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Physicochemical Parameters of Tap Water in Dhahran, Saudi Arabia: An Empirical Assessment

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Abstract**—**In this study, the physicochemical parameters of Dhahran tap water were assessed to determine its suitability for drinking purposes. A total of 45 water samples were collected from different locations. The results indicate temperature ranges of 19.76 to 22.86 °C, pH (6.5 to 8.23), dissolved oxygen (4.21 to 8.32 mg/L), conductivity (232 to 2586 uS/cm), turbidity (0.17 to 0.37 Nephelometric Turbidity unit (NTU)), total dissolved solids (93 to 1671 mg/L), total alkalinity (4.11 to 24.04 mg/L), calcium (0.02 to 164 mg/L), magnesium (0^{1}.6 to 77.9 mg/L), chloride (32.7 to 568.7 mg/L), nitrate (0.02 to 3 mg/L), fluoride (0.001 to 0.591 mg/L), sodium (18.4 to 232 mg/L), potassium (0.5 to 26.4 mg/L), and sulphate (2.39 to 258 mg/L). The results were compared with the drinking water standards recommended by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA). The study determined that though the levels of most of the physicochemical parameters comply with the standards, however, slight deviations exist. This is evident in the values of the physical parameters (conductivity and total dissolved solids), and the chemical parameters (sulphate, chloride, and sodium) recorded at a few sample sites.

Keywords**—**Physicochemical parameters, tap water, water quality, Dhahran.

I. Introduction

WATER is a natural resource with restricted and diverse distribution across various regions of the earth. All types of life and all human activities are one way or the other directly or indirectly dependent on water. Water resources are of major importance to human life and other living organisms and the economy entirely depends on it, particularly for drinking, land irrigation, industrial use, tourism, recreational and other domestic and residential use. Generally, lack of water is considered a limiting factor in the socio-economic development of a country, region, or even a state [1], [2]. Tap water is common in most cities and its water is supplied through a tap inside the household, workplace, or public place, replacing the manual carrying of water from sources outside the building, especially from a municipal distribution source. Its uses comprise of drinking, showering, washing, cooking, and flushing and cleaning the toilets. Tap water, therefore, is an essential component of "indoor plumbing" and it can be from a city water supply, municipal, or even private source [3]-[5].

In recent times, due to rapid urbanization, development of new cities, industrialization, and growing population, the degree of discharge of pollutants into the environment which eventually make their way into water bodies far exceeds the rate of purification and treatment [6]-[9]. Especially groundwater sources such as boreholes, oases and wells are the main source of drinking water in many urban and rural areas [10]-[13]. It is often assumed that surface waters are normally more polluted than groundwater although that may not be the case, especially in fluoride contamination [14]. Contaminants are substances that are dissolved in water and make it unfit for the intended use. Some contaminants can be easily identified only by assessing the taste, odour, and turbidity of the water because pure water remains tasteless, colourless, and odourless. However, most pollutants cannot be easily detected, such as radioactive elements that are notorious and require testing to reveal whether water is contaminated. Physicochemical parameters of water are important to determine the quality of tap water according to the WHO [15]-[17]. The physical parameters that are likely to give rise to a complaint from consumers are colour, taste, odour, and turbidity. While low pH contributes to corrosion in water pipes, high pH results in taste complaints [18], [19]. Other elements such as nitrates, sulphates, chlorides etc. at high concentrations beyond the recommended limit can have severe health consequences if they are not controlled [20], [21]. Microorganisms, biological indicators, and biofilms are becoming a growing concern in drinking water. Biofilms are covered with organic and inorganic materials in water pipes that can host, prevent, and permit the propagation of several bacterial pathogens, including *Legionella* and *Mycobacterium avium* complex (MAC). Factors that influence bacterial growth on biofilms include water temperature, pH, alkalinity, type of disinfectant and residual concentration, biodegradable organic carbon level, degree of pipe corrosion and treatment/distribution system characteristics [22], [23].

The major consequences of tap water pollution in communities are socio-economic, health and environmental problems. Polluted water containing turbidity and affected parameters is highly expensive to be treated to the required standard for any household or even industrial and agricultural application. This can also be joined with the financial insinuations of eliminating the associated diseases, particularly waterborne diseases. In turn, children under five years and new-born babies are mostly affected by these conditions [10], [24]. The importance of water in our daily lives is what makes it domineering in all aspects and full scrutiny, treatment, and thorough analysis must be conducted. The experimental analysis is the worry of the environmental chemist to ensure

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that the quality of water is maintained at a level suitable for all purposes. However, it depends on the intended use and to ensure that only water with good qualities is used for domestic, agricultural, recreational and industrial purposes [21], [25]. As a result, one of the largest environmental issues of our day is the need for clean water. Currently, 3 billion people (nearly half of the world's population) lack adequate access to sanitary facilities, and more than 1.2 billion people globally lack access to clean water [26]. Approximately more than 200 diseases are originating from drinking and using contaminated water and about 6,000 people a day lose their lives just by diarrheic diseases and waterborne-related complications [16]. The WHO estimates that drinking polluted water causes the deaths of 5 million people annually. By 2025, approximately 3 billion people will be in dire need of a water supply, and more than 4 billion people will lack access to appropriate sanitation due to the global trend of urbanization [16], [27].

The Kingdom of Saudi Arabia is part of water-strained regions called the Middle East and North Africa (MENA), Dhahran included. The Kingdom receives low rainfall of less than 100 mm annually, is semiarid, has variable temperature, limited groundwater reserves which are easily depleted by excessive consumption because the freshwater produced increased from 17.5 cubic meters in 2010 to 24 cubic meters [28]. However, Saudi Arabia heavily depends on groundwater (91%) compared to other sources and has no natural perennial flow, no permanent rivers or lakes [30]. Due to extreme temperatures the Kingdom also experiences high evaporation rates reducing the little available water. The city of Dhahran is one of the largest business areas in the eastern region of Saudi Arabia hence domestic, industrial, and commercial activities put a lot of pressure on the water resources. The climate of Dhahran is characterized by moderate winters and protracted, hot, humid summers. Given the city's closeness to the Arabian Gulf, summertime highs of above 40 °C (104 °F) can occur along with high humidity levels that can reach up to 73%. The highest temperature ever recorded in Dhahran was 51.1 °C (124.0 °F), and the lowest temperature ever recorded was 5 °C (23 °F) in January 1964 [28]. In winter, the temperature rarely drops below 2 °C (28 °F). Rain falls almost exclusively between November and May and Shamal winds usually blow across the city in the early months of the summer, bringing dust storms that can reduce horizontal visibility to a few meters and these winds can last for up to six months of the year contributing to the water turbidity and sedimentation in many water sources. On July 8, 2003, the temperature was 42 °C (108 °F), the dew point was 35 °C (95 °F), and the heat index ranged from 68 to 71 °C (154 to 160 °F), making it one of the highest heat indexes ever recorded [28]. All the above climatic conditions may affect the physicochemical parameters directly or indirectly, particularly the temperature, the pH and some photochemical reactions may be initiated on the surface of the water [29].

Generally, the Kingdom has four water resources, groundwater that is renewable shallow wells and alluvial as well as non-renewable groundwater from deep fossils aquafers. The other three sources are desalinated water, surface water and reclaimed or treated wastewater [30], [31].

Considering bottled water in the Kingdom, a substantial body of literature is available howsoever, the quality in terms of anionic and cationic species presence is an issue and in question. The mean level of F, Ca, and pH in bottled water was found to be much higher than what was reported by manufacturers on their labels [32]. Groundwater in Saudi Arabia is observed to have a high concentration of anions such as bromide, thus increasing the likelihood of bromate formation, especially when ozonation technologies are deployed in water treatment [33], [34]. For example, in a study, Othman and his group concluded that bromate levels in 30% of 50 bottled water samples in Saudi Arabia were within USEPA standards, while 40% fall within Saudi Arabia standards [35]. In related research, Al-Omran and Nadeem discovered that 18% of 52 water samples exhibited a concentration of bromate exceeding the allowable limits set by the KSA, WHO, and the USEPA. On the contrary, the remaining water samples investigated for other quality parameters produced concentrations within permissible limits [36]. Unlike, bottled water, literature is scarce on the quality of tap water in KSA, especially Dhahran. This study is therefore focused on bridging the existing scientific information barrier and gap in tap water quality parameters in KSA. The primary objective is to determine the physical and chemical parameters of tap water in Dhahran. The physical parameters of interest are temperature, total dissolved solids (TDS) and turbidity, while the chemical parameters are dissolved oxygen. The second objective is to establish the extent of conformity of the measured parameters with standards set at the international level (USEPA and WHO) for quality water. Furthermore, the statistical distribution of the parameters has also been studied to understand the variables.

II. Materials and Method

A. Study Area

At an average height of 91 m above mean sea level, the city of Dhahran is located between the latitudes of 26°18′15″ N and 50°07′57″ E. (Mean Sea Level (MSL)). In close proximity to Khobar's city centre lies Dhahran. The distance from Dammam to it is approximately 15 km (9.3 miles) (Fig. 1). Looking further, Dhahran is located north of Ras Tanura, one of the main oil ports, and is northeast of Abqaiq, southeast of Qatif, and further northeast of Qatif. The island of Bahrain is also within easy reach. Currently, Dhahran is home to the headquarters, facilities and company housing of the world’s largest oil company, Saudi Aramco. Numerous housing developments and suburbs have sprung up around the Saudi Aramco facilities mainly triggered by the company’s generous homeownership and welfare programs for its employees. Dhahran is also home to the King Fahd University of Petroleum & Minerals, a military base, an American consulate, and mega malls.

B. Sample Collection

The sampling locations consist of sample areas A, B and C, thus splitting the study area into three sections. Tap-water samples were collected from 45 taps at various locations within the study area during the two months at different days and different times of the day. Before any sample is collected the selected tap is made to run for 30 seconds to stabilize the parameters and avoid the stagnant water that stayed in the pipe for long. Details of the sampling locations are illustrated in Table I. Samples were collected in plastic containers to avoid unpredictable changes in characteristics [6]. The parameters were determined in the laboratory immediately after collection.

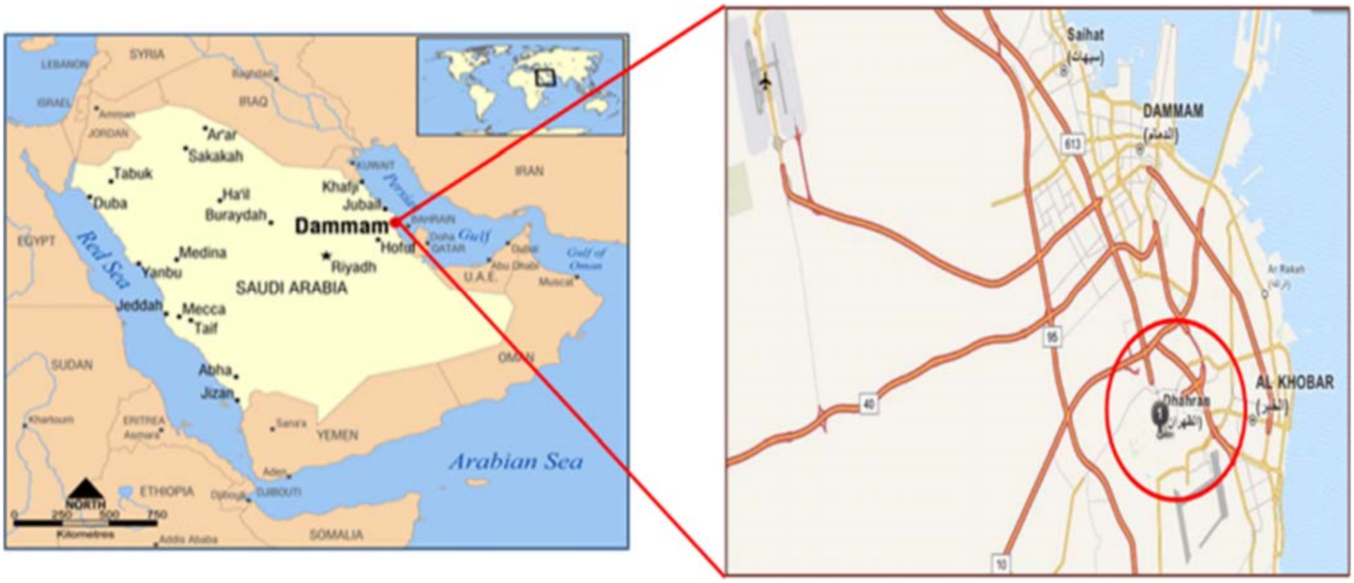

Fig. 1 Geographical location of Dhahran, Eastern province Saudi Arabia (circled red)

TABLE I
TAP-WATER SAMPLING LOCATIONS CODE WITHIN THE STUDY AREA

Sampling Location	First Sampling			Second Sampling			Third Sampling		
		CODE	MARK		CODE	MARK		CODE	MARK
Sample Area A	Sample 1	AS11	✓	Sample 1	AS21	✓	Sample 1	AS31	✓
	Sample 2	AS12	✓	Sample 2	AS22	✓	Sample 2	AS32	✓
	Sample 3	AS13	✓	Sample 3	AS23	✓	Sample 3	AS33	✓
	Sample 4	AS14	✓	Sample 4	AS24	✓	Sample 4	AS34	✓
	Sample 5	AS15	✓	Sample 5	AS25	✓	Sample 5	AS35	✓
Sample Area B	Sample 1	BS11	✓	Sample 1	BS21	✓	Sample 1	BS31	✓
	Sample 2	BS12	✓	Sample 2	BS22	✓	Sample 2	BS32	✓
	Sample 3	BS13	✓	Sample 3	BS23	✓	Sample 3	BS33	✓
	Sample 4	BS14	✓	Sample 4	BS24	✓	Sample 4	BS34	✓
	Sample 5	BS15	✓	Sample 5	BS25	✓	Sample 5	BS35	✓
Sample Area C	Sample 1	CS11	✓	Sample 1	CS21	✓	Sample 1	CS31	✓
	Sample 2	CS12	✓	Sample 2	CS22	✓	Sample 2	CS32	✓
	Sample 3	CS13	✓	Sample 3	CS23	✓	Sample 3	CS33	✓
	Sample 4	CS14	✓	Sample 4	CS24	✓	Sample 4	CS34	✓
	Sample 5	CS15	✓	Sample 5	CS25	✓	Sample 5	CS35	✓

C. Physiochemical Parameters Determination

The experiments were carried out using Metrohm 850 Professional Ion Chromatography AnCat, an intelligent ion chromatography system for determining cations without suppression and anions with or without chemical suppression and operated with various types of detection. Personal Computer Biochemical Oxygen Demand (PC-BOD)/Titrate Duo System with AutoMax73 with original titration and ion analysis was employed. This study also deployed an ICS-3000 Ion Chromatography system which automatically generates eluent in the exact amount and concentration to countercheck the results. The USEPA protocol was strictly followed throughout the chemical analysis, with minimal modifications in some instances. The collected samples were analysed for different physicochemical parameters encompassing pH, temperature, dissolved oxygen, conductivity, turbidity, TDS, total alkalinity, calcium ions, magnesium ions, potassium ion, sodium ion, chloride ion, fluoride ion, sulphates, and nitrates, and all the results obtained were compared with the USEPA and WHO set standards [37]-[42].

D. Quality Control Assurance

The reliability of the results was carefully and critically monitored by taking quality control and quality assurance checks, strictly as per the USEPA protocols. All prospective precautions were taken into consideration in the collection, transportation, preparation, and analysis of samples. Systems calibration standards were done according to the system manuals and in every ten samples, one continuous calibration standard was run. Additionally, in each batch a duplicate was made to counter check the result to monitor any difference in the systems reading, also every 10 samples deionized water samples from Millipore was run to observe if any peak will appear to monitor contamination of the column, the samples were also spiked randomly to confirm the system reading stability and the result readings from IC 850 Professionals was continuously counter checked with ICS 3000 and vice versa.

TABLE II
COMPARISON OF WATER QUALITY PARAMETERS OF DHAHRAN TAB WATER WITH DRINKING WATER STANDARDS: USEPA 2007 AND WHO 2011

Parameters	Results		WHO	USEPA	Ref.
	Minimum recorded	Maximum recorded			
pH	6.5	8.23	6.5-9.2	6.5-8.5	[37], [40]
Temperature (°C)	19.76 mg/L	22.86 mg/L	Not Specified	Not Specified	[37], [40]
Dissolved Oxygen (DO)	4.21 mg/L	8.32 mg/L	Not Specified	Not Specified	[37], [40]
Conductivity	232 mg/L	2586 mg/L		160-1600	[37], [40]
Turbidity	0.17 NTU	0.37 NTU	5 NTU	1 NTU	[37], [40]
TDS	93 mg/L	1671 mg/L	500 mg/L	500 mg/L	[37], [40]
Total Alkalinity	4.11 mg/L	24.04 mg/L	200 mg/L	Not Specified	[37], [40]
Calcium	0.02 mg/L	164 mg/L	75 mg/L	200 mg/L	[37], [40]
Magnesium	0.6 mg/L	77.9 mg/L	150 mg/L	Not Specified	[37], [40]
Potassium	0.5 mg/L	26.4 mg/L	Not Specified	Not Specified	[37], [40]
Sodium	18.4 mg/L	232 mg/L	200 mg/L	200 mg/L	[37], [40]
Chloride	32.7 mg/L	568.7 mg/L	200 mg/L	250mg/L	[37], [40]
Fluoride	0.001 mg/L	0.591 mg/L	1 mg/L	2.0 mg/L	[37], [40]
Sulphate	2.39 mg/L	258 mg/L	200 mg/L	250 mg/L	[37], [40]
Nitrate	0.02 mg/L	3 mg/L	45 mg/L	5 mg/L	[37], [40]
Appearance	Clear Colourless Liquid	Clear Colourless Liquid	Clear Colourless Liquid	Clear Colourless Liquid	[37], [40]

III. RESULTS AND DISCUSSION

A. Statistical Analysis

The experimental data obtained from the sample sites were analysed using sigma plot software 11.1, at a significance level of 0.05 employing One-way Analysis of Variance (ANOVA). Tables III and IV show the statistical distribution of physical and chemical parameters of Dhahran Tap-water.

TABLE III
STATISTICAL DISTRIBUTION OF PHYSICAL PARAMETERS

Parameter	Conductivity	Turbidity	TDS	Temp (°C)
Mean	677.32	0.24	364.7	20.97
Minimum	232	0.17	93	19.76
Maximum	2586	0.37	1671	22.86
Standard Deviation	532.68	0.05	384.7	0.75
Median	492	0.24	205	21.22
Mode	490	0.23	119	21.44

Variants in temperature as recorded across the sampling sites are shown in (Fig. 2 (b)). The water temperature appears normal, and no significant difference was observed. The average recorded temperature was 20.97 °C. Dissolved oxygen (DO) is a vital parameter in water quality assessment and analysis as it reflects both the physical and biological activities prevailing in water [23], [43]. The DO values also indicate the degree of pollution in the water bodies and the DO values were found to range from 4.21 to 8.32. Conductivity is another important property of water quality, it shows water changes, and it is the backbone to measure the level of salinity and TDS. Most water bodies maintain a constant conductivity that can be used as a baseline of comparison to future measurements and changes. This study has recorded conductivity range of 232 to 2586 uS/cm (Fig. 3 (b)). The turbidity of the water varied from 0.17 to 0.37 NTU (Fig. 4 (a)). The maximum value of 0.37 NTU was because of the presence of suspended particulate matter. Quantitatively, TDS values fluctuated from 93 mg/L to a maximum value of 1671 mg/L which can be attributed to the consequences of heavy rainfall experienced during the winter (Fig. 4 (b)).

TABLE IV
STATISTICAL DISTRIBUTION OF CHEMICAL PARAMETERS

Parameter	pH	DO	Alkalinity	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Cl^{-}	F^{-}	$SO4^{2-}$	NO^{3-}
Mean	7.09	5.47	12.30	42.31	18.34	6.97	68.87	137.43	0.10	64.99	0.96
Min	6.5	4.21	4.11	0.02	0.6	0.5	18.4	32.7	0.001	2.39	0.02
Max	8.23	8.32	24.04	164.6	77.9	26.4	232.3	568.7	0.59	258.8	3
STD	0.46	1.29	6.11	45.46	20.81	7.08	62.19	131.43	0.13	76.21	0.76
Median	6.98	4.92	11.25	19.32	7.26	3.84	39.98	82.2	0.042	32.11	0.9
Mode	6.59	4.92	5.76	N/A	2.6	5.1	21.1	37.4	0.001	5.4	0.15

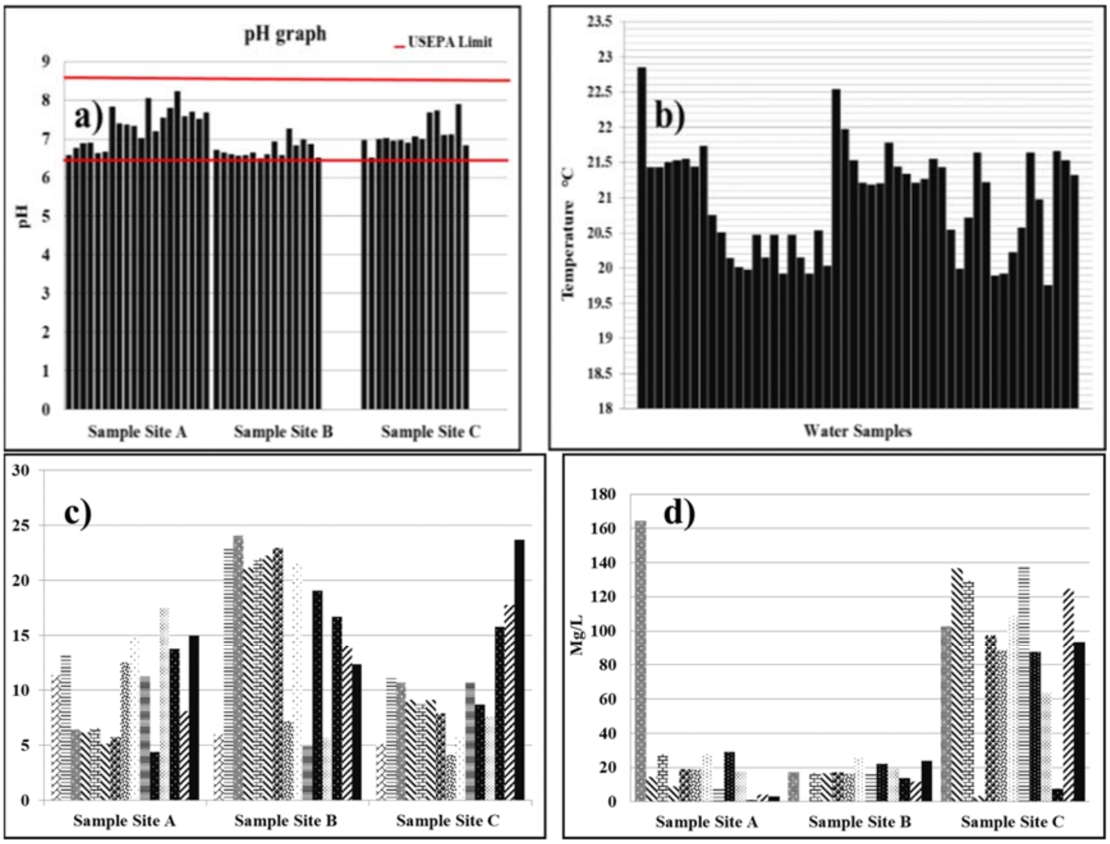

Fig. 2 (a), pH (b) temperature readings, (c) total alkalinity, and (d) calcium levels of the water samples

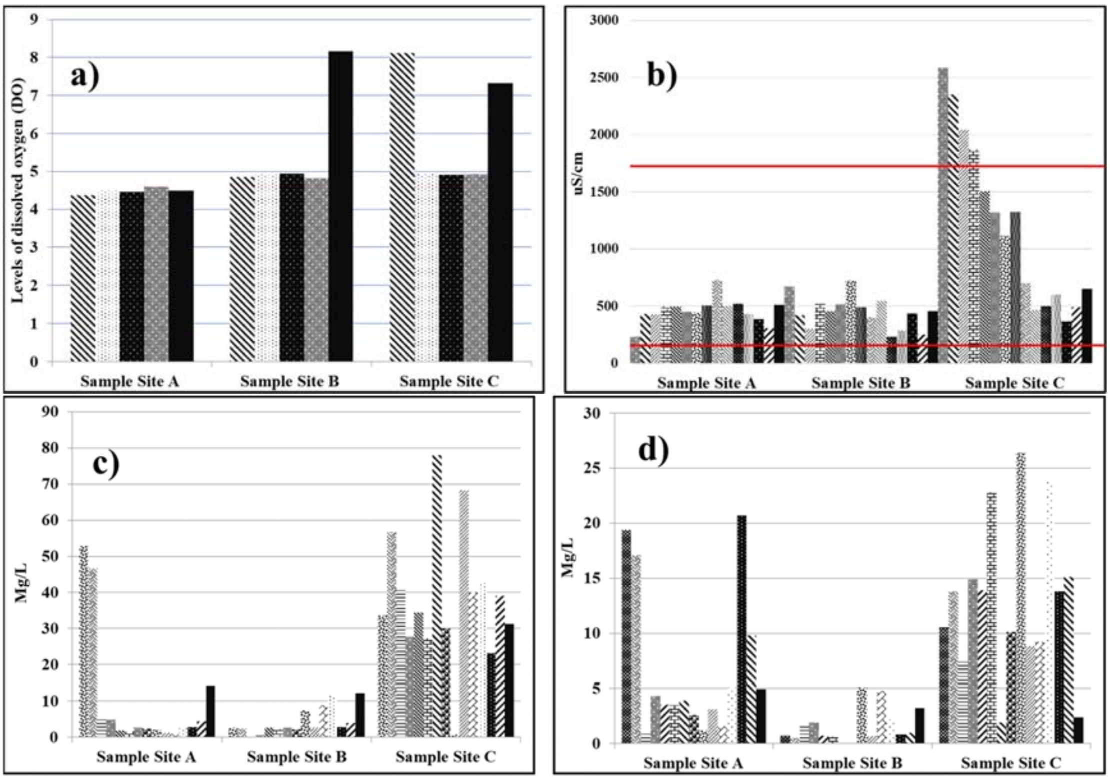

Fig. 3 (a) DO, (b) conductivity, (c) magnesium, and (d) potassium levels of the water samples

Water pH represents an essential parameter in assessing its quality. Acidic conditions will prevail as the pH value decreases and alkaline conditions will exist as the pH value increases [44]. The pH of the water samples was between 6.5 to 8.23. Remarkably, these values fall clearly within the standards given by USEPA and WHO (6.5-8.5) and 6.5-9.2 respectively and the total alkalinity levels measured in the water samples are shown (Fig. 2 (c)) with an average reading of 12.31 mg/L. The alkalinity value of water has implications for the presence of natural salts in water and can be associated with minerals dissolved in water.

Calcium and magnesium are the most plentiful elements in the groundwater. Calcium may be released from carbonate, bicarbonates, and limestone rocks or maybe leaked from the soil surface. Industrial and municipal discharges are also other sources of minerals. Dissolved Mg^{2+} concentration is generally lesser than Ca^{2+} in the groundwater. Figs. 2 (d) and 3 (c) show Ca^{2+} and Mg^{2+} concentrations in the water samples respectively. The Ca^{2+} content from the water samples was between 0.02 to 164 mg/L while Mg^{2+} was recorded at 0.6 to 77.9 mg/L and all the water samples exhibited concentrations within the acceptable limit. K^{+} represents an important nutrient for both plant and human life, however, excessive oral uptake may be harmful to human beings and living organisms. (Fig. 3 (d)), the concentration of K^{+} recorded in the water samples varied from 0.5 to 26.4 mg/L. Virtually, also sodium compounds are soluble in water and tend to stay in the aqueous phase. When water gets in contact with rocks, especially the igneous type it will dissolve sodium from its source [45]. The range of Na^{+} in water samples analysed was 18.4 to 232 mg/L (Fig. 4 (c)). Na^{+} concentration in the water samples tested was found to be 92% within the permissible limit.

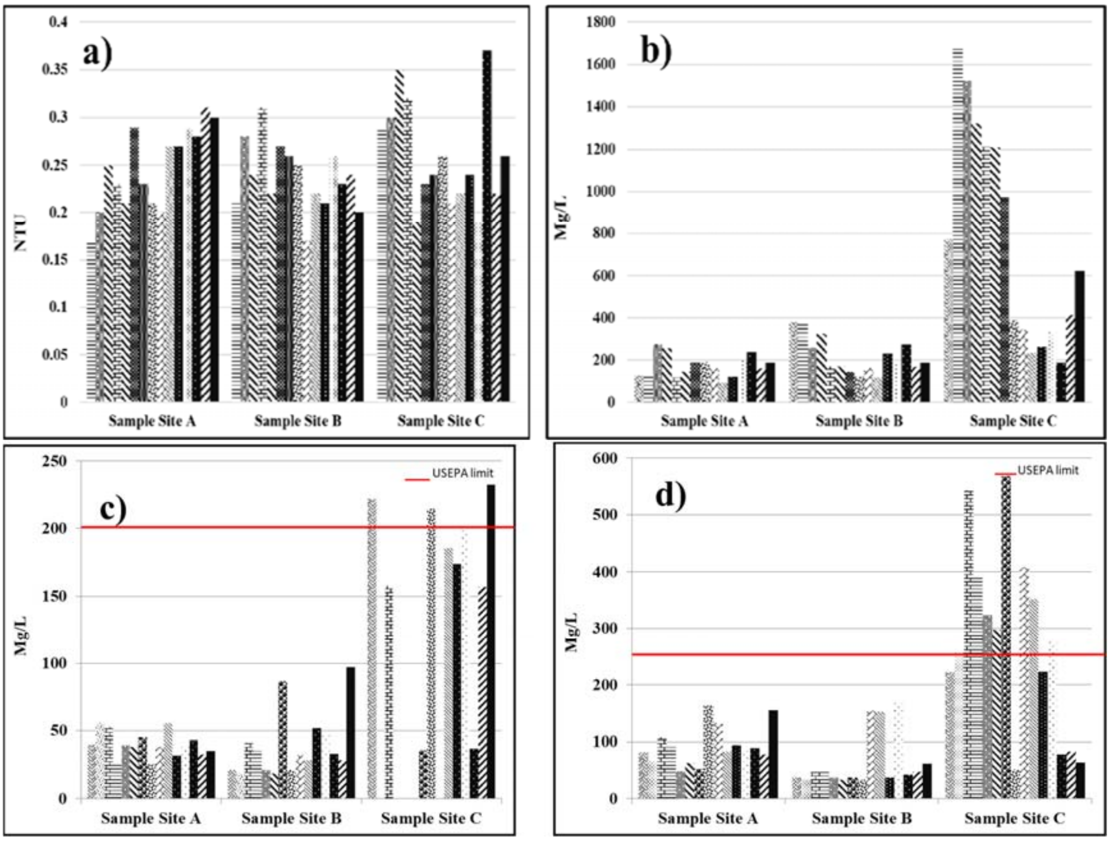

Fig. 4 (a) turbidity, (b) TDS, (c) sodium, and (d) chloride levels of the water samples

Chloride is an important element available in a variable amount in tap water. It can occur naturally in groundwater and may also originate from many different sources like weathering, and infiltration of sedimentary rocks and seawater. In the water samples analysed, the concentration of chloride ranged from 32.7 to 568.7 mg/L (Fig. 4 (d)). The chloride content of the water samples was found to be 82% within the desirable limit prescribed by USEPA. Unlike chlorides, fluoride source is predominantly from iron, steel, petroleum refining and phosphate fertilizer industries. Although fluoride preponderance is dependent on temperature variations, the study recorded stable temperatures in all the samples ranging from 19.76 to 22.86 °C, and fluoride values of the water samples were from 0.001 to 0.591 mg/L (Fig. 5 (a)). Another notable element that may infiltrate any water source through weathering and the decomposition of sulphur-containing rocks. It is typically present in the form of sulphates. The sulphate levels obtained in the analysed water samples ranged from 2.39 to 258 mg/L (Fig. 5 (b)). The samples were found to be 98% well within the permissible limit. Tap water may contain nitrates as a direct consequence of percolation and from broken water pipes carrying sewage wastes rich in nitrates or from agricultural waste [20], [46]. The nitrate concentration in this study area varied from 0.02 mg/L to 3 mg/L (Fig. 5 (c)).

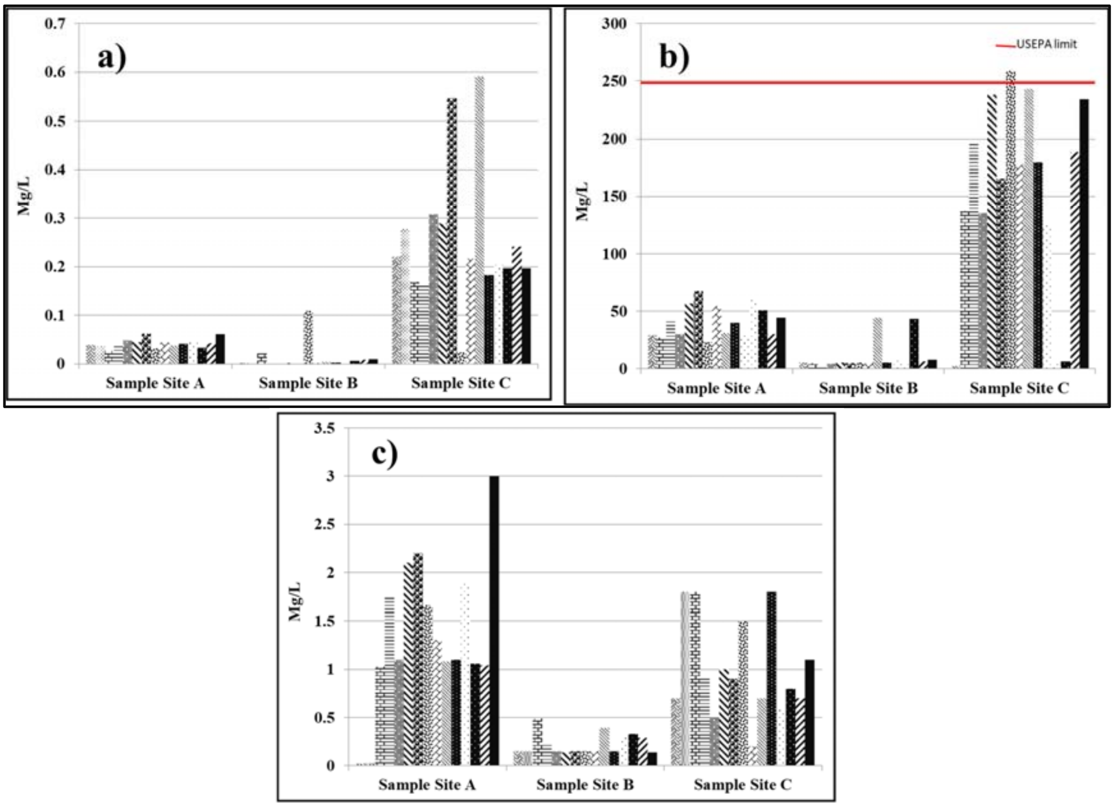

Fig. 5 (a) fluoride, (b) sulphate, and (c) nitrate levels of the water samples taken

IV. Conclusion

In this study, the physicochemical parameters of 45 tap-water samples at different locations in Dhahran were assessed. To examine the quality of tab-water every parameter was compared with the maximum allowable limits recommended by the WHO and USEPA. The water parameters investigated demonstrate the suitability of Dhahran tap water for human consumption, except for a few locations where conductivity, TDS, sodium ions, chloride ions and sulphate ions exceeded the set standards, however, not at an alarming rate. The deviations observed particularly in the chemical parameters such as sodium, chloride and sulphate could be a result of the underlying geological formation [36], [47], [48]. Physical parameters such as TDS on the other hand could be linked to dust storms, sandstorms, weathering, and wind erosion normally experienced in the area that eventually end up in water processing tanks and other reservoirs and sources. Periodic monitoring of the chemical parameters of the tab-water is recommended to subject the water to further treatment that will culminate in a drastic reduction in the concentration of the few identified ions.

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Conflict of Interest

The authors of this manuscript declare no conflict of interest.

References

[1] R. W. Company, "Ecohydrology Study of Physico-Chemical Parameters of Water Quality in the Lumbardh Deçani," no. June, pp. 154–158, 2013.

[2] G. O. Odhiambo, "Water scarcity in the Arabian Peninsula and socio-economic implications," *Appl. Water Sci.*, vol. 7, no. 5, pp. 2479–2492, 2017.

[3] I. Slavik, K. R. Oliveira, P. B. Cheung, and W. Uhl, "Water quality aspects related to domestic drinking water storage tanks and consideration in current standards and guidelines throughout the world–a review," *J. Water Health*, vol. 18, no. 4, pp. 439–463, 2020.

[4] A. J. Whelton *et al.*, "Residential tap water contamination following the freedom industries chemical spill: perceptions, water quality, and health impacts," *Environ. Sci. Technol.*, vol. 49, no. 2, pp. 813–823, 2015.

[5] A. A. Hassan, M. Sajid, A. Tanimu, I. Abdulazeez, and K. Alhooshani, "Removal of methylene blue and rose bengal dyes from aqueous solutions using 1-naphthylammonium tetrachloroferrate (III)," *J. Mol. Liq.*, p. 114966, 2020.

[6] R. Reza and G. Singh, "Physico-Chemical Analysis of Ground Water in Angul-Talcher Region of Orissa, India," vol. 5, no. 5, pp. 53–58, 2009.

[7] C. P. Liyanage and K. Yamada, "Impact of population growth on the water quality of natural water bodies," *Sustainability*, vol. 9, no. 8, p. 1405, 2017.

[8] A. A. Hassan, A. Tanimu, and K. Alhooshani, "Dispersive Micro-Solid Phase Extraction of Pharmaceutical Drugs from Wastewater and Human Urine Using (Z)-Octadec-9-en-1-aminium tetrachloroferrate (III) Ionic Liquid and Analysis by High-Performance Liquid Chromatography," *Arab. J. Sci. Eng.*, pp. 1–15, 2021.

[9] A. A. Hassan, A. Tanimu, and K. Alhooshani, "Iron and cobalt-containing magnetic ionic liquids for dispersive micro-solid phase extraction coupled with HPLC-DAD for the preconcentration and quantification of carbamazepine drug in urine and environmental water samples," *J. Mol. Liq.*, vol. 336, p. 116370, 2021.

[10] A. Galadima, Z.. Garba, L. Leke, M. N. Almustapha, and I.. Adam,

"Domestic Water Pollution among Local Communities in Nigeria ---- Causes and Consequences," vol. 52, no. 4, pp. 592–603, 2011.
[11] S. M. Mintenig, M. G. J. Löder, S. Primpke, and G. Gerdts, "Low numbers of microplastics detected in drinking water from ground water sources," *Sci. Total Environ.*, vol. 648, pp. 631–635, 2019.
[12] A. A. Hassan, A. Tanimu, S. A. Ganiyu, I. Y. Yaagoob, and K. Alhooshani, "Selective removal of Cd (II), As (III), Pb (II) and Cr (III) ions from water resources using novel 2-anthracene ammonium-based magnetic ionic liquids," *Arab. J. Chem.*, p. 104136, 2022.
[13] A. Abdi Hassan, M. Sajid, H. Al Ghafly, and K. Alhooshani, "Ionic liquid-based membrane-protected micro-solid-phase extraction of organochlorine pesticides in environmental water samples," *Microchem. J.*, vol. 158, p. 105295, 2020.
[14] P. Sahu, "Fluoride pollution in groundwater," in *Groundwater Development and Management*, Springer, 2019, pp. 329–350.
[15] Y. Sayato, "WHO Guidelines for Drinking-Water Quality," *Eisei kagaku*, vol. 35, no. 5, pp. 307–312, 1989.
[16] WHO, "Drinking-water," 2019.
[17] G. Bjørklund *et al.*, "Uranium in drinking water: a public health threat," *Arch. Toxicol.*, vol. 94, no. 5, pp. 1551–1560, 2020.
[18] C. L. Chan, M. K. Zalifah, and A. S. Norrakiah, "Microbiological and physicochemical quality of drinking water," *Malaysian J. Anal. Sci.*, vol. 11, no. 2, pp. 414–420, 2007.
[19] A. M. Dietrich and G. A. Burlingame, "Critical review and rethinking of USEPA secondary standards for maintaining organoleptic quality of drinking water," *Environ. Sci. Technol.*, vol. 49, no. 2, pp. 708–720, 2015.
[20] Bijay-Singh and E. Craswell, "Fertilizers and nitrate pollution of surface and ground water: an increasingly pervasive global problem," *SN Appl. Sci.*, vol. 3, no. 4, p. 518, 2021.
[21] N. Sharma, U. Vaid, and S. K. Sharma, "Assessment of groundwater quality for drinking and irrigation purpose using hydrochemical studies in Dera Bassi town and its surrounding agricultural area of Dera Bassi Tehsil of Punjab, India," *SN Appl. Sci.*, vol. 3, no. 2, p. 245, 2021.
[22] O. A. Ojo, S. B. Bakare, A. O. Babatunde, and B. Expressway, "Microbial and Chemical analysis of potable water in public-water supply within lagos university, Ojo," vol. 1, no. 1, pp. 30–35, 2001.
[23] D. Gianello, E. Ávila-Hernández, I. Aguer, and M. C. Crettaz-Minaglia, "Water quality assessment of a temperate urban lagoon using physico-chemical and biological indicators," *SN Appl. Sci.*, vol. 1, no. 5, p. 470, 2019.
[24] P. Verlicchi and V. Grillini, "Surface water and groundwater quality in South Africa and Mozambique—Analysis of the Most critical pollutants for drinking purposes and challenges in water treatment selection," *Water*, vol. 12, no. 1, p. 305, 2020.
[25] A. CMA, "Standard Methods for Water and Effluent Analysis. Foludex Press Ltd, Ibadan, p. 182," p. 1996, 1996.
[26] WHO, "1 in 3 people globally do not have access to safe drinking water – UNICEF, WHO," 2019.
[27] X. Kepuska, L. Daija, and I. Kristo, "Determination of Physico-Chemical Parameters of Water in Biological Minimum in the Lake" Radoniq"," *Eur. Sci. J.*, 2014.
[28] N. A. Ajadi, J. O. Ajadi, A. S. Damisa, O. E. Asiribo, and G. A. Dawodu, "Modeling Monthly Average Temperature of Dhahran City of Saudi-Arabia Using Arima Models," *J. data Sci.*, vol. 3, no. 5, 2017.
[29] A. N. Patel and E. T. Puttiah, "Analysis of Water Quality Using Physico-Chemical Parameters Hosahalli Tank in Shimoga District, Karnataka, India," vol. 11, no. 3, pp. 0–4, 2011.
[30] M. B. Baig, Y. Alotibi, G. S. Straquadine, and A. Alataway, "Water resources in the Kingdom of Saudi Arabia: Challenges and strategies for improvement," in *Water Policies in MENA Countries*, Springer, 2020, pp. 135–160.
[31] S. Chowdhury and M. Al-Zahrani, "Implications of climate change on water resources in Saudi Arabia," *Arab. J. Sci. Eng.*, vol. 38, no. 8, pp. 1959–1971, 2013.
[32] N. B. Khan and A. N. Chohan, "Accuracy of bottled drinking water label content," *Environ. Monit. Assess.*, vol. 166, no. 1, pp. 169–176, 2010.
[33] B. Tawabini and A. Zubair, "Bromate control in phenol-contaminated water treated by UV and ozone processes," *Desalination*, vol. 267, no. 1, pp. 16–19, 2011.
[34] B. S. Tawabini, "Effect of blending ratio on the formation of bromoform and bromate in blended water samples disinfected with chlorine or ozone," *Int. J. Environ. Eng.*, vol. 6, no. 4, pp. 349–360, 2014.
[35] A. A. Othman, S. A. Al-Ansi, and M. A. Al-Tufail, "Determination of bromate in bottled drinking water from Saudi Arabian markets by HPLC/ICP-MS," *Anal. Lett.*, vol. 43, no. 5, pp. 886–891, 2010.
[36] A. M. Al-omran and M. E. Nadeem, "Quality assessment of various bottled waters marketed in Saudi Arabia," pp. 6397–6406, 2013.
[37] WHO, "Guidelines for drinking-water quality," *WHO Chron.*, vol. 38, no. 4, pp. 104–108, 2011.
[38] S. Yamamura, "Drinking water guidelines and standards," *report*, p. 18, 2001.
[39] W. H. Organization, "A global overview of national regulations and standards for drinking-water quality," 2021.
[40] USEPA, "USEPA (U.S. Environmental Protection Agency) (2007)," vol. 67, no. 6, pp. 14–21, 2007.
[41] F. W. Pontius, "Update on USEPA's drinking water regulations," *Journal-American Water Work. Assoc.*, vol. 95, no. 3, pp. 57–68, 2003.
[42] J. Edzwald and A. W. W. Association, *Water quality & treatment: a handbook on drinking water*. McGraw-Hill Education, 2011.
[43] E. A. Oluyemi, A. S. Adekunle, A. A. Adenuga, and W. O. Makinde, "Physico-chemical properties and heavy metal content of water sources in Ife North Local Government Area of Osun State, Nigeria," vol. 4, no. October, pp. 691–697, 2010.
[44] C. Rout and A. Sharma, "Assessment of drinking water quality: A case study of Ambala cantonment area, Haryana, India," vol. 2, no. 2, pp. 933–945, 2011.
[45] A. M. Kalwale and P. A. Savale, "Determination of Physico-Chemical Parameters of Deoli Bhorus Dam water," vol. 3, no. 1, pp. 273–279, 2012.
[46] H. Murhekar Gopalkrushna, "Assessment of physico-chemical status of ground water samples in Akot city," *Res. J. Chem. Sci.*, vol. 1, no. 4, pp. 117–124, 2011.
[47] V. M. Wagh, S. V. Mukate, D. B. Panaskar, A. A. Muley, and U. L. Sahu, "Study of groundwater hydrochemistry and drinking suitability through Water Quality Index (WQI) modelling in Kadava river basin, India," *SN Appl. Sci.*, vol. 1, no. 10, p. 1251, 2019.
[48] C. K. Jain, S. K. Sharma, and S. Singh, "Assessment of groundwater quality and determination of hydrochemical evolution of groundwater in Shillong, Meghalaya (India)," *SN Appl. Sci.*, vol. 3, no. 1, p. 33, 2021.