A Comparative Study of Bottled and Tap Water in Abbottabad City: Implications for Stakeholders

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A Comparative Study of Bottled and Tap Water in Abbottabad City: Implications for Stakeholders

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Abstract

Access to safe drinking water is essential for human health. In Abbottabad, tap and bore water are commonly used, but there has been a recent increase in bottled water consumption. This study aimed to compare tap and bottled water quality in Jinnahabad, Abbottabad. Physicochemical and bacteriological analysis was conducted on water samples collected from various sources. Surveys and interviews were also conducted to assess consumer perceptions and costs. The study found that, on average, bottled water had better physicochemical quality, although both alternatives met WHO limits. Tap water had higher levels of E. coli due to a weak sanitation system. Interestingly, despite perceiving bottled water as safer, most respondents still consumed tap water daily. Shopkeepers reported higher bottled water purchases for travel but lower daily consumption. Tap water was the main source, according to the Cantonment Board Abbottabad, though resources were insufficient. Doctors confirmed tap water-related diseases. The study suggests further research into consumer behavior and recommends monitoring measures, staff evaluations, and penalties to reduce costs and waste.

Keywords: drinking water, contamination, health, consumer perception, Pakistan.

1. Introduction

One of the most priceless natural resources available to civilization is water. It is mostly utilized for drinking water, which is derived from both surface and subsurface sources. In the oceans, 97 % of the water is unfit for human consumption, while only 3% is fresh water. For better health, high-quality water is necessary for drinking (Garfí et al., 2016). Even so, if distributed regularly among inhabitants, the world's meagerly quantified freshwater resources can support more than five times the current global population (Heibati et al., 2017). Drinking water safety may be compromised by various contaminants (chemical, physical, and microbiological) that can cause serious health problems in humans (Jamil et al., 2023). Water from these sources is contaminated with home, agricultural, and industrial pollutants and is likely to induce water-borne diseases.

The World Resources Institute placed Pakistan at number 19 on its list of nations experiencing water scarcity (Luo et al., 2015). According to the Pakistan Council of Research on Water Resources, the lack of access to clean water is a major challenge that needs to be overcome (PCRWR). In addition, the agricultural industry contributes approximately 19 percent of Pakistan's total gross domestic product (Jamil et al., 2021). It accounts for around 91,6% of the nation's overall water consumption. As a result, water scarcity has a detrimental effect on economic development. The nation is ranked 80th in terms of its safety of drinking water, and its groundwater condition is another issue. Because of the low salt concentration (1000 ppm), only 5.75 mha of groundwater (mostly from the Indus basin) is suitable for human consumption and agricultural use. The rest of 1.84 mha has a concentration of 1000–3000 ppm, while the 4.28 mha with a concentration of >3000 ppm must be treated before being put to any practical use (WHO, 2004).

Because population growth, urbanisation, the haphazard application of agrochemicals, and the discharge of untreated sewage water are all having detrimental effects on the quality and quantity of surface and subsurface freshwater resources, there is an increasing need for clean water for human consumption, industrial processes, and environmental maintenance (Lone et al., 2021). As the groundwater moves downward through the hydrological cycle, it naturally picks up traces of different metals. The use of agrochemicals (pesticides and fertilisers), the use of coal and other inferior fuels for burning in brick kilns and other industrial processes, the discharge of untainted industrial waste, and the inappropriate municipal solid trash disposal all contribute to the introduction of these metals into water bodies (van Wezel et al., 2018).

More rapid growth in chemical production and consumption is outpacing other drivers of global change. This is true both for the total number of approved compounds and their total volume. Groundwater naturally picks up residues of various metals as it travels lower through the hydrological cycle (Bouhrara & Spencer, 2017). About 348 thousand chemicals have been registered and regulated (van Wezel et al., 2018). Similarly, due to advances in technology, drinking water may now contain a wide variety of physical, biological, and chemical pollutants. The most harmful impurity is biological, as it can cause serious health problems or even death in humans (Panhwar et al., 2019).

The availability of safe drinking water is crucial to human survival; the World Health Organization estimated in 1997 that 40 percent of deaths in underdeveloped nations were attributable to water-related diseases (Garfí et al., 2016). Worldwide, the deterioration of water quality is the most serious hazard to human health (Rahman et al., 2020). Two primary considerations go into determining the standard for drinking water. The presence of a disagreeable taste, odour, or colour, in addition to the presence of compounds that harm the body's physiological functions. However, without some sort of treatment, the vast majority of the groundwater that comes from most of its sources is unfit for immediate consumption. The quality of the raw water supply is the primary factor in determining the required treatment level (Chika & Prince, 2020). Each year, water-borne infections claim the lives of around 230,000 children in Pakistan younger than five years old (Mohsin et al., 2013). In rural and suburban regions, where water treatment facilities are virtually nonexistent, the water supply is increasingly becoming polluted due to the discharge of sewage, the application of fertilisers, the breakdown and leaching of organic materials, and other factors.

The bottled water sector has witnessed a phenomenal expansion in recent years in the United States and worldwide. The European Directive 98/83/CE defines drinking water quality standards, including microbiology, chemistry, and organoleptic parameters. It is necessary to treat and process water to fulfill the requirements outlined in the rule and achieve the goals set for it. Even though most European countries' tap water does, in fact, satisfy the requirements outlined in the rule, during the past few decades, there has been a growing trend in those nations to switch from using tap water to drinking bottled water instead. An increase in the consumption of bottled water can be linked to two primary reasons that have a significant impact on the preferences of consumers: I unhappiness with the organoleptic qualities of tap water (particularly taste), and (ii) concerns about the potential for adverse health effects (Garfí et al., 2016).

More bottled water has been bought by consumers, resulting in huge increases in the garbage generated from plastic bottles. Concerns about the safety of municipal water continue to grow with each outbreak (Pape & Seo, 2015). The national sales of bottled water continue to set new records, although health concerns raised by bottled water businesses have led to recalls (Graydon, 2017). In 1976, the average amount of bottled water used by an American was only 1.6 gallons (6.1 L) (Baldowska-Witos et al., 2019). Over the past two decades, the consumption rate has climbed, reaching a high of 39.0 gallons (147.6 L) per person in 2016, translating to 12.8 billion gallons (48.5 billion L) consumed. The bottled water market has surpassed the carbonated soft drink market to become the largest beverage category by volume due to the fall in consumption of carbonated soft drinks to an average of 38.5 gallons (145.7 L) per person in 2016.

Bottled water sales also continued their upward trend, reaching a new all-time high of $15.96 billion in the United States in 2016. Although producers, marketers, media, environmental groups, and consumers all have a role in molding consumers' opinions and affecting demand and desire for bottled water, individuals remain the most important factor in this process (Graydon, 2017). Consideration must be given to the effects of this phenomenal increase on public health and the natural environment. The rapid growth of the sector is giving rise to growing worries regarding the consumption of resources, the effects on human health, and the detriment to ecological systems (van Wezel et al., 2018).

The research objective of the study are to:

- Assess the key sources of tap water and major bottled water brands consumed in the study area.
- Examine whether the bottled water is safe and pure compared to tap water in the study area.
- Investigate health cost of bottled water and tap water in the study area.
- Implications for sellers

1.1. Justification/purpose of the study

The preferred drinking water source for most consumers in Abbottabad city comes from tap water. However, it has been found in previous studies that tap water is unsafe for drinking due to biological and physico-chemical contaminations. Using unsafe drinking water could lead to various health concerns for consumers. In contrast, bottled water is considered healthier and safe for consumption.

Generally, it is perceived that the consumption of bottled drinking water has been increasing in Abbottabad owing to its health benefits. However, there is a lack of empirical evidence in this regard, i.e., whether the consumers in Abbottabad think bottled water is healthier than tap water? And whether this health perception translates into higher consumption of bottled water? Therefore, this study aims to examine consumers' perceptions and behaviors about water, health, and disposal costs of both water alternatives. Regarding this, the data from households, shopkeepers, water supply administrators, and doctors were cross-examined with phyisco-chemical and biological parameter analysis.

The findings of this study are important from a local government and policy implementation standpoint. It is necessary to know the health and environmental impacts (bottle waste) of bottled water and natural drinking water in Abbottabad city. The findings of this study underpin the possible flaws in the water supply system and associated health consequences. A strategic understanding (Shah et al., 2015) of those issues could guide the local government and water supply administrators to devise a better water supply system, ensuring clean and safe water delivery to households. On the other hand, higher disposal costs indicate a need for consumer awareness and education regarding waste disposal. Based on the findings, additional actions could be taken to create awareness among consumers about safe drinking water and reduce possible health and disposal costs.

2. REVIEW OF LITERATURE

Drinking water in the household comes typically from tap water and bottled water. Both sources offer their benefits and drawbacks. The present study aims to compare both water alternatives. In this regard, the following sections present a comprehensive literature review on alternative sources of drinking water, the health impacts, and finally, the cost of disposing of plastic waste from bottled water.

2.1. Sources of drinking water

2.1.1. Tap water

In general, consumers all over the world perceive tap water to be lower quality and unsafe for drinking. For example, Vinturini et al. (2021) conducted a study on customers' perceptions of tap water delivered by water supply systems (WSS) in a metropolitan city in Brazil. The findings from a survey based on a random sample indicate that most consumers negatively perceive water quality, citing flavor, color, and irregular availability as fundamental difficulties, particularly during droughts. These conditions are almost entirely connected to an increase in the sum of the dissolved solids in the raw water.

A selection of water supply schemes (WSS) in the northern Pakistani districts of Chitral, Peshawar, and Abbottabad was examined as part of the current inquiry to learn more about the circumstances of corrosion scales and drinking water quality at the same time (Baig et al., 2017). In characterising the byproducts of corrosion, it was found that different proportions of the major constituents like Fe_3O_4, and SiO_2 were present. Compared to other WSS, All of the Peshawar WSS's representative XRD peaks' components were found to be negligible. One possible explanation for this finding is that the quality of the source water varies. The appearance of well-crystallized particles in SEM pictures suggested that a dense oxide layer had formed on the corrosion byproducts. Only in the Chitral and Abbottabad WSS did an expanded asymmetric vibration peak of SiO_2 appear; this indicated that the water source contained a higher concentration of siltation. One-way ANOVA analysis revealed significant differences in the pH, turbidity, TDS, K, Mg, PO_4, Cl, and SO_4 values, showing that each parameter affected the source water's quality differently. The results of this study recommended the adoption of appropriate corrosion prevention strategies as well as the creation of international collaboration for the sharing of knowledge, developing standards, and best corrosion practices.

One of the biggest problems for people in Karachi is getting clean water. The contingent valuation approach is used in this investigation to figure out how much the average person would be willing to pay (WTP) for better tap water services that provide a steady supply of high-quality water that can be drunk without boiling or any other treatment. The study examines WTP and what causes it to alter using single and double-bound dichotomous choice elicitation approaches. The study uses dichotomous single and double bound choice elicitation techniques to look at WTP and what makes it change. The results show that as income goes up, so does the average WTP. The average WTP for people of all income levels was rupees seven hundred and three. These results show that people are willing to pay much more than they do now for a safe and reliable water supply service (Asim & Lohano, 2015).

Abeer et al. (2020) investigated the pollution of Pakistan's drinking water sources with heavy metals (HM) and arsenic (As). For this, samples (n=60) were gathered from diverse sources of drinking water (bore wells, tube wells, tap, filtration plants, and bottled water). Samples (n=60) were obtained for this purpose from diverse sources of drinking water (bore wells, tube wells, tap, filtration plants, and bottled water). Sixty samples (from diverse sources of drinking water) were gathered for this purpose (bore wells, tube wells, tap, filtration plant, and bottled water). For this, samples (n=60) were gathered from diverse sources of drinking water (bore wells, tube wells, tap, filtration plants, and bottled water). CR posed by as usage surpassed the USEPA's (US Environmental Protection Agency) regulatory levels of (1.0E04 to 1.0E06).

The study done by Akhtar et al. (2021) analysed the quality of drinking and tap water in Nawabshah City by following the recommendations of the World Health Organization. Eighteen tap and drinking water samples were taken in Nawabshah City at six distinct sites. The current study adheres to World Health Organization standards. Six separate sites in Nawabshah City were used to collect 18 tap and drinking water samples.

In another recent study, Brewis et al. (2021) surveyed a metropolitan area in the United States residing in the elite class of the population. According to the results, community members associated devaluing their social status if they consume tap water. This highlights the importance of the perceptions of the elite community regarding drinking water resources.

A cross-regional comparison study was done in Singapore, Hong Kong, and Macau to examine university students' drinking habits (Brewis et al., 2021). Students were polled to see if they preferred bottled water to filtered tap water. Bottled water consumption among university students in Singapore was discovered to be relatively low. On the other hand, one-fourth of the student body prefers bottled water over tap water. The most important factors that contributed to the choice of drinking water were safety, hygiene, convenience, and availability. Additionally, taste, price, and personal habits also contributed to the choice of drinking water source.

Graydon (2017) conducted a study to analyze tap and bottled water habits and perceptions in the United States. Four thousand students and thirty-five hundred university teachers were surveyed in the study. According to the findings, undergraduate students and people of colour had significantly higher rates of bottled water consumption, while females and people of colour had significantly higher levels of concern regarding the safety of the tap water on campus.

Similarly, Javidi and Pierce (2018) designed a study to examine the use of alternate drinking water among households who suspected that their tap water was hazardous. The study sampled households who suspected that tap water was unsafe and should consume bottled water instead, spending $5.65 billion annually. The study's findings suggested that novel secondary treatment methods and information campaigns are required to address the perceptions that tap water is unhealthy. Furthermore, these approaches will reduce consumer spending on switching to alternative sources.

2.1.2. Bottled water

Hameed et al. (2020) worked on a study of the physicochemical properties of bottled water sold in the province of Iraq. They employed the local bottled water brands (10 samples) and international brands (one sample). All the standard physicochemical measures (pH, total dissolved solids, calcium, magnesium, chloride, and sulphate) were performed to assess the water quality. Overall, foreign bottled water brand was better quality than local brands. Except for the foreign sample, the potassium levels in all samples were quite low.

When compared to municipal tap water, bottled drinking water had significantly better bacterial purity (Pant et al., 2016). In the study, bacteriological purity, pH, and all of the following counts were taken: total plate count, total coliform count, faeces coliform count, and faecal streptococcal count on 100 drinking water samples. The study concluded tap water is polluted while bottled water is safer.

As part of the investigation, 100 drinking water samples were assessed for bacterial purity, pH, total plate count, total coliform count, faecal coliform count, and faecal streptococcal count (Yilkal et al., 2019). One hundred samples of drinking water were used to conduct the study. Bacteriological purity, pH, total plate count, total coliform count, faecal coliform count, and faecal streptococcal count were all performed. To determine the purity of the bacteria, pH, the total number of coliforms in faeces, and the number of streptococci in faeces, the study used 100 drinking water samples.

Emery et al. (2019) argued that Perfluorinated alkyl chemicals have recently come under attention and have been found in Groundwater at many locations around the United States. They used life cycle models to investigate the long-term effects of treating drinking water at one such location. Ion-exchange columns and granular activated carbon filtration were modelled as treatment approaches. Bottled water production and availability effects were investigated using two data sets that covered a range of production and supply chain assumptions. Monte Carlo simulations were used to capture the uncertainty in the input data.

In urban India, three methods of water purification were investigated: heating water, bottled, filtered water, and residential reverse osmosis (RO) systems (Zhao et al., 2021). The study used the Quantis water database's Life Cycle Assessment analysis. Due to the manufacturing and shipping of bottles, bottled water was found to have the most significant effects across all impact categories examined. The impact category under consideration determines the preferred system among the other two. The liquefied petroleum gas was used to boil the water. Additionally, it was found that water from a residential RO device had a greater impact on climate change and the use of fossil fuels than water from a commercial RO device. Additionally, it was found that water from a residential RO device had a greater negative impact on climate change and the use of fossil fuels than water from a commercial RO device.

Ahmed et al. (2021) examined how temperature variations affect the calibre of bottled water. They investigated what happened when they froze and cooled bottled water and when they heated the water in plastic bottles in the sun, oven, and microwave. They examined the impacts of cooling and freezing bottled fluids and the effects of heating water in plastic bottles in the sun, oven, and microwave. This finding had policy ramifications for strengthening the existing regulations regarding bottled water storage.

In the last 15 years, Pakistan's use of bottled water has skyrocketed. In 1999, 33 million litres of bottled water were consumed, and 70 million in 2003. The 2003 estimate was 70 million litres, or 0.5 litres per person. Recent data suggest a yearly consumption of 2 litres per person. The annual consumption of bottled water is 360 million litres and is expected to double by 2025. Annual bottled water consumption is 360 million litres, expected to reach 500 million litres by 2025. The industry uses 67% of its water in material production, 16.5% in processes, 10% in energy, and 6.5% in product. 67% of the industry's water consumption is during manufacturing, 16.5% in processes, 10% in energy, and 6.5% in the actual product. If trends continue, this will reach 7.7 million cubic meters in 2025. Optimizing water consumption in material production can reduce the water footprint of bottled water (Qureshi & Nawab, 2014).

The water footprint of bottled water can be reduced by maximising water consumption in material production, which uses the most water during the production process (Bibi et al., 2014). The study concludes that the price of bottled water, household income, the cost of alternatives, consumer awareness, taste preferences, and taste preferences are the primary determinants of bottled water demand. The data analysis reveals that, with a p-value of -0.21, bottled drinking water can be viewed as an ordinary but price-elastic good. The data analysis demonstrates that bottled water can be viewed as a common but price-elastic good with a p-value of 0.21.

2.2. Water contamination and health impacts

2.2.1. Water contamination

One of our world's significant challenges is the contamination and degradation of freshwater quality beneath the earth. Some of the most important water quality indicators include TDS (Total Dissolved Solids), salinity, dissolved oxygen, temperature, metabolic wastes, hazardous chemicals, and conductivity. These items are sometimes connected, and any change in one element may cause another change. This effort aims to create an understanding of water contamination caused by dissolved chemicals or biological oddities. The difference in the conductivity parameter, which is a major electrical property that impacts the Electromagnetic reflectivity of the surface ground, has mostly been explored as an indicator of this shift (Akkaya & Yilmaz, 2021).

People worldwide are in danger because of changes in the physical, chemical, and biological properties of the air, water, and soil (Patil et al., 2012). Water has a lot of harmful chemicals in it because of the growing human population, industry, use of fertilisers, and human activity. Color, temperature, acidity, hardness, pH, sulphate, chloride, DO, BOD, COD, and alkalinity are used to assess water quality. Heavy metals, including Pb, Cr, Fe, Hg, and others, can poison aquatic species.

Multiple studies were conducted in light of the growing fear of water contamination. Reyes-Toscano et al. (2020) surveyed groundwater hydro geochemistry and drinking water to explain water and rock chemistry. During the dry and wet seasons, temperature, pH, electrical conductivity, colour, turbidity, solids, total hardness, total alkalinity, chemical and biochemical oxygen demands, major components (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), and trace elements were all examined (As, Fe, Mn, Ba, Al, Sb, Co, V, Cu, Cd, Cr, Ni, Zn, Tl, Pb). The findings found that groundwater in the research area had a minor alkaline inclination, indicating that the water is safe to drink.

Polish water's physicochemical characteristics (temperature, conductivity, and pH) changed due to the Klimkówka Reservoir, which was put into service in 1994. The study used measurements between 1982 and 1993 before the reservoir was created and from 1994 to 2006, after the dam was operational. The readings were taken 16 kilometres downstream of the dam. According to the study, the Klimkówka Reservoir significantly changed the Ropa River's temperature conditions and annual cycle for water conductivity. The Ropa River had the least impact on the pH of the water. For the vast majority of rural communities worldwide, groundwater is The principal source of drinking water (Obijole et al., 2021).

Kareem et al. (2021) examined the water quality of the Euphrates River's Shatt Al-Kufa branch by computing two instances of each of three different water quality indices., The phosphate (PO_4) concentration was the parameter that most closely matched the requirement, including and excluding it. According to the findings, the water quality at three locations was fair to moderate. The Oregon Water Quality Index (OWQI) showed that two of the three sites had very poor water quality, with scores of less than 59. Water quality for three stations was very poor in two instances, with an OWQI score of less than 59, according to the Oregon Water Quality Index (OWQI).

In a recent study, the most recent development of uranium contamination in Groundwater has been evaluated for a more in-depth understanding of the current situation (Xudong et al., 2021). Uranium is a key resource that is found throughout the earth's crust. Uranium can be discharged into natural water bodies due to natural and anthropogenic processes, resulting in uranium contamination in Groundwater, which poses latent ecological and human health hazards. As a naturally occurring actinide element, Uranium exhibits both radiotoxicity and chemotoxicity. Due to the long half-lives of its natural isotopes and the features of natural uranium exposure, i.e., low-dose and long-term, the health effects of Uranium in Groundwater are mostly chemo toxic. The authors focused on Uranium's health risks and toxicological pathways in drinking water and the concerns and obstacles associated with Uranium's health risks in drinking water.

An experimental study in Nigeria was performed using the Weighted Arithmetic Water Quality Index (WAWQI), which categorises water quality according to its purity, among numerous predefined indicators. Physicochemical parameters are used to calculate the WAWQI. The study's findings revealed that most of the samples' mean values of Physicochemical parameters were below WHO (2004) maximum acceptable limits, while others were beyond WHO (2004) requirements. Except spring and packaged water samples, which are of excellent quality in terms of physicochemical properties and hence acceptable for human consumption, this finding indicates that the tested water samples from various sources were of low water quality (Olowe et al., 2021).

Another recent study evaluated the quality of various drinking water sources, the impact of low water quality on human health, and the causes of pollution in Bajaur, Pakistan. 331 spring, hand pump, open well, and tube well samples were tested for hazardous substances and E. coli. Waterborne illness cases were recorded using a questionnaire. All four water sources were contaminated with suspended particles and microorganisms. Some samples had elevated Cd, Pb, and Mn. Hand pumps, open wells, and tube wells are safer for adults and children than spring water. Geologic and anthropogenic activity damage drinking water, according to statistics. Spring drinkers reported the greatest waterborne infections, while well and hand pump drinkers reported the fewest. The study recommends water from tube wells (Khan et al., 2021).

Abeer et al. (2020) studied the poisoning of Pakistan's Islamabad with heavy metals and arsenic. We sampled 60 drinking water sources (bore wells, tube wells, tap, filtration plants, and bottled water). pH, electrical conductivity, total dissolved solids, anions fluoride, chloride, and HM Pb, Cd, Ni, Zn, and Fe were among the sample's physicochemical parameters. The findings revealed that Pb, Cd, Ni, Fe, and As were above the WHO (2004) drinking water recommendations. It also highlighted that the contamination of drinking water might be caused by both geogenic and anthropogenic activity. Examples of statistical methods include Pearson correlations and principal component analysis.

2.2.2. Bottled water contamination

From September 2009 to June 2010, the bacteriological quality of 187 different mineral water bottle brands sold in Karachi was investigated. All collected samples were tested for coliform bacteria, faecal coliform bacteria, E. coli, faecal enterococci, and total viable plate count (TVPC). Surprisingly, 67 (36 percent) of these samples did not meet Pakistan and WHO (2004) drinking water standards. Forty-nine samples had more than 200 heterotrophic cfu/ml. The presence of coliform bacteria in drinking water indicates the presence of pathogenic enteric microorganisms, making the water unsafe to drink. The data presented here clearly raises concerns about the quality of drinking mineral water and emphasises the threat to public health (Khatoon & Pirzada, 2010).

Insecticides, fertilisers, industrial waste, inadequate sanitary services, and unsanitary practises all impact drinking water quality. The research's objective of Jatoi et al. (2018) was to assess the physicochemical qualities of several bottled water brands. American Society for

Testing and Materials techniques were used to analyse several physicochemical quality characteristics of branded water samples. The bottled water brands that used S8 and S9 were slightly below the acceptable range outlined by WHO (2004). Likewise, samples' physical and chemical quality parameters were confirmed to be within norms (Jatoi et al., 2018).

2.3. Health impacts

A recent study analyzed water quality and health risks based on China's tap and bottled water hadrochemical features. The results suggest that Fluorine and Arsenic are the most harmful chemical compounds to human health in tap water research. The non-carcinogenic dangers of high Fluorine in tap water samples are unsuitable for children (Vinturini et al., 2021).

Jamil et al. (2021) found that water supply shortages and water-borne infections have recently increased in Pakistan. To stop the situation from worsening, handling this issue as soon as possible is vital. Small domestic-scale water treatment systems could be prioritised instead of large-scale projects that demand a lot of resources, money, and time as a potential solution. The analysis demonstrates that the suggested approach can effectively handle Pakistan's drinking water challenges in underserved areas. A total expenditure of PKR 3,000 ($20) will yield an average water productivity of 1.5 $L/d/m^2$.

Leishear (2021) investigated the water and health impacts, and argued that E. coli research is a new and urgent priority to address the prevalent source of outbreaks, which causes many diseases and deaths yearly. As part of a global epidemic, E. coli infects more than 73,000 people and kills more than 60 people annually in the United States alone. There is also a link between urinary tract infections and E. coli transmissions from water main breaks, affecting five to seven million people in the United States annually. E. coli causes infections and fatalities, and it is avoidable. Although facts explain deadly E. coli outbreaks, experimental theory validation is necessary following a future epidemic.

The study performed by Rani et al. (2021) investigated the annual effective dose received from radon ingestion and inhalation from drinking water. Samples were gathered in Sri Ganganagar's Rajasthan region to determine radon concentrations and evaluate the health risk. One hundred water samples were gathered from different water sources, divided into subsurface and surface water sources. A scintillation-based radon monitor was used to measure the amount of Rn-222 in the environment. With a mean of 0.92 0.12 BqL 1, Rn-222 concentrations ranged from 0.13 0.04 to 3.74 0.26 BqL 1. These numbers are far below the 100 BqL 1 maximum contamination limit suggested by the WHO (2004). Less than the suggested dose of 100 Svy1 is used in the computed doses.

In China, Ji et al. (2020) studied the seasonal variations in water quality for domestic use. The risks to a person's health were also assessed. The US Environmental Protection Agency methodology was employed in addition to the physicochemical and biological data to evaluate the potential non-carcinogenic risks of Cr^{6+}, As, F, and NO_3- N to consumers and the potential carcinogenic risks of Cr^{6+} and As. Adults and children are more likely to experience non-carcinogenic health concerns during the summer and dry season. The water quality indicators used in the risk assessment that are considered during the dry and rainy seasons contribute differently to the overall non-carcinogenic risk.

A detailed review was done by Li and Wu (2019) on Drinking water quality that affects human health. The relationship between poor water quality and public health was evaluated, emphasizing each study's unique and useful contributions. Then they suggested several study areas and directions to help advance the field of drinking water quality and public health research. Similarly, domestic physicochemical and trace element concentrations are used in Nigerian ground and surface water sources, including potentially hazardous elements (PTEs) (Nnorom et al., 2019). However, their outcomes were contrasted with regional and global requirements for drinking water.

Usman et al. (2019) assessed the effect of sanitation practices and drinking water quality. The study used various estimation techniques, such as E. coli, to determine how water quality and sanitation practises affect children's diarrhea incidence. Safe child stool disposal and uncontaminated household storage water cut down the prevalence of child diarrhoea by 16% and 23%, respectively. On the other hand, a pit latrine's presence in a neighbourhood increases the frequency of child diarrhoea by 12%. It is insufficient to eradicate open defecation from rural communities to reap the anticipated health benefits of sanitation.

In another study on the relationship between drinking water and health impacts, effects of brick kiln pollution on groundwater quality in Balochistan, Pakistan. Standard protocols were used to assess groundwater quality utilizing physiochemical parameters. With a few exceptions, the study's findings revealed that the investigated physicochemical parameters were determined to be over WHO (2004) permitted limits. The studied area's water was not fit for human consumption, according to the estimated groundwater quality index (WQI) (Khalid, 2019).

Yousefi et al. (2018) evaluated the fluoride levels and health issues in 112 drinking water samples from 28 Iranian localities. According to the findings, fluoride levels in drinking water ranged from 0.27 to 10.3 mg L^{-1} (average 1.70 mg L^{-1}). The fluoride limit in drinking water surpassed 57 per cent of the samples tested. According to the results of this study's health risk assessment, young consumers, children, and teenagers had the highest levels of fluoride exposure in various locations in Iran. Additionally, the majority of rural populations had their water contaminated with fluoride.

3. Material and methods

This research aims to analyze the water bottled water and tap water quality in the study area and compare them with WHO (2004) standards. Further, the physicochemical and biological parameters of both drinking water alternatives, their sources and health impacts, and disposal cost will be investigated.

3.1. Data collection

We collected three different brands of bottled water (Dasani, Nestle, and Boond), which are freshly packed, 3-4 weeks old packed, and near to expiry date, were selected and compared with natural drinking water (collected from source, pipelines, and storage place of the study area. The bottled water brands were selected in response to surveys from households and shopkeepers. Therefore, on the recommendations of households and shopkeepers, the three most commonly purchased bottled water brands were selected in the study area. Moreover, relevant literature also suggests that the three most commonly used bottled water brands are sufficient to tap any physicochemical or biological variations in quality (Ahmed et al., 2020; Duru et al., 2017; Sala-Comorera et al., 2019).

Replicates of freshly bottled, 15 days old, and near-expiry samples were also collected from the selected brands of bottled water. In this regard, Duru et al. (2017) suggested that physico-chemical properties of bottled water tend to change over a while, with newly packed water having the highest drinking quality. Therefore, it is necessary to observe drinking water quality over time. Similarly, Sala-Comorera et al. (2019) also tested the bacteriological properties of drinking water over the shelf life (from freshly packed to near-expiry). Based on these recommendations, we collected and compared the samples of each brand's fresh, 15 days old, and near-expiry bottles.

Furthermore, the study aimed to identify the cost-effectiveness, including their health, plastic bottled waste disposal, and water costs, by interviewing doctors, shopkeepers, water supply administrators, and residents of the community environment, health, and cost.

3.2. Site identification

The sites for sampling points were chosen in Abbottabad from Jinnahabad. The natural water supply sources were identified, and samples were collected from sources, distribution lines, and storage places/tanks in the study area. The study area of Jinnahabad is an urban settlement located in Abbottabad city. It comes within the jurisdiction of the Cantonment Board Abbottabad. The total population of Jinnahabad is 138311 (with a mix of middle and upper social class) residing in the area of 6936.21 acres (CBA, 2017). Inadequate water supply infrastructure for water distribution causes leaks, pipeline deterioration, and intermittent variations in water pressure in some urban populations, which can result in the intrusion of polluted water and an escalation of the likelihood of waterborne diseases. Customers receive contaminated water due to these flaws, even if the water may have come from high-quality or physically and chemically treated sources (Ahmed et al., 2020). Since the purpose of the study was to compare tap and bottled water. The most suitable study area in such circumstances is where people consume bottled water and tap water. A recent surge has been observed in bottled water consumption in Jinnahabad (Ahmed et al., 2021; Ahmed et al., 2020), making it a suitable area for site selection and water alternatives comparison.

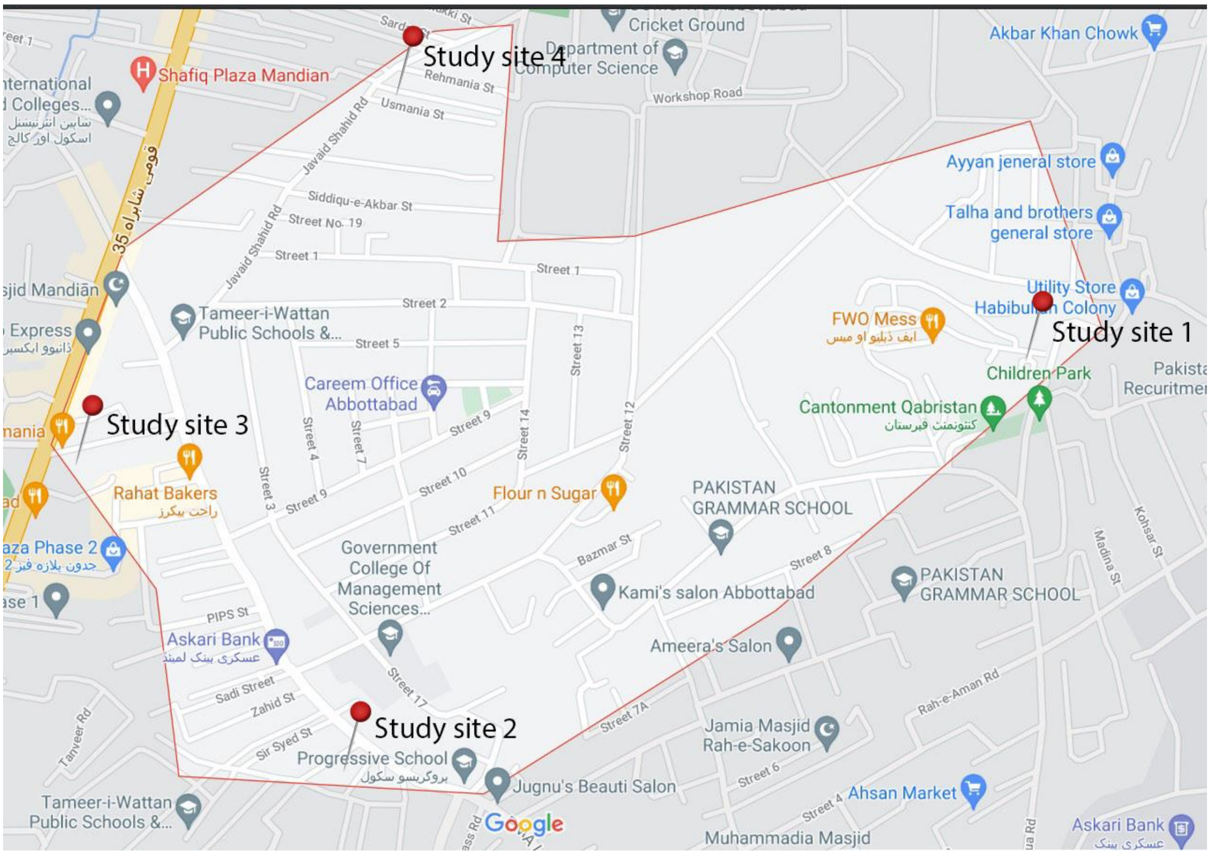

Figure1: Location map of Jinnahabad, Abbottabad

3.3. Sample collection for tap water

We collected water samples from different areas of Jinnahabad (e.g., from the main source, pipelines, and storage places). The polyethylene bottles were cleaned three times with tap water, then with distilled water, after being washed with detergent thrice. The water was allowed to run for five to ten minutes before sampling. The bottles were rinsed three times with sample water, filled to the brim, and tightly sealed and labelled in the field so that no air bubbles remained in the samples. All necessary procedures were followed during sample collection, transportation, and storage. Samples were collected in June (2021) Lai et al. (2022).

3.3.1. Sample collection for bottled water

For bottled water, single-use bottled water served in 250-500 ml bottles (which are highly consumed and fresh-packed, 3-4 weeks old, and near to expiry date) was taken from different points of the study area. These samples were collected and transported to a laboratory for examination.

People from the locality were interviewed to collect data about health and socio-economic effectiveness (Water cost, Health cost, and disposal cost) and water choice (bottle vs. natural). The researcher visited three nearby hospitals for interviews with doctors regarding health impacts. The researcher visited Cantt. Board Abbottabad (water supply administrator) for interviews regarding water supply, treatment, and waste disposal. These procedures were performed per the guidance of Manuilov and Martynov (2017).

3.3.2. Sampling design

For bottled water, the number of samples is 3, i.e., three bottles of selected brands with a capacity of 250-500 ml were taken for lab testing. In addition, each bottled water brand was taken at three instances of the life cycle, i.e., newly packed, 3-4 weeks after packed, and near to expiry.

Tap water was collected from 3 different points; the main source, pipeline, and tap water in households. One sample was taken from the main source, two samples from the pipeline, and 23 samples of tap water from the household.

3.4. Analytical method

Methods for measuring physical and chemical properties are listed below.

3.4.1. Water quality parameters

The physico-chemical and biological parameters of drinking water are extremely important because significant instability in these parameters directly impacts human health and strength.

3.4.2. Physical parameters

It includes the analysis of colour, taste/odour, and electrical conductivity.

3.4.3. Methods for chemical parameters

The following methods were used to analyze the chemical water quality parameters: pH, dissolved oxygen, sulphate, chloride, magnesium, potassium, sodium, total dissolved solids, and fluoride.

3.4.4. Biological parameters

Bacteriological parameters include E-coli bacteria and faecal coliform microbiological analysis. All of the parameters were compared to WHO (2004) standards to determine whether the samples were "Unsafe" or "Safe" for drinking.

4. Results and discussions

Drinking water samples were taken from selected parts of the city of Abbottabad. First, data were analyzed for physicochemical and biological parameters, including Color, Odor, Taste, pH, EC, DO, TDS, F, Cl, SO_4, Mg, Na, and K.

Additionally, surveys and interviews were conducted to determine the opinions of the shopkeepers, households, water supply administrators, and doctors to assess water quality. Statistical Package for Social Sciences (SPSS) 23 and Microsoft Excel were used to analyze the data.

The structure of the chapter is as follows:

- Physicochemical parameters
- Biological Analysis
- Surveys
  - Households' survey
  - Shopkeepers' survey
  - Interview with water supply administrator
  - Interviews with doctors

4.1. Physicochemical analysis

When analyzed, all samples were colorless, tasteless, and odorless. Next, pH, EC, DO, TDS, F, Cl, SO_4, Mg, Na, and K were performed on fresh, 15 days old, and near-expiry states of water. Water samples from the Jinnahabad area of Abbottabad city, were collected. All the properties were within acceptable range expect magnesium as shown in Table 1.

Table 1: Physico-chemical parameters

Parameter	Bottled water	Tap water	WHO limit
pH	7.40	7.42	8.5
Fluoride	0.39	0.50	1.5
Dissolved oxygen	7.21	6.99	8
Conductivity	301	560	
Sodium	14.20	15.88	200
Chloride	77.40	90.82	250
Magnesium	116.87	109.45	50
Potassium	2.07	3.23	12
Sulphate	30.20	30.30	250
TDS	177.40	239.47	500

Mg is important because it is a co-factor for more than 350 enzyme systems, how energy is used, and how the heart, blood vessels, and hormones work (Naeem et al., 2012). Most adults have about 40 g of Mg in their bodies. Half of it is found in bones, the other half in soft tissues, and about 3% in the blood (Agarwal & Dubey, 2002).

Freshly packed bottled water ranged from 45.40 to 145.37 mg/l, with an average value of 92.72 mg/l. While 15 days old bottled water ranged from 28.63 to 123.27 mg/l with an average value of 111.07 mg/l and near to the expiry date, bottled water ranged from 133.53 to

183.60 mg/l with an average value of 146.8 mg/l. Interestingly, all three states of bottled water exceeded the acceptable limits of WHO 2004. According to the WHO (2004), the permissible limit of Mg in drinking water should not exceed 50 mg/l. The results of ANOVA test showed that the samples of fresh, 15 days old, and near-expiry bottles were significantly different. Whereases, bottled water near-expiry had the highest concentration of Mg. These differences might be attributed to Abbottabad being a hill station. Most of the drinking water in Abbottabad comes from the mountains. Even bottled water sellers source, purify and sell water from mountains (Baig et al., 2017), thus resulting in higher Mg concentration.

4.2. Microbiological parameters

Escherichia coli was found in water samples taken from the area under study. The EMB, INDOLE, and catalyse tests showed that Escherichia coli was present. Human and animal excrement, sewage, treatment effluents, water, and soil recently exposed to faecal contamination are the most common sources of E. coli contamination. Animal, human, or agricultural activity may be responsible for the contamination.

Poor water and sanitation systems were to blame for high levels of coliforms and contamination in the study area's water samples. The water supply pipes are leaking and placed near the sewage lines, resulting in contamination. Additionally, research has shown that leaking pipes and poor hygiene can cause waterborne diseases (Galappaththige & Amarasekara, 2022). Table 2 shows the bacteriological analysis of bottled and tap water.

Table 2: Bacteriological analysis of bottled and tap water

Sample Points	**Total coli forms CFU/100ml**	**Fecal coli forms CFU/100ml**
Bottled water	11.26	0
Tap water	96.81	4.54

4.3. Survey with household consumers

A survey of 49 houses was carried out in the Jinnahabad area. Data were entered into SPSS 23 and coded according to the available response. First, household respondent's demographic information was collected based on gender, age, permanent residency, education, occupation, and monthly household income. Next, data were collected on the water supply, storage, and water-borne issues. Furthermore, responses were also collected regarding water consumption behavior and disposal behaviors. The mian highlights of survey are captured in Table 3.

Table 5: Summary of survey with household

Items			
	Bore well / Hand pump	Household water supply (pipeline)	Other
Primary source of drinking water?	10	30	9
	I use bottled water	do not use bottled water	

Proportion of bottled water usage in study area	29	20	
	Overhead tank	Underground tank	Other
Storage mechanism used by households in study area	23	22	4
	Yes	No	
Filtration system/ Reverse Osmosis used by households in study area	19	30	
	There is a relation between drinking water quality and illness	There is no relation between drinking water quality and illness	
Household opinion regarding drinking water quality and illness	29	20	

4.4. Shopkeeper's survey

The data was collected from shopkeepers. The total number of respondents was 17. There were 17 male respondents in gender-wise responses, and there were no females. Age-wise, there were three respondents aged 19 to 30, 4 respondents aged 31 to 40, and 10 respondents aged 40 and above. Local residents were 13, and from other places, respondents were 4. In education, 14 respondents had matric or less education. Two respondents had intermediate and one respondent that had a Bachelor's degree. One respondent has less than one year of service. Eight respondents had 1 to 5 years of service, and eight had more than five years.

Table 4 shows the most consumed brands of bottled water in study area.

Table 3: Brands of bottled water sold in study area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Nestle	11	64.7	64.7	64.7
	Aquafina	1	5.9	5.9	70.6
	Dasani	3	17.6	17.6	88.2
	Boondh	2	11.8	11.8	100.0
	Total	17	100.0	100.0	

4.5. Interview with water supply administrator

The water supplier for Jinnahabad, Abbottabad, is the Cantonment Board of Abbottabad. To obtain the useful information, the in-charge water supply was interviewed for valuable outcomes. The officer informed that the current water supply system was enough to meet the demands of the public, and efforts are made to maintain the system regularly. To ensure the health of residents, water is purified using a chlorination technique before distribution to the study area. Finally, the officer made some suggestions presented in Table 5.

Table 5: Summary of interview with water supplier

Questions	Responses
1. Does the existing water supply system effectively meet the water demand masses?	Yes
2. Do you replace the water supply lines after the regular interval?	Yes
3. Is the location of the water bore adequate?	Yes
4. Do you treat water before water supply?	Yes
5. What methods do you use for water treatment/cleaning the water tank?	Chlorination
6. How do you dispose the waste?	In a dumping ground near Salhad, Abbottabad
7. What is the monthly cost of waste management in the Jinnahabad area?	• 20 employees X 30,000 Rs salary = 600,000/month • 6 vehicles operating and maintenance cost = 50,000 Rs/month • Total cost = 600,000 + 50,000 = 650,000/month
8. What is the total monthly waste of Jinnahabad?	200 tons
9. What is the study area's monthly plastic water bottle waste?	40-50 kg
7. Suggestion for Improvement	• Awareness among water supply employees to ensure the cleanliness of the water. • Household purification of water like boiling. • Awareness among people to stop water wastage.

4.6. Doctors' opinion regarding water borne diseases

An interview was conducted with senior doctors in Ayoub Medical Complex regarding waterborne issues and suggestions. The details of the interviews are observable from the following Table 6.

Table 6: Doctor opinion regarding water issues in Jinnahabad

Question	Dr 1	Dr 2	Dr 3

No. of patients suffering from water-borne diseases in a month?	5	15	10-15
Which water-borne disease(s) is(are) most common	Diarrhea, Typhoid, Hepatitis, Blood pressure	Diarrhea, Typhoid, Hepatitis, Cholera, Stomach pain, Blood pressure	Diarrhea, Cholera, Stomach pain
How can we eradicate water-borne diseases?	Boiling, filtration plant, chlorination, awareness	Boiling, filtration plant, chlorination	Boiling

5. Conclusions

Assessment of the drinking water quality of the study area revealed that most of the physicochemical parameters of drinking water fluctuated within the WHO (2004) recommended permissible limits. The fluctuations in physicochemical indicators imply that the study area residents faced some health issues, although issues were not detrimental in nature. The physicochemical analysis revealed that bottled water quality was better than tap water in the study area.

Most of the study area's physicochemical parameters (pH, EC, TDS, Cl, SO4, Na, K, Fluoride, and dissolved oxygen) were found within the safe limits recommended by the WHO (2004). However, the samples of water showed higher than average magnesium concentration. Although magnesium is good for health, the higher concentration of Mg in drinking water could be the reason for a higher proportion of abdominal pain and diarrhea in Jinnahabad. Regarding bacteriological analysis, faecal coliforms were reported in tap water samples, which could be attributed to poor sanitation systems or broken pipelines. Overall, the bacteriological analysis revealed that bottled water had better quality and safety for drinking than tap water.

In addition to lab analysis, surveys and interviews were conducted to understand the perceptions of households, shopkeepers, doctors, and water supply administrators. First, the household survey revealed that tap water is the primary source of daily consumed water. While most households believe that non-treated tap water could be unsafe, no adequate steps are taken daily to improve water quality. The interviews of shopkeepers informed the researcher that consumers mostly buy bottled water to carry with them when they are travelling.

The interview with the water supply administrator highlighted that they understand the importance of safe and clean drinking water. The main source is serviced regularly to ensure water quality. Additionally, the chlorination process is used to clean drinking water. It was also learnt during interviews that waste management is expensive, requiring human, financial, and time resources.

The interviews with doctors confirmed the results of lab analyses. Doctors informed us that patients from the study area complained about stomach pains, diarrhea, and gastrointestinal disorders. These findings corroborate those of findings from lab analyses.

Moreover, doctors also reported that a lack of awareness about water quality could be one of the main concerns for health issues.

In conclusion, bottled water had better quality than tap water, which aligned with the researchers' expectations. Furthermore, the overall quality of the tap was within the acceptable range as per quality standards. One of the reasons for better quality water could be the demographics of the study area. Jinnahabad is a posh area of Abbottabad, residing in the city's most educated and influential people. Thus, these people are usually more health conscious and connected; water supply administrators are constantly under pressure to ensure safe and clean drinking water in that area.

6. Implications for policy makers

Water is one of the most valuable natural resources known to humanity. It is mainly utilized for drinking water, which is derived from both surface and subsurface sources. Our body is composed of about 60% of water; the same helps maintain the balance of body fluids, covers digestion, absorption, circulation, and creation of saliva, transportation of nutrients, and maintenance of body temperature. Human-being needs drinking water to sustain life and social prosperity. For better health, high-quality water is necessary for drinking. Therefore, this study makes many recommendations regarding drinking water quality, health impacts, and disposal costs.

- Tap water is generally of lower quality than bottled water. However, if periodic physicochemical and biological analyses are done, tap water quality can be guaranteed and enhanced. The Cantonment Board Abbottabad (CBA) role is imperative in this regard. The CBA's job is to ensure that physicochemical and biological examination should be done at the source, taking subsequent remedial measures if any contamination is observed.
- Apart from the physicochemical and biological assessments at the source, periodic checkups should be done by the concerned department to ensure that distribution systems and pipelines are intact from any breakage/leakage. The breakage in pipelines is especially critical when drainage lines, gutters, and toilets are nearby. The higher proportions of faecal coliform in the drinking water could result from the breakage of pipelines near toilets or gutters. Therefore, CBA should regularly examine pipelines and perform maintenance if necessary.
- In households, it is advisable to treat water before consumption. The recommended techniques to improve home drinking water quality are filtration and boiling. Since the data analysis revealed that most households do not filter or boil water before drinking, in this regard, the government and CBA can play a significant role in creating awareness among households.
- Doctors also recognize that poor quality of drinking water results in health issues such as abdominal pain, diarrhea, blood pressure, and cholera. Doctors suggest that consumers of Jinnahabad should use water treatment such as filtration and boil before consumption.
- As discussed earlier, bottled water has better drinking quality than tap water. Yet, it is recommended that tap water should be used after ensuring its safety and quality. The consumption of bottled water comes with many associated costs, including disposal and environmental costs. The disposal of plastic waste is a major issue these days. Increased consumption of bottled water will only add to these issues. Alternatively, it is recommended to use tap water after ensuring the necessary safety measures at the main source (regular filtration), pipelines (regular maintenance against leakage), and households (filtration and/or boiling).

6.1. Implications for sellers

The important findings of the present study are that consumers are aware of higher quality in bottled water in consumer health, yet they don't consume it regularly. Some possible reasons are consumer skepticism or lack of trust (Jamil & Qayyum, 2023) in bottled water sources or general lack of concern for health as observed in Pakistani consumers (Jamil et al., 2023). In this regard, sellers of bottled water should utilize various marketing tactics such as word of mouth (Jamil & Qayyum, 2023) and influencer marketing (Jamil & Qayyum, 2022) to develop trust among potential users (Zaman et al., 2016). Similarly, seller should work on social responsibility initiatives by involving relevant doctors in study area and create awareness regarding health impacts of poor drinking water. Furthermore, the awareness among consumer regarding the hazards of waste (Qayyum et al., 2022) should not be ignored. Regarding this seller, can put more research into developing better bottling material, having less environmental impact.

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