respondents believed that bottled water has better quality compared to their household freshwater supply.

These findings highlight a significant disconnect between the measured water quality and public perceptions. The strong preference for BW, even among those satisfied with tap water, suggests deep-seated skepticism about the reliability and safety of local water infrastructure. Water authorities should investigate the reasons for this mistrust and implement strategies to address community concerns through improved communication, monitoring, and potential infrastructure upgrades. Addressing the root causes of this widespread tap water skepticism could reduce reliance on the more expensive and environmentally-taxing BW alternative.

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