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Assessment of physicochemical properties of various sources of water and their impact on human health

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ABSTRACT

Concern over the potential negative health effects of drinking water components has led to a decrease in the use of tap and well water and an increase in the use of bottled water. The physical and chemical quality of various sources of water available in Justice Basheer Ahmed Sayeed College for Women, Chennai was compared. Some physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), fluoride (F^-), chloride (Cl^-), nitrate (NO_3), bicarbonate (HCO_3), calcium (Ca), potassium (K), sodium (Na) and magnesium (Mg) were measured for four samples labeled as reverse osmosis (RO) water, well water, tap water and bottled water. The results of the present study showed that the measured parameters except for bottled and RO water were of national and international standards. There was no significant difference between the qualities of well water when compared with tap water. Therefore, regardless of the place in which this study was conducted, there is no need to develop RO water system and bottled water for consumption because of their deleterious effects on human health. The well water and tap water in our college's water supply network was of a suitable quality, ensuring that students' health was not in danger. The findings of this study are like a wake-up call for the students, causing them to stop quenching their thirst with RO and bottled water.

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INTRODUCTION

Water is frequently referred in classical mythology as the "elixir of life." "A potion that grants the drinker eternal life or eternal youth" is what the name "elixir" refers to. It was also stated that this elixir could heal any illness. Alchemists from all eras and backgrounds tried to figure out how to prepare the elixir. Water is one of the most precious natural resources on this planet. It is essential to all living things and every human activity is either directly or indirectly dependant on it. Only 3% of the water on Earth is fresh water, whereas the remaining 97% is made up mostly of salt water. Remarkably, it is projected that two-thirds of the world's population will reside in regions with limited access to freshwater supplies by 2050. Many countries are facing water stress, water scarcity, and poor drinking water quality issues today (Biswas and Tortajada, 2019).

Following various reports, certain components of drinking water may be harmful to our health. Epidemiological studies investigated into the relationship between exposure to trace elements such as copper, zinc, arsenicand minerals such as magnesium and the occurrence of diseases such as reproductive issues, specific cancers, and uncommon innate abnormalities of the central nervous system, cardiovascular disorders, and sudden death (McGrane, n.d.). It has been suggested that drinking water could be an important source of mineral administration because minerals in water are ionic and are easily absorbed by the digestive system.As a consequence of the rapid technological advancements in the field of research is improving, requiring an assessment of the quality of various drinking water resources, such as tap water, well water, and even bottled water, particularly in developing countries.

Although the government is taking many steps to assess the quality of drinking water, the consumption of bottled water was increasing predominantly in India. According to the latest statistics, India's largest metropolis, Mumbai, had the most amount of bottled water consumption in 2021. The city consumed 1,190 million liters of packaged bottled water. Delhi came in second with a consumption volume of 1,036 million litres.The global market for bottled water is expected to reach a value of USD 304154.2 million in 2024 and develop at a compound annual growth rate (CAGR) of 6.20% between 2024 and 2031, predicts Cognitive Market Research.The chemical, physical, and microbiological characteristics of some bottled water brands do not meet the national and international standards, despite the fact that producers of bottled water adhere to stringent quality regulations.

During the last few decades, demineralization or desalination has been widely practiced in urban areas for providing fresh water supplies. Demineralised water is defined as water almost or completely free of dissolvedminerals, obtained by distillation, deionisation, reverse osmosis (RO) or Nanofiltration etc. Recently, a study was conducted by The energy and Resource Institute on Water sustainable assessment on Chennai Metropolitan area (The Energy and Resources Institute, 2021). This research has provided information about the available new sources of water, water that has been wasted and potential risks involved in demineralized water. Long-term RO water intake may have negative health impacts, which is of great concern not only in countries without enough fresh water supplies but also in countries where bottled water and other household water purification systems are commonly utilized. Therefore, it is important to take into account the hazards and exposures at both the individual and family levels in addition to the community level.

Against this background, the aim of the present study is to evaluate the physiochemical properties of four forms of drinking water used by the students of Justice Basheer Ahmed Sayeed (J.B.A.S) College for Women. Portal water in college is in the form of RO water, well water (GW) and tap water (TW). However, most of the students consume RO water and bottled water (BW). Some physiochemical parameters including pH, electrical conductivity (EC), total dissolved solids (TDS), chloride, calcium, magnesium, nitrates, fluoride, sodium, potassium, carbonates, bicarbonates and total hardness were identified for each sample by using standard method IS 3025 as per Bureau of Indian Standard (BIS) 2012 (Bureau of Indian Standards, 2020).

MATERIALS AND METHODS

Sampling

Sampling was carried out as follows:

RO water: The samples were collected from 2 RO units placed in two different sites of JBAS College and by preserving standard conditions of the sample transfer, they were transferred to the laboratory for experiments.

Well water: Sampling was carried out in 11 water supply wells of JBAS college.

Tap water: Tap water sample was collected from five different sites of JBAS college and were mixed together to prepare an integrated sample.

Bottled water: The most widely used brands of bottled water were purchased from supermarkets as samples and transferred to the laboratory for analysis.

Experimental procedures

The procedure outlined in standard techniques for the evaluation of water and wastewater (APHA, 2012) was used to examine the water samples. After being selected, the samples were moved to the lab and stored at 4 °C in an ice box. Nitric acid and deionized water were used to thoroughly clean all glass containers and other equipment that were brought into contact with the samples. EC, pH, TDSs, fluoride, chloride, nitrate, and total hardness were among the physicochemical parameters that were measured in order to analyze the water. The parameters were listed on bottle labels and were selected based on their significance for water resources.

The standard titration method was used to determine the hardness, and a pH meter was used to assess the pH (IS 3025 Part 11: 1983 RA 2017). The TDS meter was used to determine the EC (IS 3025 Part 14: RA 2013) and TDS (IS 3025 Part 16: 1984 RA 2017). At the sampling the spot, EC, TDS, and pH were measured. The turbidity meter was used to measure the turbidity.

The Mohr method and SPADNS method were used to measure the chlorine (IS 3025 Part 32: 1988 RA 2014) and fluoride (IS 3025 Part 60: 2008 RA 2013) concentration. A spectrophotometer was used to measure nitrate (APHA 23rd Edn.2017-4500 NO_3) using the conventional colorimetric approach. All chemicals used in this investigation are of analytical grade and are purchased from the Merck Company. Hardness, fluoride, chloride, nitrate, calcium, magnesium, carbonate, bicarbonate, sodium, potassium and total dissolved solids concentrations were expressed as milligrams per liter (mg/L).

Statistical analysis

All experiments was run in triplicate, and the mean value ± standard deviation (SD) was used to present the results. Analysis of variance (ANOVA) was utilized to ascertain whether there was a statistically significant difference between the physical and chemical characteristics of the four water groups after the data were processed using SPSS software (IBM, n.d.).

Table 1. Standard values of each parameter of drinking water guidelines

Parameters	WHO	BIS	IBWA
pH value at 25°C	6.5-8.5	6.5-8.5	6.5-8.5
Electrical conductivity (μ/cm)	400-1000	1000	1000
Total dissolved solids (mg/L)	500-1000	500	500
Chloride as Cl^- (mg/L)	100-200	250	250
Calcium as Ca(mg/L)	100-200	75	30
Magnesium as Mg (mg/L)	30-50	30	10-30
Nitrate as NO_3 (mg/L)	50	45	-
Fluoride as F^- (mg/L)	0.5-1.5	1	<1.3
Carbonate as CO_3^{2-} (mg/L)			
Bicarbonate as HCO_3 (mg/L)	-	200-600	-
Sodium as Na (mg/L)	20-1756	200	-
Potassium as K (mg/L)	10-12	10	-

Table 1 shows the results of a comparison between the measured values of each parameter and the intended values found in the drinking water guidelines and standards created by the International Bottled Water Association (IBWA), Bureau of Indian Standards (BIS), and the WHO.

RESULTS AND DISCUSSION

pH

pH is a crucial variable because it affects the solubility of most metals and also most bacteria can only survive in a limited pH range. Controlling pH is necessary for the proper chemical treatment of water, including disinfection. The measured pH values fall between 6.5 and 8.5, which is within WHO guidelines. There is no direct negative impact of pH on health. Waters with a pH of less than 4 taste acidic, while those with a pH of 8.5 taste alkaline-bitter. Trihalomethanes, which are poisonous, are produced when the pH increases. At pH values lower than 6.5, corrosion in the pipes begins releasing toxic metals like Zn, Pb, Cd, and Cu.

Of the four samples studied the lowest value of 6.50 was found in well water, followed by tap water 6.65 and the highest pH of 6.96 was recorded in Bottled water (Fig. 1). With only one sample displaying the maximum value, this indicates that bottled mineral water samples are outside of the recommended range, although RO and well water samples are closer to the range, at 6.5. This is important since drinking water with a neutral pH is better for the normal functioning of our body. The municipal tap water samples had pH value of 6.65 within the recommended range of 6.5 when compared with bottled water. Carbonel *et al.* (2019) found that the average pH of bottled mineral water was 6.55 and that of municipal tap water was 6.595.

Toxic chemicals dissolve and absorb more readily at low pH values (Rendal *et al.*, 2011). Even at modest levels, hyperacidity from prolonged use of this water can cause cardiovascular damage and cancer, according to medical experts. It can also cause constriction of blood vessels and a decrease in oxygen delivery.

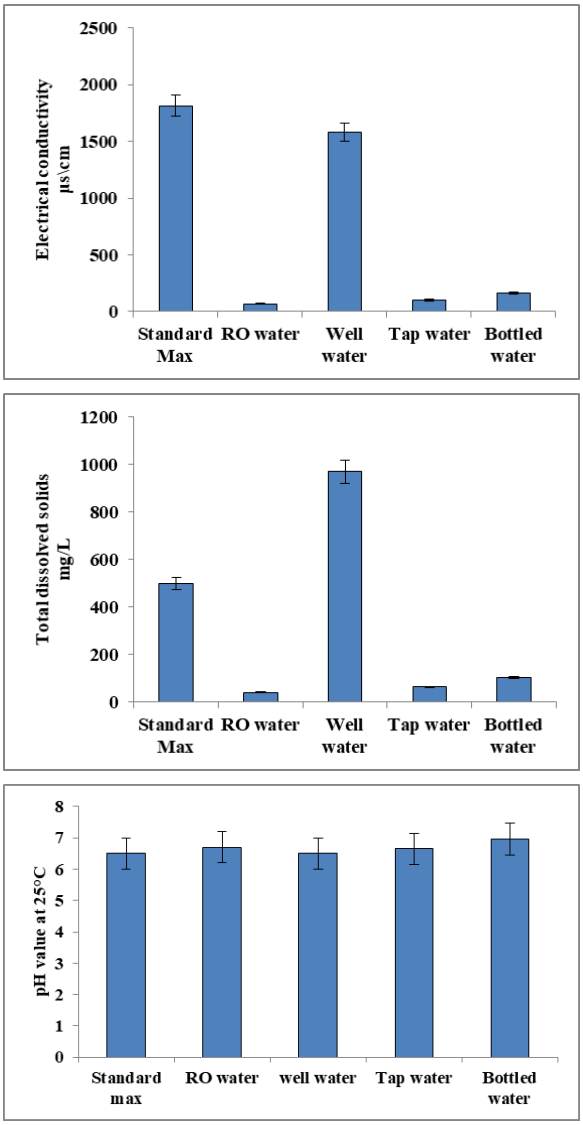

Fig. 1. pH, electrical conductivity and TDS of various sources of water

Electrical conductivity (EC)

Pure water is an excellent insulator rather than a good conductor of electric current. The electrical conductivity of water rises as the ion concentration does. Electrical conductivity in water is generally determined by the amount of dissolved particles present. The ionic mechanism that gives a solution the ability to transmit electricity is measured by electrical conductivity, or EC. Increasing the concentration of ions in water improves its electrical conductivity, however a high concentration of electrical conductivity has no medicinal effects. Drinking water conductivity typically ranges from 50 µS/cm to 1500 µS/cm. In this study, higher electrical conductivity of 1580 µS/L was observed in

groundwater when compared with other samples (Fig. 1). This is because well water originates from deeper arid regions of earth and moreover, higher conductivity may lead to lowering aesthetic value of water giving water a mineral taste.

The EC values for bottled mineral water varied from 0.105 mS (105 mS) to 0.473 mS (473 mS), according Marjan and Aliakbar (2022) (Ghanbarian *et al.*, 2022). The EC values for samples of municipal tap water varied from 0.478 mS (478 mS) to 0.872 mS (872 mS). However, EC has no direct effect on human health.

Total dissolved solids (TDS)

TDS has a variety of effects on water quality. Because of the mineralization of different salts, excessive TDS makes the water taste sour. More than 2000 mg/l of dissolved solids exerts a laxative effect. This is caused by magnesium sulfate and a small amount of sodium sulfate.

Components of sodium have an impact on the heart and pregnant women who have pregnancy-related toxicity (Uddin *et al.*, 2021). The Bureau of Indian Standards (BIS) states that 500 ppm is the maximum amount of TDS that can be present in water. Nonetheless, the WHO recommends a TDS level of 300 ppm . Minerals like salt, calcium, magnesium, and others may be absent at 0-250 ppm, as per the report. Fig. 1 shows the concentration of TDS in well water 970 mg/L which may be due to leaching of salts from soil and also domestic sewage may percolate into the groundwater. On the other hand TDs value of RO water, tap water and Bottled water were found to be 42 mg/L, 64 mg/L and 103 mg/L respectively. Water lacking TDS is more corrosive and can leach harmful metals such as lead and copper present in pipes and hardwares. TDS value is generally used to assess the quality of water. A TDS value of less than 600 mg/liter is typically regarded as having high palatability; when the TDS content surpasses 1000 mg/liter, the drinking water becomes noticeably and progressively less palatable (World Health Organization, 2011).

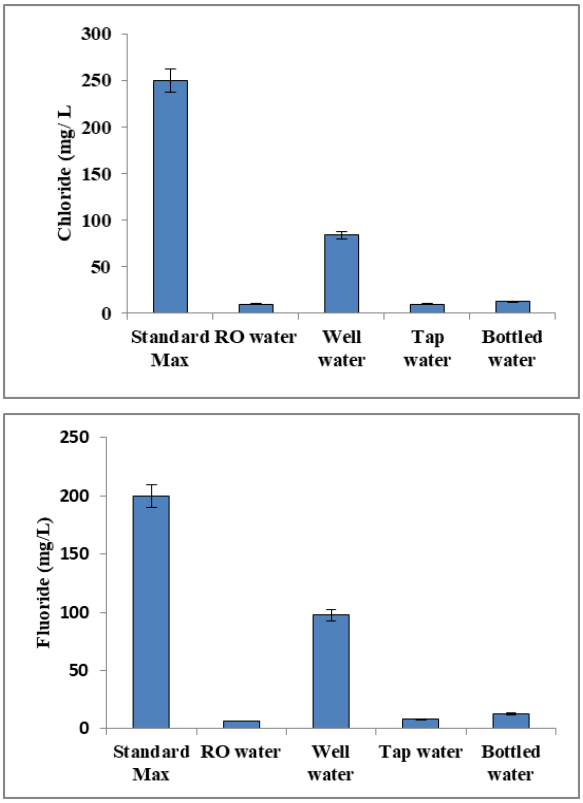

Fig. 2. Chloride and fluoride contents of various sources of water

Chloride (Cl^-)

Chlorides are readily soluble in water and are leached from rocks and soils, eventually reaching the sea. Normally it contributes < 2% in drinking water to the average daily intake of about 6 g/day. It is an essential element and does not seem to have any deleterious effect on human health. In the current study (Fig. 2), increased levels of Chloride was reported in well water (84 mg/L) followed by Bottled water (12.7 mg/L) whereas, RO water and Tap water displayed the value of 9.78 mg/L. The health benefits of Chloride are numerous; Firstly, it increases the electrical conductivity of water and production of gastric hydrochloric acid in stomach enhancing digestion (Gaikwad *et al.*, 2020). Secondly, in metal pipes it reacts with metal ions thus increasing the availability of healthy metals in drinking water. It combines with electrolytes such as sodium and potassium to maintain the acid-base balance in the human body. Finally, if chloride level drops in drinking water a person can become unconscious and dehydrated. Therefore, the increased levels of

chloride in well water is beneficial for its consumption to human beings when compared with Bottled water.

Fluoride (F^-)

Fluoride is present in water as a fluoride ion and is present in the Earth's crust at a concentration of roughly 625 mg kg^{-1}. The primary cause of fluorosis in people is drinking fluoridated water.

Depending on the total amount of fluoride ingested over time, fluoride may be beneficial or detrimental to humans. Fluoride deficiency results in tooth cavities and bone deterioration when the concentration is less than 0.5 mg /L, while fluorosis occurs when the intake exceeds 1.5 mg /L. When fluoride levels exceed the allowable limit, it can cause serious health problems for adults, children, and newborns. Although fluoride has no short-term effects, it accumulates in the brain and gradually damages the body over time.

Fig. 2 shows the value of Fluoride in Well water sample was found to be 0.59 mg/L and there was no fluoride content in the rest of the samples. Aquifers' geological, chemical, and physical characteristics, the acidity and porosity of the soil and rock, local temperatures, well depth, and the effects of other chemicals all affect the amount of fluoride in groundwater. In the presence of calcium, which has a concentration of 40 ppm, fluoride's concentration is limited to 3.1 mg /L due to its solubility in water. Its increased concentration is also stable if there is no calcium in the solution. As a result, it is anticipated that groundwater in areas with fluoride-containing minerals and aquifers with low calcium levels will contain more fluoride. In groundwater, where cation exchange of sodium for calcium takes place, the fluoride content is also anticipated to rise (Shaji *et al.*, 2024).

Nitrate

The primary source of nitrates in drinking water is agricultural activities, specifically the decomposition of plant matter in the soil, which absorbs the released nitrate when no plants are growing. Surface nitrate concentrations are typically less than 18 mg/L, but they can be greater in areas with agricultural runoff, animal waste, or sewage effluent contamination. Fig. 3 displays the value of nitrate in RO water is 15.3 mg/L followed by Well water 6.97 mg/L, Tap water (1.52 mg/L) and Bottled water (0.71 mg/L) respectively.

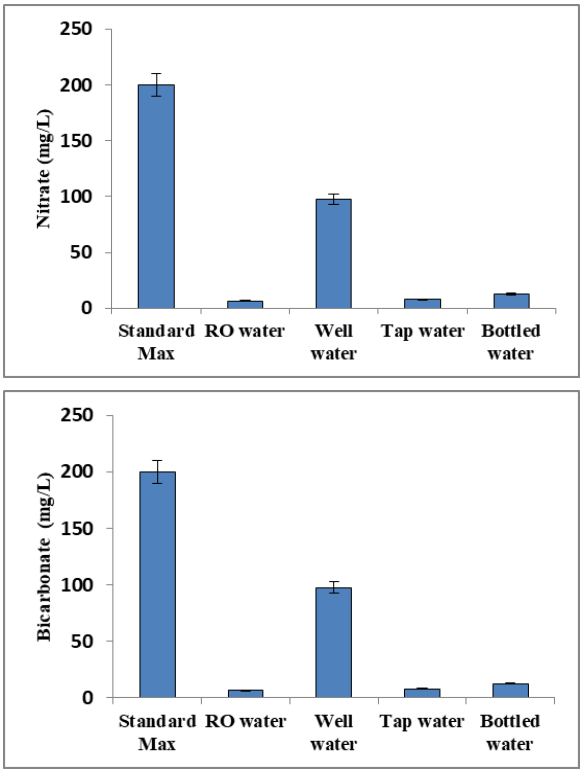

Fig. 3. Nitrate and bicarbonate contents of various sources of water

Excessive nitrate consumption of RO water can cause methemoglobinemia, or "blue baby syndrome," which alters how oxygen is carried by the blood. Babies under six months old who are bottle-fed are most at risk for developing methemoglobinemia. In addition to causing bluish skin, methemoglobinemia can cause fatalities or severe disease. Methemoglobinemia is also associated with headaches, stomach cramps, vomiting, elevated heart rate, and reduced blood pressure.Scientific data evaluating the health effects of drinking water with high nitrate levels on adults has only recently surfaced. An increasing amount of research suggests possible links between exposure to nitrates and nitrites and additional health problems such headaches, nausea, cramping in the abdomen, and elevated heart rate (Grout *et al.*,

2023). Moreover, high nitrate level of Well water may be due to improper well construction, well location, overuse of chemical fertilizers or improper disposal of human and animal waste.

Bicarbonate (HCO_3)

In all well waters bicarbonate is a natural component. Well waters that are sourced from limestone rich areas typically have higher bicarbonate content. Bicarbonate plays a critical role in buffering acids and provides pleasant, clean and refreshing taste to water. From Fig. 3 it's highly evident that Well water has highest bicarbonate content of about 556 mg/L when compared with other sources of water. This is because rainwater itself is a good source of bicarbonate ions.

Bicarbonates are formed when carbon dioxide in water reacts with carbonate rocks like limestone and dolomite, creating an alkaline environment. Carbon dioxide dissolved in water forms carbonic acid, which dissociates into bicarbonate and hydrogen ions depending on the buffering capacity (Lal *et al.*, 2022). The benefits of bicarbonate are as follows, it has an neutralizing effect, it is a part of the salt contained in carbonic acid, it provides neutral and natural taste to the drinking water, it is responsible for maintaining the acid-base balance in the body. On the other hand, extreme levels of bicarbonate leads to hypernatremia or increase in sodium levels.

Calcium (Ca) and magnesium (Mg)

In our work, the value of calcium and magnesium was found to be maximum in Well water 172 mg/L and 29.8 mg/L (Fig. 4) when compared with other sources of water. Normal level of Ca in drinking water varies between 21.8 to 208 mg/L. Moreover, the level of Ca in well water is in this permissible range whereas RO water has the lowest value of 2.45 mg/L. Tap water and Bottled water has the same value for Ca 5.72 mg/L. On comparative analysis, Ca in well water has come in contact with certain rocks and minerals like limestone and gypsum. When these minerals dissolve they release Ca. The concentration of multivalent cations dissolved in the water is correlated with the degree of harness, which increases as the calcium content rises.

There are many evidences showing the incidence of coronary heart disease is greatly reduced in areas supplied with public water supply with high degree of hardness, the primary constituent of which is Ca. Hence the presence of this vital element is beneficial to human community.

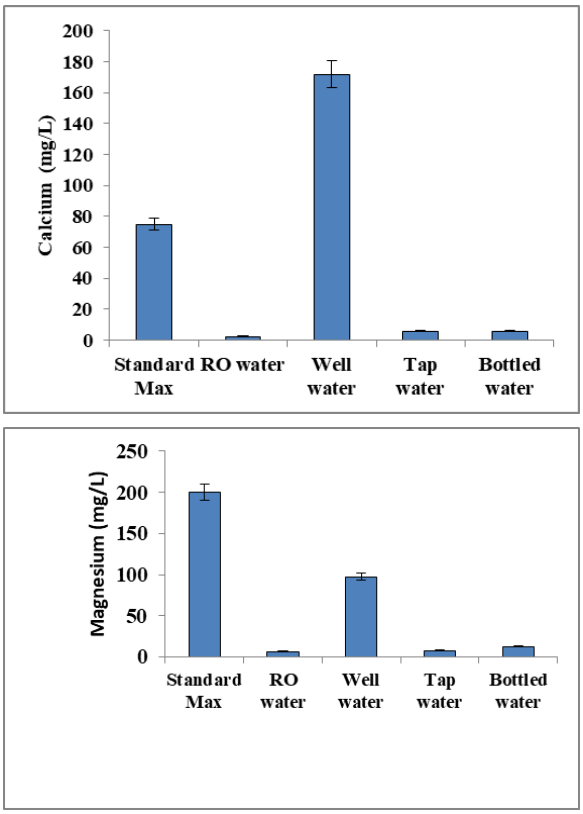

Fig. 4. Calcium and magnesium contents of various sources of water

Mg is one of the dietary constituent of all organisms. It is a central element of chlorophyll and is therefore required for photosynthesis. Low levels of Mg has been reported in Bottled water (1.49 mg/L) and is associated with increased risk of sudden death and high risk of motor neuronal disease, pregnancy disorders (preeclampsia). Mg helps to maintain normal nerve and muscle function, provides a healthy immune system, supports the heartbeat steady and helps to maintain bones remain strong. It also regulates blood glucose levels and aids in the production of energy and protein. Therefore, higher levels of Mg in Well water is not a health risk.

Ca and Mg are the important intracellular cations that play a major role in numerous enzymatic systems of the human body. They are necessary for a number of biological functions, including as hematopoiesis, heart health, and the prevention of cancer. Academic research has extensively demonstrated the importance of both elements in drinking water for cardiovascular illnesses, primarily the connection between elevated incidence or mortality rates for CVD with the deficiencies in the levels of Ca and Mg (Rapant *et al.*, 2017).

Sodium (Na) and potassium (K)

Sodium salts are highly soluble in water and therefore can leach strata bearing such salts. A number of water treated chemicals contain Na and domestic water softeners can substantially increase Na levels in water. The highest value of Na was found in Well water 97.6 mg/L followed by Bottled water 12.6 mg/L, Tap water 7.88 mg/L and RO water 7.8 mg/L (Fig. 5).

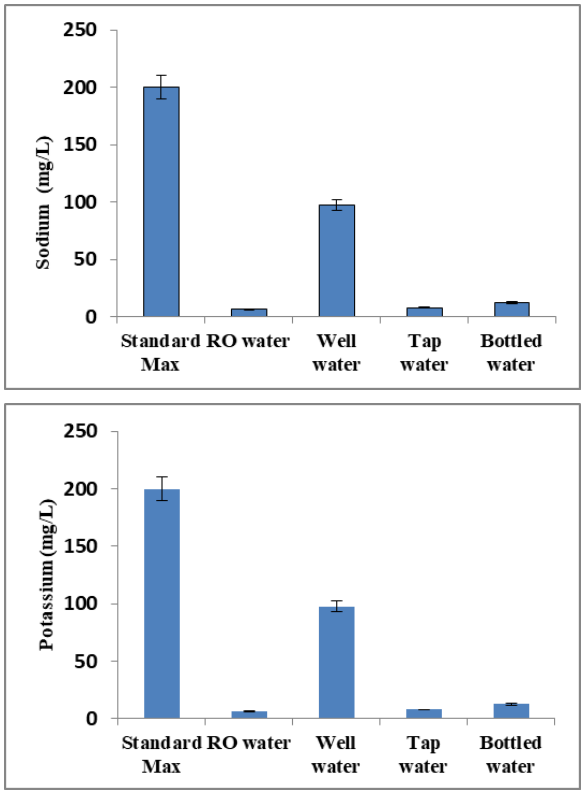

Fig. 5. Sodium and potassium contents of various sources of water

Sodium is naturally present in groundwater. Sources such as road salt, water softeners, natural underground salt deposits, pollution from septic system as well as salt water intrusion due to proximity to the ocean are often causes of elevated levels of Na in groundwater (Banerjee and Prasad, 2020). Na is of extremely low toxicity but evidence from animal studies does indicate that high levels of salt in the diet may result in hypertension.

The major effect of Na levels in drinking water for most individuals is an adverse effect on taste. The taste threshold in water depends on both the associated anion and temperature. It can also cause hypernatremia or neurological damage. Na in drinking water makes only a very minor contribution to total Na intake. Exacerbation of congestive heart failure, which is aggravated by excessive salt intake, has also been reported as a consequence of high Na levels in drinking water.

Potassium is a non-water soluble, but it does react with water forming a colorless basic potassium hydroxide solution and hydrogen gas. The levels of potassium is highest in Well water 24.7 mg/L and the lowest value in RO water 0.86 mg/L. Potassium is commonly found in many rocks and leaching of K through soil profile into groundwater is predominant only in coarse textured soils. K has many industrial applications such as glass production to make it stronger and solid. Potash alums act as bases for paper glue and are applied as a filter of synthetic rubber (Wu *et al.*, 2020). Potassium nitrate is a popular fertilizer. In this study, the potassium content of Well water is below the permissible limits and it is an advantage to the people who drink it. Since, potassium helps to regulate fluid balance, muscle contractions and nerve signals. High potassium levels may reduce blood pressure, water retention, protect against stroke and prevent osteoporosis.

CONCLUSION

To conclude, irrespective of where this study was carried out, the question remains: When regional water quality is high, Is the usage of bottled water really necessary? The evaluation of the criteria

assessed in this study revealed that Well water and tap water's chemical and physical qualities were completely in conformity with national and international standards and were not hazardous to the health of consumers. Thus, there is no need to construct RO water systems or other types of water treatment systems like bottled water.

Because bottled water is exposed to strong sunlight while being transported, it is frequently possible for plastic monomers to diffuse from the bottle wall into the water in hot or cold temperatures, causing a risk to the health of the consumers. The well water and tap water in our college's water supply network was of a suitable quality, ensuring that students' health was not in danger. However, many people use RO water systems, and they are unaware that if the filters in this treatment system are not cleaned, organic waste or microbes and their toxins may mix with the water they drink.The findings of this study are like a wake-up call for the students, causing them to stop quenching their thirst with RO and bottled water.

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