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Differences in Water Consumption Choices in Ghadames City: Perceptions of Environmental and Health Risks

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الاختلافات في خيارات استهلاك المياه في مدينة غدامس: تصوّرات المخاطر البيئية والصحية

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Abstract
Safe and reliable drinking water is a fundamental public health concern, particularly in arid regions where water sources may be limited or vulnerable to contamination. The results revealed a clear dominance of bottled water consumption (53%), followed by domestic desalinated water (51%), indicating a decline in trust toward traditional water sources. The preference for bottled water was primarily driven by health and contamination concerns (56%), better taste (48%), and availability (36%), while the low reliance on wells and public network water was linked to uncertainty about chemical composition and supply safety. Information about water quality was mostly obtained through the internet (34%) and bottle labels (38%). Participants also expressed specific health related fears, including the absence of essential minerals in bottled water and the potential hazards of plastic containers, whereas concerns about tap or well water centered on mineral content, chlorine levels, and supply quality. Overall, the findings underscore a growing public preference for bottled and filtered water due to perceived safety and quality advantages, coupled with a declining confidence in local water infrastructure.

Keywords: bottled water, tap water, well water, health risks, contamination.

الملخص
تُعدّ المياه الصالحة للشرب الآمنة والموثوقة قضيةً أساسيةً في مجال الصحة العامة، لا سيّما في المناطق القاحلة حيث تكون مصادر المياه محدودة وأكثر عرضة للتلوث. وقد أظهرت النتائج هيمنة واضحة لاستهلاك المياه المعبأة (53%)، تليها المياه المُحلّاة منزليًا (51%)، مما يعكس تراجع مستوى الثقة في مصادر المياه التقليدية. وقد ارتبط تفضيل المياه المعبأة بشكل أساسي بالمخاوف الصحية ومخاطر التلوث (56%)، وتحسّن المذاق (48%)، وسهولة التوافر (36%). في المقابل، عُزي انخفاض الاعتماد على مياه الآبار ومياه الشبكة العامة إلى عدم اليقين بشأن التركيب الكيميائي وسلامة الإمداد المائي. وقد استقى المشاركون معلوماتهم المتعلقة بجودة المياه بشكل رئيسي من ملصقات عبوات المياه (38%) ومن شبكة الإنترنت (34%). كما عبّر المشاركون عن مخاوف صحية محددة، شملت غياب بعض المعادن الأساسية في المياه المعبأة والمخاطر المحتملة المرتبطة باستخدام العبوات البلاستيكية، في حين تمحورت المخاوف المتعلقة بمياه الصنبور أو الآبار حول المحتوى المعدني ومستويات الكلور وجودة الإمداد. وبوجه عام، تُبرز هذه النتائج تزايد تفضيل الجمهور للمياه المعبأة والمُفلترة نظرًا لما يُدرك من مزايا تتعلق بالسلامة والجودة، إلى جانب تراجع الثقة في البنية التحتية المحلية للمياه.

الكلمات المفتاحية: المياه المعبأة، مياه الصنبور، مياه البئر، المخاطر الصحية، التلوث.

1. Introduction

Libya exemplifies acute water stress, situated in the heart of North Africa's arid belt with one of the lowest precipitation rates globally. Consequently, the nation is almost entirely dependent (over 98%) on non-renewable, fossil groundwater resources stored in vast southern desert aquifers, primarily the Kufra, Sirt, and Murzuq basins [1]. To address this challenge, the Great Man-Made River (GMMR) project was established, representing the world's largest water transfer scheme, designed to extract water from these southern basins and convey it to the populous coastal cities (GMMRA, n.d.). However, this absolute reliance on a finite water stock raises serious long-term sustainability concerns [2,3]. The situation of water supply has turned into more problematic with rapidly increasing population and minimum rainfall [4]. Decades of intensive abstraction to meet escalating agricultural and domestic demands have led to declining groundwater levels in some areas, threatening the country's future water security [5,6]. Historically, groundwater from the deep aquifers of southern Libya, particularly in the Murzuq Basin, was renowned for its exceptional purity and high quality, characterized by very low Total Dissolved Solids (TDS) (Alfarrah & Al-Indinsy, 2022). The situation, however, is far more complex when considering the shallow wells that many residents and farmers rely on directly for their daily needs [7,8]. Chemical Contamination: Nitrate (NO_3^-) pollution is one of the most significant documented risks in the agricultural zones of southern Libya. A study in the Samnu and Zaygan areas revealed that an alarming 87% of tested water wells were contaminated with high nitrate concentrations, exceeding the limits recommended by the World Health Organization (WHO), rendering the water unsafe for drinking and, in some cases, even for agriculture [7,9]. According to the U.S. Environmental Protection Agency (EPA, 2023), nitrate contamination in shallow groundwater is directly linked to the excessive use of nitrogenous fertilizers in agriculture, which leach through the soil layers [10]. Furthermore, other studies in various parts of Libya, including the south, have reported elevated concentrations of minerals such as iron and manganese, which adversely affect the organoleptic properties (taste and color) of the water [11,12]. Salinity also poses a major challenge in shallow wells, where levels can exceed 3000 mg/L, making the water unpalatable and unsuitable for consumption [13]. Although most focused studies on bacterial contamination have been conducted in northern cities, their findings indicate a risk pattern that is highly applicable to the south. Studies in Misurata, Zliten, Jefara District, and southeastern of Libya have shown widespread contamination of well water with total coliforms and fecal coliforms (E. coli), indicating seepage from untreated sewage into groundwater reservoirs [14,15,16,17]. Given that many areas in the south rely on rudimentary sanitation systems (e.g., septic tanks and cesspools) in close proximity to water wells, the risk of biological contamination remains a potent and direct threat to public health [10]. In response to the deteriorating quality of well and public network water, the turn to bottled water has become a widespread phenomenon across Libya. Assessments indicate that approximately 50% of Libyan households now depend on it as their primary source of drinking water [18], driven by the perception that it is a safer and purer option. Scientific research, however, paints a different and more alarming picture. Multiple studies conducted in various Libyan cities have revealed that a significant proportion of bottled water brands, both local and imported, fail to meet Libyan national standards or WHO guidelines [19]. In a comprehensive study in Benghazi, most of tested brands exceeded the recommended limits for Total Dissolved Solids [20]. Similar findings have been documented in other studies in Tripoli [21]. The problem extends beyond non-compliance to include misleading information provided to consumers. A comparative study found significant discrepancies between the mineral concentrations stated on bottle labels and the actual values measured in the laboratory [22]. More alarmingly, contaminants have been detected in some bottled water products. In the southern city of Sabha, a study found that some samples contained potassium and magnesium levels exceeding permissible limits [23]. Researchers concur that these quality failures are a direct consequence of weak regulatory and monitoring mechanisms governing the water bottling industry in the country [24]. This regulatory vacuum leaves consumers exposed to potential health risks and undermines the very trust that drove them to an alternative they believed was safer than well water. Despite the existence of valuable studies on water quality in Libya, there is a clear gap in the literature that directly links water quality (of both wells and bottled sources) to consumer behavior and preferences specifically in Ghadames city within the southern west Libyan context. Most studies focus on chemical or biological aspects in isolation, without exploring the socio-economic dimensions that drive individuals' daily decisions regarding drinking water. This study aims to help fill this gap by providing a comprehensive analysis that connects documented risks with the declared preferences of consumers in this vital and strategic region.

2. Methodology

2.1 Study Design and sampling

A cross-sectional survey design was adopted to investigate the variations in water consumption preferences and the level of awareness of associated health risks among residents of Ghadames City, situated in northwestern Libya. This approach was selected to capture a detailed snapshot of the population’s knowledge, perceptions, and attitudes toward water choices within a defined timeframe. Data were gathered from 300 participants (n = 300) between November 2023 and September 2025. The selected sample size was considered sufficient to ensure statistically reliable and meaningful results for the analyses conducted.

2.2 Data Collection

The survey was administered through both online and paper-based questionnaires. The dual-mode strategy aims to optimize reach and convenience for individuals with diverse preferences and access to technology. Paper surveys were delivered in-person around Ghadames city, while computerized questionnaires were circulated online. Both formats used the same set of questions to maintain uniformity in data collecting. The questionnaire gathered detailed information on participants' water preferences, health hazards linked with various water sources, and demographics.

2.1 Ethical Considerations

All participants were informed of the study's goal, their ability to withdraw at any time, and the voluntary nature of their participation. One critical ethical aspect was the secrecy of participant data. The data were securely maintained and accessible only by the research team for the purposes of this study.

3. Results and discussion

3.1 Demographic Characteristics of the Participants

The results of the study showed that females represented 53% of the total sample, compared to 47% males, as shown in figure (1), indicating a slight predominance of females among the participants. This difference may be attributed to the higher level of awareness and interest among females regarding the subject of the study, or to the ease of access and their active participation in related activities. In terms of age group, the results revealed that the majority of participants were between 26 and 45 years old, representing the most active and productive segment of society. This group is typically characterized by a high degree of intellectual and professional maturity, which lends credibility and depth to their responses and interpretations of the studied phenomenon. Regarding the educational level, the results indicated that 80.5% of participants held university degrees, reflecting a high educational and cultural level within the sample. Such a level of education contributes to enhanced data quality and response accuracy, given the participants' ability to comprehend and analyze questions objectively. Overall, the demographic characteristics of the sample suggest that the participants represent a knowledgeable and productive segment of society, which strengthens the reliability and scientific validity of the study's results and conclusions.

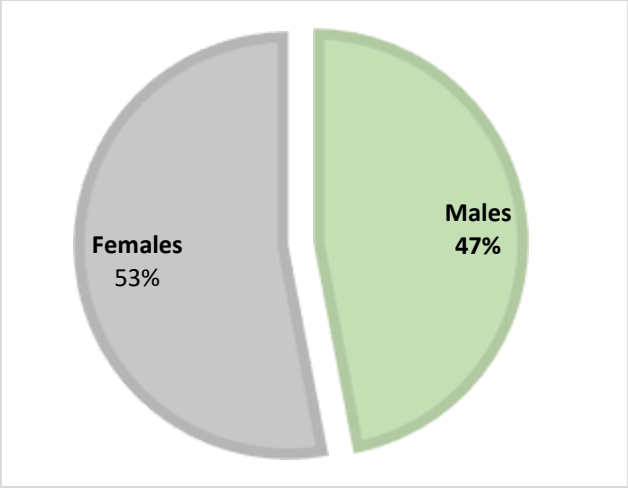

Figure 1 Gender distribution of the study participants.

Table 1. Demographic Characteristics of the Study Sample**.**

Age	18-25	12.3%
	26-35	27%
	36-45	37%
	46-55	12.2%
	> 55	8.8%

Education	Primary	1.4%
	Secondary/ technical	17.8%
	graduate/ Postgraduate	80.5%
	No formal education	0.3%

3.2 Patterns of Household Water Use

The results showed that 3.5% of participants used private well water, 5.9 % relied on the public water network, while 52.1% used home filtered water, and 53.8 % depended on bottled water, as shown in figure (2). These findings indicate a low reliance on traditional water sources, likely due to concerns about groundwater contamination and the inconsistent quality of public water supplies, which may be associated with the random disposal of wastewater. The widespread use of filtered and bottled water reflects growing public awareness of health and environmental issues and a decline in confidence in conventional water sources in arid regions of Libya.

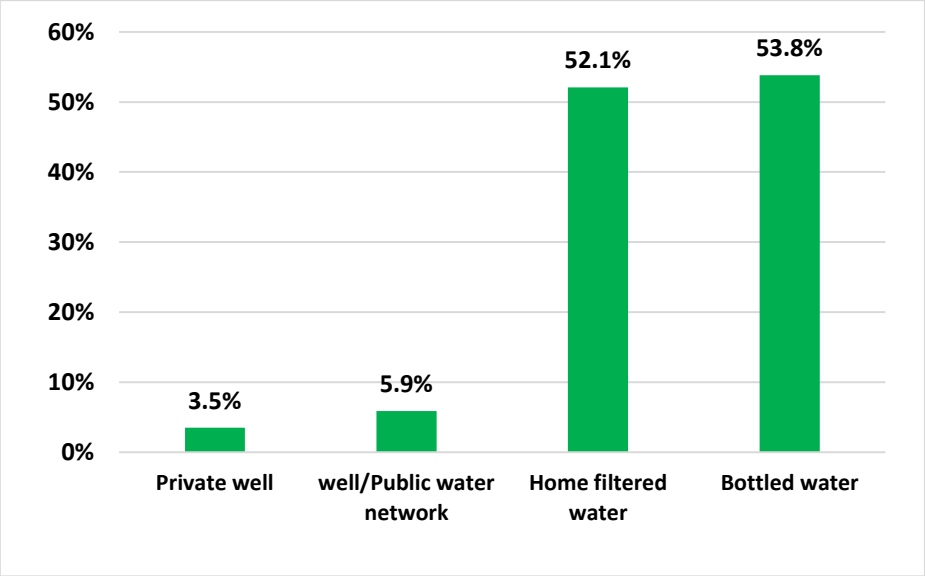

Figure 2. Patterns of household water use.

3.3 Consumption of Bottled Water in Different Settings

The results showed that 63.9% of participants used bottled water at home, 57.2% at work, 21.8% at educational institutions, 27.4% in mosques, and 35.4% in other places, as shown in figure (3). This indicates that bottled water is the preferred source of drinking water in most daily settings, reflecting public concerns about the safety and reliability of local water supplies. The high consumption at home and work suggests that bottled water has become an essential part of daily life, emphasizing a growing lack of trust in conventional water sources and the need to improve water quality management.

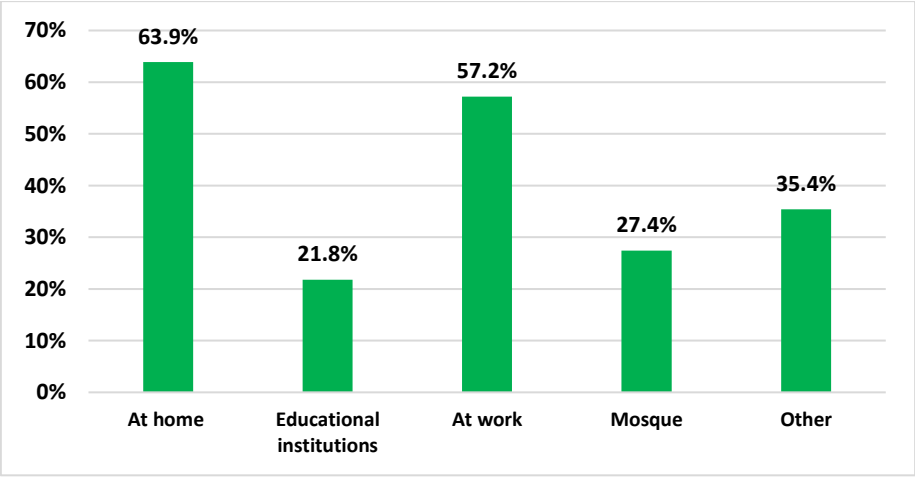

Figure 3. Consumption of bottled water in different sitting.

3.4 Source of Information About Drinking Water

Participants reported obtaining information about drinking water from multiple sources. For bottled water, as shown in figure (4), the main sources were product labels (38.9%) and the Internet (35.8%), with smaller contributions from friends (17.2%), printed media (2.1%), and television (7.4%); (33%) did not consult any source. Regarding tap, well, or public network water, information was primarily obtained from the Internet

(33.6%), friends (21.7%), and water testing laboratories (19.5%), with minimal reliance on television (5.8%) or printed media (3.5%); (43.8%) reported not consulting any source, figure (5). These findings indicate that consumers' knowledge of both bottled and conventional water is largely shaped by easily accessible yet potentially unverified sources. The reliance on product labels, online platforms, and informal networks underscores the need for accurate information, standardized testing, and transparent reporting to ensure safe consumption.

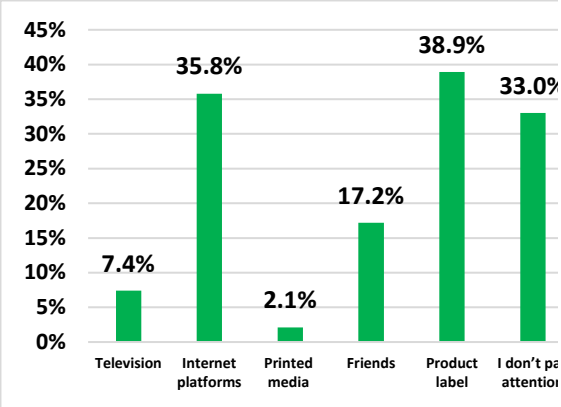

Figure 4. Source of information about bottled water.

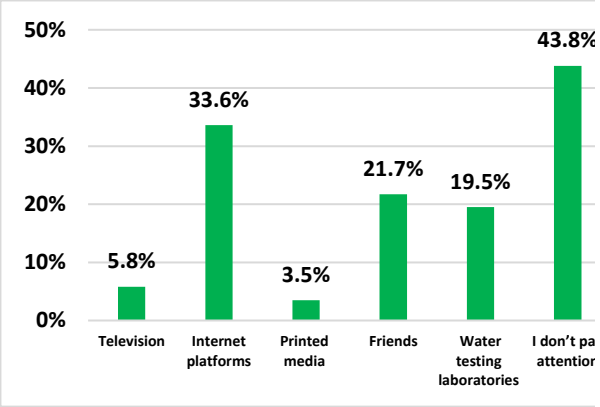

Figure 5. Sources of Information About Tap, Well, or Public Network Water.

3.5 Factors Influencing the Choice of Bottled Water

The results indicate that the most influential factor in the preference for bottled water is concern about contamination (57.3%), reflecting a lack of trust in the quality of local water sources, whether from wells or public networks. This finding aligns with previous studies conducted in developing regions, where bottled water is often perceived as a safer and more reliable option for consumption. Additionally, health-related reasons (47%) ranked second, highlighting an increasing awareness among individuals of the relationship between water quality and human health, particularly given the growing concern about waterborne diseases. The pleasant taste (52%) also appeared as a major factor influencing choice, suggesting that sensory characteristics play a significant role in shaping consumer preferences, in addition to health and environmental considerations. Furthermore, (31.2%) of respondents attributed their preference to the lack of access to well or public network water, indicating deficiencies in water supply infrastructure and emphasizing the need for improvements in water distribution systems in some areas. Other factors, such as ease of transport and handling (11.5%), habitual consumption (11.5%), and low cost (10%), were less influential yet. Additionally, 10% of participants indicated other personal or local factors that warrant further investigations, figure (6).

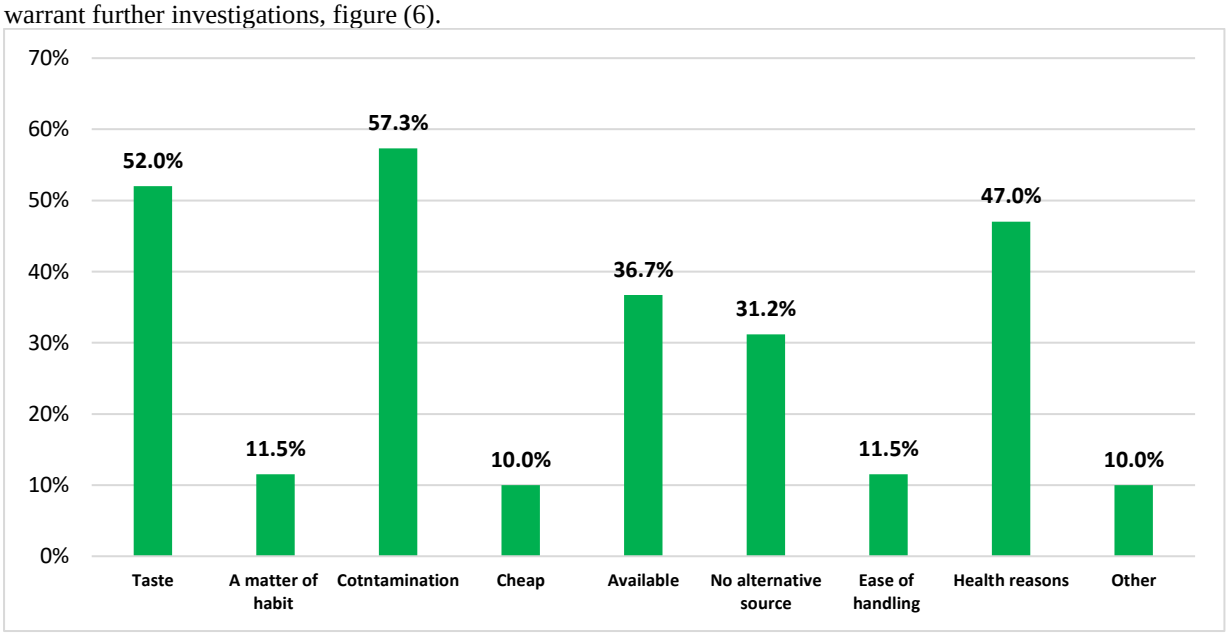

Figure 6. Factors influencing bottled water use.

3.6 Factors Influencing the Choice of Tap, Well, or Public Network Water

The results indicate that the main factors influencing the choice of well or public network water were availability and accessibility (37%) and low cost (26.8%), highlighting the practical and economic advantages of these sources. Taste preference (22.5%) was also a notable factor. Health-related reasons accounted for 10% of responses, whereas concerns about contamination or water quality were reported by 32.4%, reflecting ongoing uncertainty regarding safety and potential environmental pollutants. Other influences included ease of handling (15.7%) and habitual use (16.7%), while (41.3%) of participants cited "other" factors, suggesting the presence of additional personal, local, or contextual determinants affecting water source selection. Overall, these findings demonstrate that while well and public network water are valued for their practicality and affordability, perceived health risks and contamination concerns significantly influence consumption patterns, emphasizing the need for improved water treatment, monitoring, and public awareness to enhance trust in local water supplies, figure (7)**.**

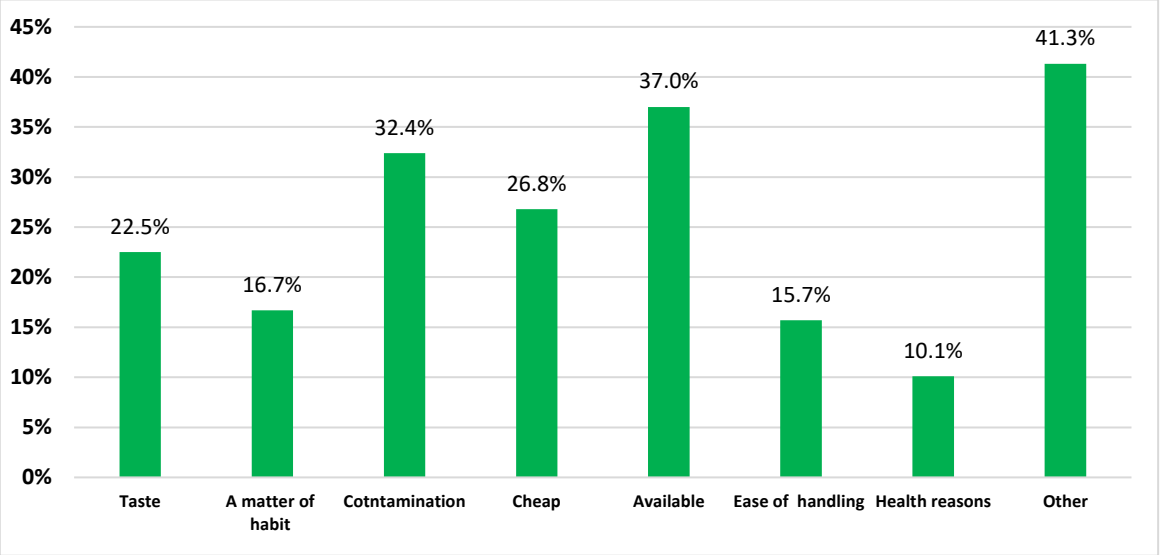

Figure 7. Factors influencing well, public network use.

3.7 Health and Safety Concerns Regarding Bottled and Conventional Water

Participants expressed multiple health and safety concerns regarding both bottled and conventional water sources. For bottled water,53.4% worried about insufficient mineral content, 47.7% were concerned about plastic packaging safety, 32% cited issues related to transport and storage, as shown in figure (8). Regarding tap, well, or public network water, concerns focused on unknown mineral content (49%), chlorine levels (35.7%), and supply safety and quality (55.6%), as shown in figure (9). These findings indicate that perceived deficiencies in mineral composition, chemical contamination risks, and distribution practices are central to public concern across all water sources. From a practical perspective, this underscores the importance of rigorous quality control, standardized monitoring, transparent labeling, and clear reporting to ensure safe consumption and maintain consumer confidence in both bottled and conventional water supplies.

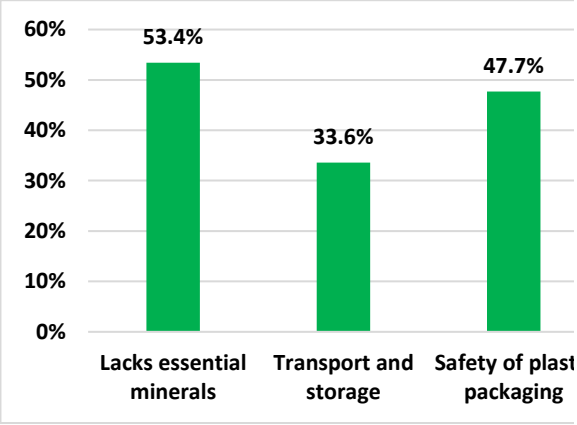

Figure 8. Concerns regarding bottled water.

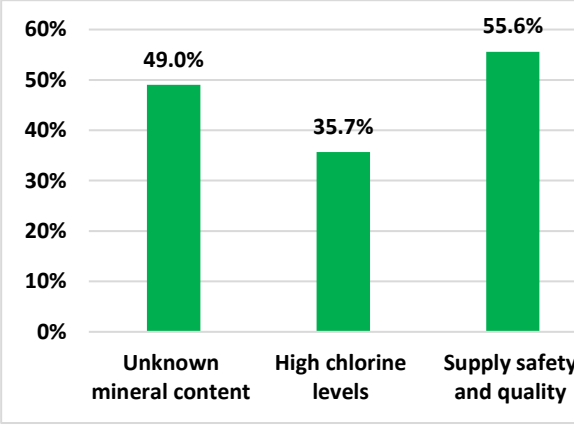

Figure 9. Concerns regarding bottled well, public network.

3.8 Cost Evaluation and Its Impact on Bottled Water Use

The findings indicate that the majority of participants (66.9%) considered bottled water to be moderately priced, while 21.6% perceived it as cheap and 12.5% as expensive, figure (10). From a practical standpoint, this suggests that cost is generally not a major barrier to bottled water consumption, which may explain its widespread use.

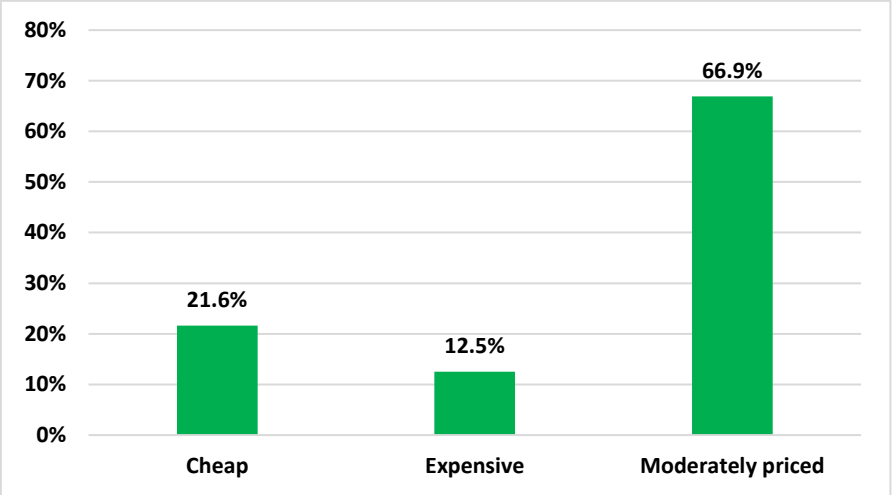

Figure 10. Cost evaluation.

3.8 Public Preference for Bottled Water Compared to Tap or Well Water

As shown in figure (11), the results revealed that 90% of participants considered bottled water more suitable for drinking, while only 10% preferred tap or well water. This indicates a lack of public confidence in the quality of tap or groundwater, likely due to concerns about possible contamination, which may stem from inadequate infrastructure and insufficient water quality monitoring. In contrast, bottled water is perceived as safer and more consistent because of its controlled purification and disinfection processes. However, this preference poses environmental challenges, emphasizing the need to enhance the monitoring and management of public water supply systems to ensure safety.

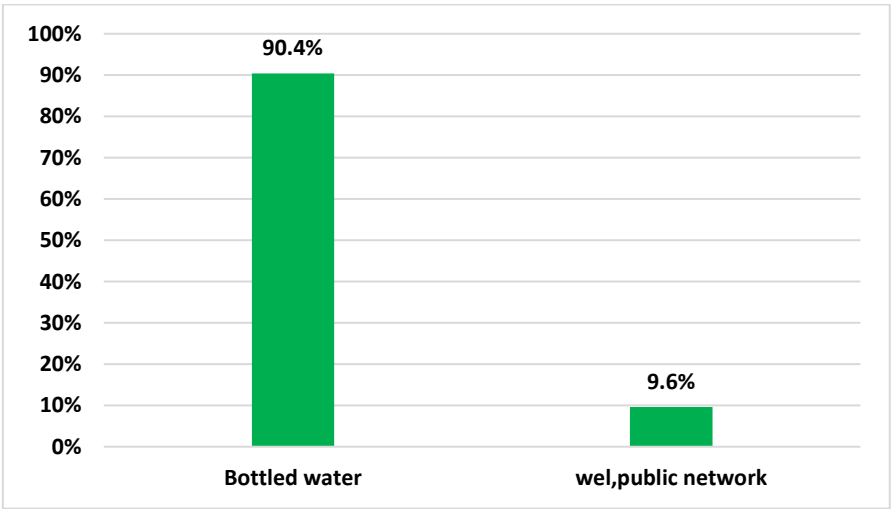

Figure 11. Public Preference for Bottled Water Compared to Tap or Well Water.

4. Conclusion

The results of this descriptive study reveal distinct trends in water consumption and perception among participants living in Libya's arid regions. The sample, primarily composed of university-educated adults, demonstrates a population with a relatively high level of health and environmental awareness. A notable preference for bottled and partially desalinated (filtered) water was identified, indicating reduced confidence in traditional sources such as wells and the public water supply. Participants' choices were largely shaped by concerns over contamination, taste, and safety, emphasizing the ongoing challenges of groundwater pollution and insufficient water treatment infrastructure. The study also shows that most information regarding water quality is obtained through non-specialized channels such as the internet or product labels, while scientific or institutional sources remain underutilized, highlighting a need for better public communication and transparency. Health-related concerns

including the lack of minerals in bottled water, potential risks of plastic packaging, and uncertain composition of tap or well water illustrate a cautious attitude toward locally available water. Economically, bottled water was generally perceived as affordable, which explains its widespread preference. In summary, the prevalence of bottled water consumption points to the necessity for stronger regulatory measures, improved public education, and enhanced water treatment and monitoring systems. These steps are essential for rebuilding public trust in domestic water sources and ensuring sustainable access to safe drinking water in arid regions of Libya.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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