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Assessment of Drinking Water Quality from Groundwater Sources at the University of Rajshahi, Bangladesh with Respect to Bottle Water Available in Local Market

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ABSTRACT

This study aimed to assess the quality and suitability of groundwater for drinking purposes, as well as to examine the spatial variation within the area of Rajshahi University, which is located near the mighty Padma River, approximately seven kilometers east of the Rajshahi City Center. A total of twelve water samples were collected from various locations on the campus. The sampling points included Sher-e Bangla Fazlul Haque Hall, Bangabandhu Sheikh Mujibur Rahman Hall (Bijoy-24) Hall, Matihar Hall, Sayed Ameer Ali Hall, Nawab Abdul Latif Hall, Shah Makhdum Hall, Shahid Shamsuzzoha Hall, Madar Bux Hall, Huseyn Shaheed Suhrawardy Hall, Shahid Ziaur Rahman Hall, Shahid Habibur Rahman Hall, and the Jabir ibn Hayyan Academic Building. The quality of the groundwater was evaluated by measuring several physicochemical parameters: color, taste, odor, temperature, pH, salinity, electrical conductivity (EC), total dissolved solids (TDS), and total hardness. In comparison to WHO and BDS standards, most of the groundwater samples from the study area fell within permissible limits and were deemed safe for consumption. We also compared the groundwater quality with that of commercially available bottled water in the market. However, when compared to bottled water, most groundwater samples showed significant differences in their quality parameters.

1. Introduction

Water is one of the most vital elements on Earth [1]. It is undeniably the most important resource for human existence and well-being [2]. All forms of plant and animal life depend on water for survival. Groundwater serves as a reliable and decentralized source of water for millions of people in both rural and urban areas. Consequently, groundwater is among the most important, abundant, and renewable resources available. It serves as the primary source of drinking water for communities across different settings and is also a significant supplier to the agricultural and industrial sectors. Additionally, groundwater is essential for irrigation, making agriculture a key source of income for many populations [3]. Groundwater is contaminated by various sources, including residential, industrial, and agricultural activities. In recent years, rapid population growth, urbanization, and industrial expansion have adversely affected groundwater both in terms of quality and quantity [4-8]. In many cities and industrial zones in Bangladesh, pollution from urban waste and industrial discharges into water bodies has become a significant concern [1, 9-12]. Although 91% of the global population has access to safe drinking water, 2.4 billion people rely on wells or public taps, and approximately 4.2 billion have access to tap water. Unfortunately, about 1.8 billion people still consume contaminated drinking water for various reasons. Contaminated water sources can lead to the transmission of illnesses like typhoid, cholera, and various diarrheal diseases [13]. According to the World Health Organization, approximately 80% of human diseases are attributable to waterborne pathogens. Once groundwater is polluted, it is nearly impossible to restore its quality by simply removing the contaminants at the source. Therefore, regular monitoring of groundwater quality and the development of strategies to protect it are essential [9]. Reliable access to clean water is crucial for both economic stability and human life. In the Rajshahi University region, the drinking water supply may be compromised due to its geographical location and extensive agricultural activities. It is essential to assess the purity of drinking water. The term "water quality" encompasses the state of water, including its chemical, physical, and biological characteristics, particularly in relation to its suitability for specific uses such as swimming, fishing, or drinking. In this

Table 1. Sample collection point and numbering of the sample

Sample collected from hall and building	Sample no
Sher-e-Bangla Fazlul Haque	S-1
Bangabandhu Sheikh Mujibur Rahman	S-2
Motihar Hall	S-3
Nawab Abdul Latif Hall	S-4
Shah Makhdum Hall	S-5
Sayed Ameer Ali Hall	S-6
Shahid Shamsuzzoha Hall	S-7
Shahid Sohrawardi Hall	S-8
Madar Bux Hall	S-9
Shahid Ziaur Rahman Hall	S-10
Shahid Habibur Rahman Hall	S-11
Jabir ibn Hayyan Academic Building	S-12

context, the current study aims to measure several critical parameters, including pH, salinity, and hardness, to evaluate the quality of drinking water [13]. To determine whether groundwater of a particular quality is suitable for its intended use, water quality standards are necessary [14-16]. Residents in the university area rely exclusively on groundwater for domestic and drinking purposes. Surface water is seldom utilized for cooking, cleaning, or bathing. The remaining demand is satisfied by open water sources and several shallow tube wells in the research region.

Consequently, the objectives of this study are to assess the primary dissolved ion chemistry of the groundwater in the area, evaluate the drinking water quality, and examine the geographic variation of water quality parameters within this region. We collected water from 12 different point at University of Rajshahi campus as mentioned in **Table 1**, and analysis physical parameters as well as TDS, EC, Hardness, pH and salinity which are very important for drink water quality that recommend by WHO.

2. Materials and methods

Rajshahi University is situated seven kilometers east of Rajshahi City Center, next to the powerful Padma River. Twelve water samples were collected from different parts of the campus. Bangabandhu Sheikh Mujibur Rahman Hall, Sher-e-Bangla Fazlul Haque Hall, Motihar Hall, Sayed Ameer Ali Hall, Nawab Abdul Latif Hall, Shah Makhdum Hall, Shahid Shamsuzzoha Hall, Madar Bux Hall, Shahid Sohrawardi Hall, Shahid Ziaur Rahman Hall, Shahid Habibur Rahman Hall, and Jabir ibn Hayyan Academic Building were the sampling points as **Figure 1** shown the locations. Visual inspection was used to identify the sample's color. Taste was assessed by directly drinking the water sample, while odor was assessed by physical inspection.

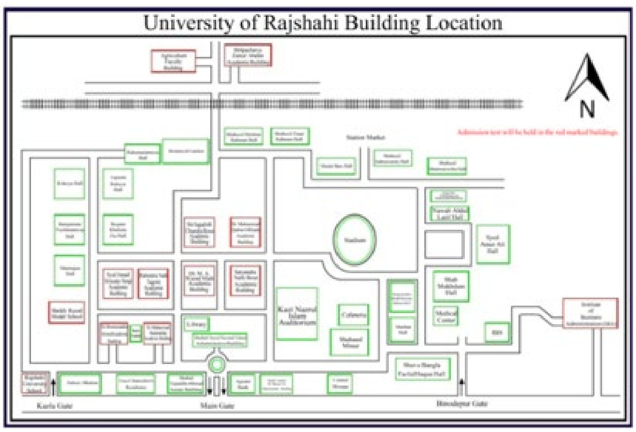

Figure 1. University of Rajshahi Campus Map.

Multiple digital meters were employed to assess various physicochemical characteristics of drinking water. The TDS Meter (Hanna-HI8730N) was utilized to monitor temperature, electrical conductivity (EC), and total dissolved solids (TDS), while the glass electrode pH meter (Hanna-H986107) was used to measure pH levels. A portable multimeter was also employed to evaluate the salinity of the drinking water samples as shown in **Figure 2**. Additionally, EDTA titration was conducted to determine the overall hardness of these water samples. Each physicochemical parameter was measured three times, and the final values were calculated by averaging the three results.

3. Result and discussion

Taste was assessed by directly drinking the water sample, while odor was examined through physical inspection. Various digital meters were employed to measure other physicochemical properties of the drinking water. The Hanna HI8730N TDS meter was utilized to assess temperature, electrical conductivity (EC), and total dissolved solids (TDS), whereas the Hanna H986107 glass electrode pH meter was used to monitor pH levels. Salinity of the water samples was tested using a portable multimeter. Additionally, water samples were titrated with EDTA to determine their total hardness. All physicochemical characteristics were measured three times, and the final values were calculated by averaging the three results. A **Table 2** summarizes the physical characteristics of the water collected from the study regions.

All drinking water samples collected from the site were found to be transparent, colorless, and clean. Turbidity, a measure of water clarity, indicates how much light is scattered by the constituents within a water sample. Water with a turbidity of 0 NTU is considered the clearest [17]. Remarkably, all our samples exhibited a turbidity of zero NTU.

Additionally, all drinking water samples from various locations were pleasing to the palate, free from any unpleasant odors. Each sample was determined to be odorless and had temperatures that aligned with WHO guidelines.

Temperature is a vital physical characteristic of wastewater, particularly when it is discharged into open water bodies. Wastewater often has a higher temperature than surrounding

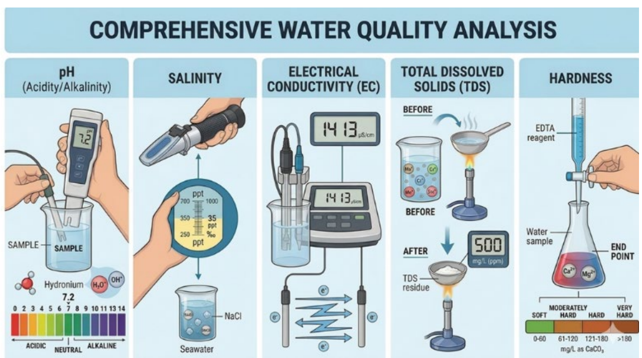

Figure 2. Comprehensive water quality analysis in the experiment.

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Table 2. Physical properties of collected water samples.

Sample no.	Color	Taste	Odor	Temperature
S-1	Clear	None	Odor-free	26.0
S -2	Clear	None	Odor-free	26.0
S -3	Clear	None	Odor-free	26.7
S -4	Clear	None	Odor-free	27.0
S-5	Clear	None	Odor-free	27.0
S-6	Clear	None	Odor-free	27.0
S-7	Clear	None	Odor-free	27.6
S -8	Clear	None	Odor-free	27.6
S-9	Clear	None	Odor-free	28.5
S-10	Clear	None	Odor-free	28.6
S-11	Clear	None	Odor-free	28.6
S-12	Clear	None	Odor-free	28.6

water, which can directly impact aquatic life by reducing the concentration of dissolved oxygen (DO) and, consequently, the oxygen available for respiration. Additionally, temperature influences the suitability of wastewater for irrigation, as it affects the chemical processes and reaction rates occurring within it [18]. The chemical, physical, and biological properties of water are largely determined by temperature. As indicated in **Table 2**, the temperature ranged from 26.3 ºC to 28.6 ºC. According to the standards set by WHO (1996) and ECR (1997) for drinking water, this temperature range is considered acceptable. **Table 3** presents a summary of the physicochemical characteristics of the water samples collected from the research areas.

One essential aspect of both wastewater and natural water quality is the hydrogen-ion concentration, commonly

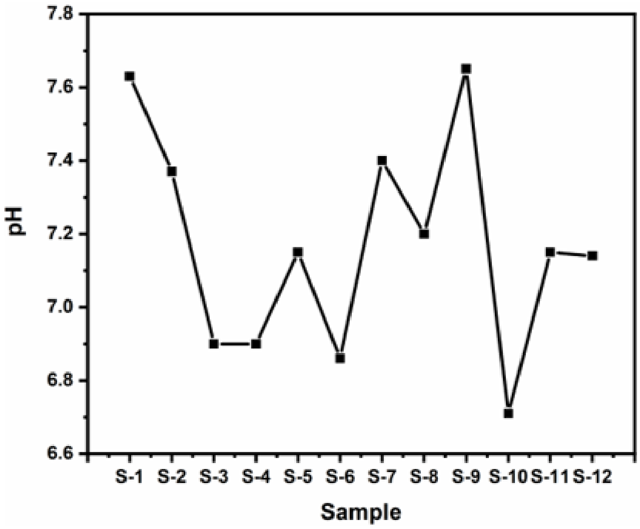

Figure 3. The pH of the collected samples.

Table 3. Assessment of physicochemical properties of collected water samples.

S. no.	pH	Salinity (ppm)	EC (µs/cm)	TDS (ppm)	Hard-ness (ppm)
S-1	7.63	376	769	384	225
S-2	7.37	415	857	427	205
S-3	6.9	371	743	371	243
S-4	6.9	475	930	475	180
S-5	7.15	472	952	476	275
S-6	6.86	494	990	495	304
S-7	7.4	432	878	437	245
S-8	7.2	410	850	420	232
S-9	7.65	396	800	400	276
S-10	6.71	393	785	397	295
S-11	7.15	381	763	384	315
S-12	7.14	350	706	353	289
max	7.65	494	990	495	315
min	6.71	350	706	353	180
BD STD	6.5 ~8.5	<1,000	600-1000	250	200-500
WHO STD	6.5 ~8.5	<10,000	1000	<1000	500

represented as pH. This value is the negative logarithm of hydrogen ion concentration. Most forms of biological life thrive within a specific and critical pH range, typically between 6 and 9 [19]. pH serves as a vital indicator of water suitability for various uses, reflecting the concentration of hydrogen ions and the water's acidity or alkalinity. In this investigation, the highest pH value recorded at several drinking water locations was 7.65, while the lowest was 6.71 both of which fall within the recommended range as shown in **Figure 3**. Typically, the pH of groundwater ranges from 6 to 8.5 [20].

Salinity, which indicates the concentration of dissolved salts in water, has a standard limit of zero for drinking water, as per WHO guidelines from 1996. The current study found that the maximum salinity value was 4%, and the minimum was 1%, which corresponds to less than 100 ppm. Although these values adhere to the percentage limit, they show some deviation in ppm. Overall, all locations displayed only slight to very slight salinity, which, according to the results, is outside acceptable limits as represent in **Figure 4**.

Electrical conductivity (EC) increases with ion concentration, making it a useful proxy for total dissolved solids (TDS) [21]. EC is important for assessing the salinity of irrigation water. While the conductivity test can indicate the likelihood of salinity issues, it does not identify the specific dissolved salts or their potential impacts on crops or soil. Furthermore, since dissolved salts elevate the osmotic potential of soil water, plants are required to expend more energy to absorb water. This increased energy expenditure leads to heightened respiration rates and, over time, a decline in plant productivity as osmotic pressure continues to rise. When salinity remains below a specific threshold, crop yields typically show little to no dependence on salt concentration. However, as salt levels increase beyond the tolerance threshold of a particular crop, yields tend to decline steadily, ultimately reaching zero.

The overall concentration of charged ionic species in water is commonly represented by electrical conductivity (EC). According to the World Health Organization (WHO, 1996),

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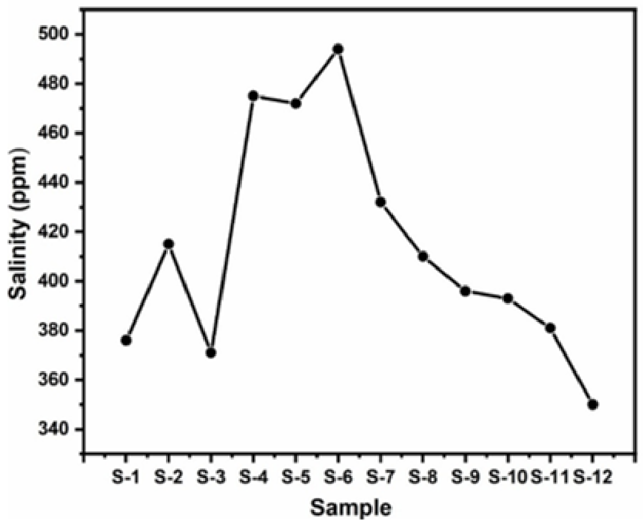

Figure 4. Salinity of the collected samples.

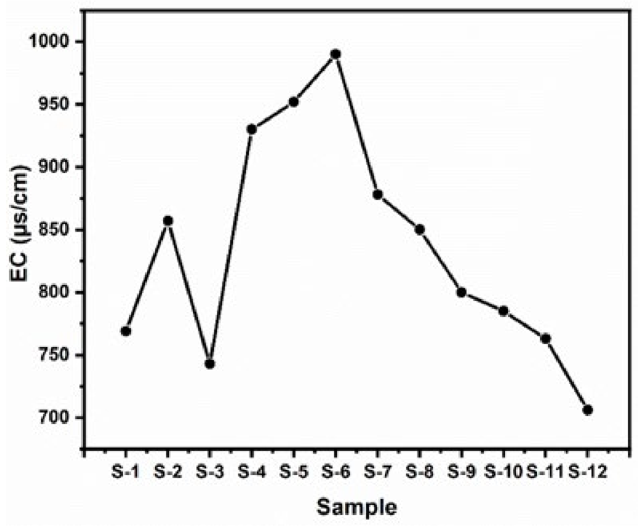

Figure 5. EC of the collected samples.

the acceptable limit for EC in drinking water is 1000 µS/cm [20]. The highest electrical conductivity (EC) values recorded were 706 µS/cm at the Jabir ibn Hayyan Academic Building and 990 µS/cm at Sayed Ameer Ali Hall. The sampling points at Shah Makhdum Hall, Shahid Shamsuzzoha Hall, Madar Bux Hall, Shahid Sohrawardi Hall, Shahid Ziaur Rahman Hall, Shahid Habibur Rahman Hall, Bangabandhu Sheikh Mujibur Rahman Hall, Sher-e-Bangla Fojlul Haque Hall, Motihar Hall, Sayed Amir Ali Hall, Nawab Abdul Latif Hall, and Jabir ibn Hayyan Academic Building all fell within the permissible range as shown in **Figure 5**.

Total dissolved solids (TDS), consisting of both colloidal and dissolved substances in water, primarily indicate the presence of various minerals such as ammonia, nitrite, nitrate, phosphate, alkalis, certain acids, sulfates, and metallic ions, among others. TDS is also a vital chemical characteristic of water. Typically correlated with conductivity, TDS readings reflect the overall quality of the water [22]. The World Health Organization (WHO) recommends a standard limit of less than 1000 ppm for TDS. Among the measured samples, Syed Ameer Ali Hall recorded the highest TDS level at 495 ppm, while Jabir ibn Hayyan Academic Building reported the lowest as we can see in **Figure 6**. All samples fell within the acceptable range of the WHO standard, although they did not meet the BDS standard.

Figure 7 representing the hardness of the samples. Water hardness is determined by the concentration of dissolved calcium and magnesium. The World Health Organization (WHO) and the European Commission for Regulation (ECR) recommend standard hardness levels to be between 200 and 500 ppm. Among the various locations assessed, Shahid Ziaur Rahman Hall exhibited the highest hardness value, while Nawab Abdul Latif Hall recorded the lowest. All measured values were within the acceptable range.

The **Figure 8** compares four popular bottled water brands (Kinley, Fresh, Mum, and Aquafina) across four key water quality parameters. All brands appear to have a standard, safe pH level hovering around 6.5 to 7.5. Mum brand is a massive outlier. It features exceptionally high levels of EC (around 233), Salinity (~116), and TDS (~116). This indicates it is heavily mineralized water. While its massive bars look alarming on a graph, a TDS of ~116 ppm is actually well within the ideal range for excellent, crisp drinking water (the World Health Organization considers TDS levels under 300 ppm to be excellent). The higher TDS and EC mean it contains naturally occurring essential minerals like calcium, magnesium, and potassium.

Fresh & Kinley: These two brands sit comfortably in a moderate "middle ground." They feature low-to-moderate TDS (around 20–30) and EC (around 40–60). If we want

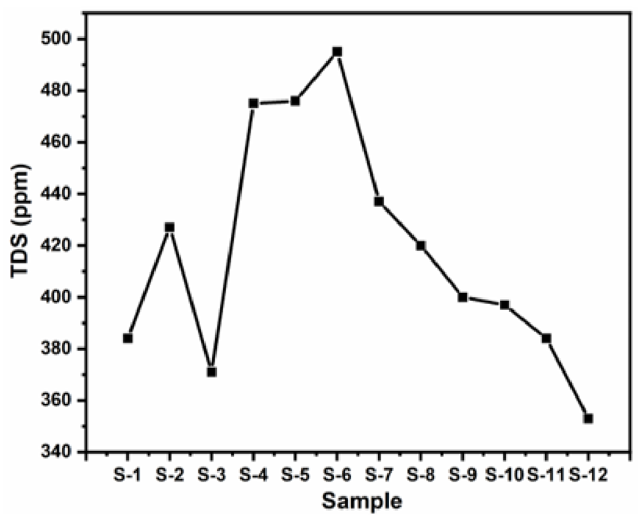

Figure 6. TDS of the collected samples.

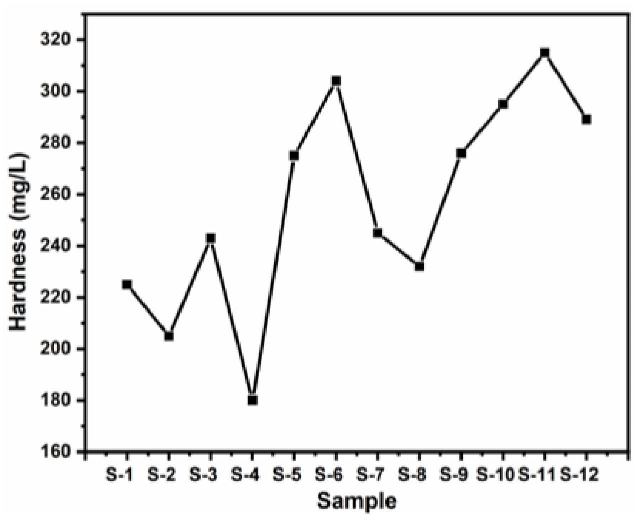

Figure 7. Hardness of the collected samples.

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Table 4. Physicochemical properties of some branded bottle water.

Brand Name	pH	Salinity	EC	TDS
Kinley	7.2	21	42	21
Fresh	6.8	30	61	30
Mum	6.71	116	233	116
Aquafina	7.18	23	23	31

middle ground—water that has been purified but still retains a very light touch of minerals for taste—Kinley and Fresh offer the most balanced, middle-of-the-road profiles as shown in **Table 4** and **Figure 8**.

Aquafina: This brand features the lowest EC (~23) and standard low TDS (~31). This is characteristic of highly purified water (usually via reverse osmosis), which strips out almost all dissolved solids and minerals. If we prefer highly purified, crisp-tasting water with minimal mineral buildup, Aquafina is better one for kidney health.

The chart displays water quality parameters across 12 different water samples (S-1 to S-12) as shown in Figure 9. Each sample is evaluated based on five parameters. Samples S-4, S-5, and S-6 show the highest contamination or mineralization levels, with peaking EC, Salinity, and TDS values. Samples S-1, S-3, and S-12 show lower overall values for EC, Salinity, and TDS. To determine the best drinking water, we look for the sample with the lowest overall dissolved solids (TDS/Salinity) and electrical conductivity (EC), while maintaining a reasonable hardness level. According to standard World Health Organization (WHO) and EPA guidelines: Excellent drinking water TDS is typically below 300–400 ppm.Values between 60–120 ppm is moderately hard, while 120–180 ppm is hard. Levels above 180 ppm are very hard but not necessarily a health hazard. Sample S-3 stands out as the most balanced option based on the visual data.

Lowest TDS & Salinity: Along with S-1 and S-12, S-3 features the lowest green (Salinity) and yellow (TDS) bars on the chart (sitting well below 400). Lowest Electrical Conductivity (EC): S-3 has the lowest purple bar among all 12 samples (around 740), indicating the fewest total dissolved ionic concentrations. Moderate Hardness: Its hardness (blue bar) sits around 240. While this is considered hard water, it is lower or comparable to the other low-TDS options and perfectly safe to drink. S-1 is a very close second. It has a slightly lower hardness value than S-3, but its EC and TDS values are slightly higher than those of S-3.

4. Conclusion

To analysis the drinking water quality in 12 different point at University of Rajshahi was analysis with standard method and compare them each other. And also, compared the four popular bottle waters available in the local market. Among the samples in 12 different point at University of Rajshahi, the sample S-3 (collected from Motihar hall) is structurally the better overall water sample presented in this dataset because it contains the lowest concentration of dissolved solids and conductivity, making it the cleanest starting point for drinking water. And among four popular bottle water ultra-pure drinking water quality was found with Aquafina. For a mineral and electrolyte boost water quality was present with Mum.

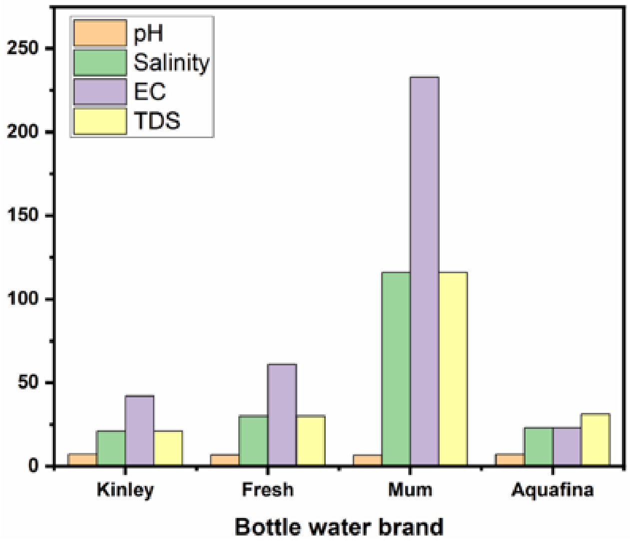

Figure 8. Analysis of some brand bottle water.

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Ethical Approval
It does not contain any experimental studies involving human participants or animal subjects performed by any of the authors.

Consent to Participate
Not applicable. No human participants or patients were involved in this study.

Consent to Publish
All authors have reviewed the final version of the manuscript and give their explicit consent for publication in the journal. This study does not contain any individual person's personal data, likeness, or private identification.

Author Contributions
The first author and second author have equal contribution in the research work. All authors read and approved the final manuscript.

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