Egypt. J. Chem. **Vol. 64,** No. 6 pp. 3175 - 3185 (2021)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Chemical and Bacteriological Assessment of Groundwater in Tathleeth Region of Asir

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Abstract

The current study aims to identify and assess the validity of groundwater in Tathleeth Region of Asir, Saudi Arabia for human and irrigation uses. The efforts, in this work, included a collection of different groundwater samples from Tathleeth area. After collection, the samples were put in appreciate containers, transferred to laboratory and kept for further analysis. The collection, preservation and analysis were done according to the standard methods. Then after, the physico-chemical proprieties of the collected groundwater samples as well as the concentration of different anions and cations were determined. Further, a bacteriological analysis was performed to evaluate the possible use of the groundwater, in this area, for human use. Finally, the obtained results were compared with the allowed limits set by Gulf Standard Specification (GSS).

Experimentally, many groundwater samples were collected from different wells, have different depths and distributed throughout the area of study. From all these groundwater samples, only nine samples were selected, to exclude repetition, and subjected to chemical and bacteriological analysis. The physical characteristics including: odor, color, turbidity and conductivity of the collected samples were determined. The values of different chemical parameters as: pH, total dissolved salts (TDS), total hardens, total alkalinity were measured according to the standard methods of analysis. In addition, the concentration of many anions (chloride, fluoride, nitrite, nitrate, ammonia and sulphate) and some major cations (iron, magnesium and calcium) were determined. Finally, a bacteriological analysis for E.coli, and T. coliform were performed for all collected samples.

The revealed results showed that pH has values ranged from 7.3 to 8.5 and the electrical conductivity exhibited values between 754 - 8944 µS cm^{-1} while the total dissolved salts between 520 to 6171 mg L^{-1}. The results demonstrate the validity of certain samples for human uses and the suitability of most of samples for irrigation purposes.

Key words: Assessment, Groundwater Quality, Tathleeth, GSS.

1. Introduction

Water is the most essential need for the existence of living organisms and its quality is directly associated with the good life of humans, plants and animal kingdom [1]. The increases in human population and rapid industrialization have increased the stress on the natural water resources and their conservation is one of the major challenges for humankind [2]. Due to the shortage of surface water mainly from limited rivers, groundwater is a major water resource in semi-arid area like Saudi Arabia and becomes a most vital resource for millions of people for both drinking and irrigation.

The quality of groundwater, as its quantity, is an important issue because it is the major factor in determining its suitability for drinking, domestic, irrigation and industrial purposes. The concentrations of chemical constituents, which are greatly influenced by the geological formations and anthropogenic activities, determine the groundwater quality. Both the agricultural and anthropogenic activities have resulted in deterioration of water quality that rendering serious threats to human beings [3]. The over-pumping of groundwater for aquaculture leads to land subsidence, seawater intrusion, and soil salinization [4]. Over-pumping also introduces excess dissolved oxygen that may oxidize the immobile mineral, and increases their concentration in water. The continual and excessive abstraction associated with a low recharging rate, will eventually lead to the depletion of groundwater and deterioration of its quality [5-6]. Moreover, groundwater quality is largely influenced by both the

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Receive Date: 04 February 2021, Revise Date: 02 March 2021, Accept Date: 02 March 2021
DOI: 10.21608/EJCHEM.2021.61442.3320

natural processes and anthropogenic activities occurred in the surrounding area [7-8].

Generally, the quality of water can be directly affected by the infiltration of pollutants in the recharge area of aquifers [9-10]. In addition to natural sources, groundwater quality could be affected by urbanization, agricultural waste, and land cover. Further, the intensive applications of fertilizers, pesticides, and utilization of wastewater for irrigation as well as leakage from wastewater lagoons, landfill disposal sites, septic tanks and industrial discharge have serious effects on groundwater quality [11-21]. Environmentally, domestic wastewater is considered as a major source of pollution to groundwater. Urban runoff, fertilizers from agricultural return flows and solid waste disposal appear to be secondary sources [22]. Actually, the groundwater in different country was contaminated probably due to lack of proper waste management protocols [23].

The contamination of ground water creates hazards to public health, where the presence of different anions and/or cations in groundwater put serious threats especially to human health. Fluoride occurs naturally in groundwater and provides protection against dental caries, especially in children. The low fluoride concentration, less than 0.5 mg L-1, leads to the risk of tooth decay while higher concentration causes dental fluorosis [24]. Nitrate concentration above 45 mg L-1 may prove harmful to human health causing methemoglobinemia (blue babies) which generally affects bottle-fed infants [25]. High concentration of sulfates may induce diarrhea and intestinal disorders. Elevated concentrations of Fe, in natural water resources, can lead to several serious health problems like cancer, diabetes, liver and heart diseases as well as neurodegenerative diseases [26]. In addition, presence of arsenic, in drinking water, is related to occurrence of skin lesions [27].

The present work aimed to assess the quality of groundwater in Tathleeth, Asir area, Saudi Arabia for human and irrigation consumption through the determination of major ions affecting the water quality. It was looking that the results of this study to be helpful in the sustainable management of groundwater resources in Asir region. Actually, the current work is the first study performed to evaluate the groundwater quality in Tathleeth area, Asir province, Saudi Arabia.

2. Materials and Methods

2.1. Location of study area

The Asir Region is a region of Saudi Arabia located in the southwest of the country. It has an area of 76,693 square kilometers and an estimated population of 2,211,875 [28]. It shares a short border with the Saada Governorate of Yemen. Asir region is situated on a high plateau that receives more rainfall than the rest of the country and contains the country's highest peaks, which rise to almost 3,000 meters at Jabal Sawda near Abha. The average annual rainfall in the highlands probably ranges from 300 to 500 millimeters. It falls in two rainy seasons, the chief one being in March and April, with some rain in the summer. The study area has the coordinates 19o.52475', 43o.5174' and the location of the wells is presented in Fig. (1).

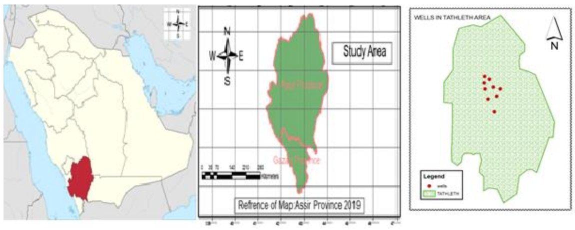

Fig. (1): The location of the study area and the wells of collected samples.

Samples collection

Nine groundwater samples were collected from different wells in Tathleeth area, Asir province during January and February 2020. The depth of all wells ranges from 60 to 70 meters. The samples were collected in polyethylene bottles and preserved by adding an appropriate reagent according to the standard procedures [29]. The water samples for trace element analysis were collected in acid-leached polyethylene bottles and preserved by adding ultrapure nitric acid (5 ml L-1) while samples for bacteriological analysis were collected in sterilized high-density polypropylene bottles covered with aluminum foils. All the samples were stored in sampling kits maintained at 4 oC and brought to the laboratory for detailed chemical and bacteriological analysis. The source of different collected samples and their codes are given in Table (1).

The priority parameters, which should be considered in assessment of any drinking water quality, are those having the greatest health impact and are most commonly detected at significant concentrations in drinking water [30].

Table (1): The source of different collected groundwater samples and their codes.

No	Sample location	Code
1	Hajis Fuhayd 1	HF1
2	Hajis Fuhayd 2	HF2
3	Hadi Romiah	HR3
4	Hajis Hassan	HH4
5	Zafir Fahad	ZF5
6	Hawayzi Jafin	HJ6
7	Eyd Hamda	EH7
8	Bandar Hawizi	BH8
9	Tahus Eubayd	TE9

Thus, eighteen parameters were selected, in this study, to assess the quality of the collected groundwater samples. These parameters are pH, total dissolved solid (TDS), total hardness (TH), total alkalinity (TAlk), turbidity (Turb), electric conductivity (EC), oder, color, sulphates (SO_4^{2-}), chlorides (Cl^-), fluorides (F^-), nitrites (NO_2^-), nitrates (NO_3^-), iron (Fe), magnesium (Mg^{2+}), calcium (Ca^{2+}), ammonia (NH_3) and Escherichia coli (E.coli).

All chemicals and reagents, used in this study, are of analytical grade purity and used without further purifications. The samples were analyzed in triplicates for their chemical constituents in accordance to the standard methods for the examination of water and wastewater [29]. Determination of pH value, electrical conductivity (EC), turbidity and total dissolved solids (TDS) were conducted on site with portable meters, which were calibrated prior to taking of readings. Analysis of pH was conducted using Hana pH meter, model 211, Italy. The pH electrode was calibrated with buffer solutions of pH 4, 7 and 10, prior to taking the readings. The electric conductivity was measured using conductivity meter JENWAY, Model 4010, UK. The color of collected samples was detected using ELICO 690 Spectral colorimeter. The samples turbidity was measured using Hach Turbidimeter device, model 2100AN. Total alkalinity (TAlk) was determined by acid titration method while the total hardness (TH) of water was analyzed volumetrically by ethylene diamine tetra acetic acid (EDTA) titration method using Eriochrome Black T and Murexide indicators, respectively. The concentrations of the anions: chloride, fluoride, nitrite, nitrate, and sulphate were determined, after filtration of water samples, using the recommended procedures [29]. The volumetric titration was performed using HACH Automatic Titrator, model DR6000, from Metrohm. The concentrations of different cations were measured using Atomic Absorption Spectrophotometer (AAS).

Mathematical calculations

Contamination Index (Ci)

The contamination index is a group of parameters beyond the accepted limits and may be harmful to the environment. The Ci was calculated by applying the formula described below [31]:

$$C_i = c_i / S_i - 1 \qquad (1)$$

where: Ci is the contamination factor of ith parameters, ci is the analytical value of the concentration corresponding to ith parameter (mg L^{-1}) in a given groundwater sample, and Si is the higher permissible level of ith parameters given by the WHO for human consumption.

Relative Weight (Wi)

The unit weight was assigned to each of the parameters under consideration (wi) according to its health effects when present in drinking water. The maximum weight assigned is five (the highest effect on drinking water quality) and the minimum weight assigned is one (the least effect on drinking water quality). The relative weight for each parameter (Wi) was calculated by dividing its unit weight by the sum of unit weight of all parameters as per the following formula [32]:

$$W_i = w_i / \left(\sum_{i=1}^{n} w_i\right) \qquad (2)$$

where: Wi is the relative weight, wi is the unit weight of each parameter, and n is the number of selected parameters (n = 16 in this study).

Quality Rating (Qi)

The quality rating (Qi) for each parameter was calculated by dividing its concentration by its permissible limit value as defined in WHO guideline and the result multiplied by 100 according to the following equation:

$$Q_i = C_i / S_i \times 100 \qquad (3)$$

where: Qi is the rating scale, Ci is the concentration corresponding to ith parameter (mg L^{-1}) at in a given groundwater sample, and Si is the drinking water standard for ith parameter (mg L-1) according to the WHO.

Water Quality Index (WQI)

The water quality index was determined the sum of multiplying the relative weight (Wi) with the rating scale (Qi) for all selected parameters as per the following equation [33]:

$$WQI = \sum_{i=1}^{n} W_i \times Q_i \quad (4)$$

The groundwater quality types were determined according to the computed WQI values. These types were classified into five categories shown in Table (2) [34].

Table (2): The water quality index (WQI) range and water quality classification for drinking purposes.

No	Water Quality Type	*WQI* Range
1	Excellent water	< 50
2	Good water	50 – 100
3	Poor water	100.1 – 200
4	Very poor water	200.1 – 300
5	Water unsuitable for drinking	> 300

Magnesium Hazard (MH)

Magnesium Hazard (MH) is used to determine whether the groundwater is suitable for irrigation or not. It was calculated based on the following equation [35]:

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad (5)$$

3. Result and discussion

3.1. Physico-chemical characteristics

The analytical values of each measured groundwater quality parameter at each sampling location are presented in Table (3). Further, the summary of the revealed results of the determined quality parameters and some statistical measurements as well as their recommended permissible limits in the World Health Organization (WHO) and Gulf Standard Specifications No. 2014/149 (GSS) are given in Table (4).

3.1.1. Physical Features

The pH of water is important parameter because it controls many of the geochemical reactions and solubility calculations within groundwater. Further, it is an important operational parameter in treatment plant. The data in Table (3) clarify that pH values ranged from 7.3 to 8.5 with an average value of 7.98, which indicates the slightly alkaline nature of groundwater in all studied locations.

The alkaline nature of groundwater is mainly caused by bicarbonate concentration in the water aquifers. The electrical conductivity (EC, μS cm–1) is a useful tool to evaluate the purity of water and a good measure of salinity hazard to crops. Electrical conductivity values of groundwater samples ranged between 754 and 8944 μS cm–1, Table (4). The result indicates that almost the groundwater samples crossed the permissible limits of the WHO and GSS except that of the wells in EH7 and BH8 sites. The EC values of 758 and 754 μS cm–1 were detected for EH7 and BH8 sites, respectively. The high conductivity of groundwater in these wells may be caused by the high level of Ca^{2+}, Mg^{2+}, and SO_4^{2-} ions. The total dissolved solids (TDS, mg L–1) in the study area ranged from 520 to 6171 mg L–1 with an average of 2947 mg L–1. The results of 7 samples exceeded the allowable limits of the WHO and GSS of 1000 mg L–1. Contrary, the groundwater samples collected from the wells in EH7 and BH8 sites were within the guidelines. It is important to note that the standard for total dissolved solid is up to 500 mg L–1 and the maximum permissible quantity is 1000 mg L–1. The high salinity of groundwater may be due to leaching of soluble salts in the water. A water containing TDS less than 1000 mg L–1 can be considered to be fresh water' for irrigation use and will not affect the osmotic pressure of the soil.

Alkalinity is mostly due to the presence of bicarbonates in water. The total Alkalinity (TAlk, mg L–1) values measured for the collected groundwater samples varied from 200 to 494 mg L–1 with a mean value of 289.6 mg L–1. Based on the standard limit of the WHO (300 mg L–1), the result indicates that almost groundwater samples were under the permissible limits. In contrast, all samples crossed the GSS limits except the sample collected from ZF5 well. The total hardness (TH as: $MgCaCO_3$, mg L–1) of the groundwater samples in the studied locations ranged from 245 to 2231 mg L-1 with a mean value of 1244.6 mg L–1. Generally, hardness of groundwater results mainly from presence of alkaline earth metals calcium and magnesium. Most of groundwater sampling locations had a TH value exceeding the permissible limit of the WHO and GSS standards (500 mg L–1 as CO32-). Generally, Sawyer et al. [36] classified the quality of groundwater according to TH as soft (TH < 75), moderately hard (75 < TH < 150), hard (150 < TH < 300) and very hard (TH > 300). Based on these classification criteria, the groundwater of majority of the studied wells is hard to very hard water. Out of the 9 sampling locations, seven locations belong to very hard water and only two locations belong to hard water [30].

The level of turbidity in drinking water is important parameter for the good operation of treatment plant and for aesthetic reasons, where high quality drinking water should have a low level of turbidity. The turbidity (Turb, NTU) of the groundwater samples varied from 0.3 to 2.1 NTU with a mean value of 1.03 NTU and a standard deviation value of 0.648. None of the studied locations exceeds the maximum allowable turbidity limit for drinking water according to WHO and GSS guidelines (4 and 5 NTU). High turbidity of water can protect pathogenic microorganisms and often associated with high levels of disease causing organisms such as viruses, and bacteria [3]. The color intensity (TCU) of collected groundwater samples changed from 4 to 21 TCU with an average value of 11.8 TCU and a standard deviation value of 5.8. The revealed analytical results show that seven groundwater samples had color values below the permissible limit of WHO and GSS guidelines (15 TCU). Only, two groundwater samples, which collected from the wells in HR3 and HH4 sites, had values crossed the permissible limits (18 and 21 TCU, respectively). The high color intensity of these samples may be due to the presence of some metals ions such as iron, or manganese**.** In addition, the groundwater samples are completely odorless, assigned as (0, mg L^{-1}). This means that there are no odor organic compounds in the samples.

3.1.2. Traced anions

Fluoride concentration in drinking water shows unique properties as its level in optimum dose is beneficial but the elevated concentrations may seriously affect the human health. The amount of F in water is dependent on the geological nature of the study area, depth of the aquifer and physico-chemical characteristic of the groundwater. The fluoride content (F^-, mg L^{-1}) in the groundwater samples showed a range of 0.05 to 2.07 mg L^{-1} with a mean value of 1.08 mg L^{-1}, Table (4). The results show that fluoride concentration, in the three samples (ZF5, HJ6 and TE9), were above the permissible limits of the WHO and GSS (1.5 mg L^{-1}) which is considered as a toxic level and may be a cause of fluorosis. The other 6 samples exhibited fluoride concentration within the permissible limits. Generally, the primary cause of fluoride (F^-) in water is fluoride-containing rocks like fluorapatite, fluorspar, hydroxylapatite, fluorite and cryolite.

Chloride is not harmful to the humans at low level; however, at concentration above 250 mg L^{-1} it gives a salty taste to water. Moreover, excessive chloride concentrations can affect the corrosion of metals in the water's distribution system pipes and may increase the metals concentrations in the drinking water [30]. In the studied locations, the concentration of the chloride ion (Cl^-, mg L^{-1}) varied from 112 to 1091 mg L^{-1} with a mean value of 583 mg L^{-1}. The maximum desirable limit of chloride for drinking water is specified as 200 mg L^{-1} while the maximum permissible limit is 600 mg L^{-1}. The chloride concentration values of 5 samples fall within the allowable limits of GSS standards, while the four samples HF1, ZZF5, HJ6, and TE9 crossed the GSS guidelines, Tables (3, 4). A relatively high concentration of chloride is observed at TE9 location (1091 mg L^{-1}), while the lowest one was detected in BH8 site.

The nitrite and nitrate concentrations (NO_2^- & NO_3^-, mg L^{-1}) of the groundwater samples collected from Tathleeth region ranged from 0.026 to 0.3 mg L^{-1} and 7 to 108 mg L^{-1}, respectively (Table 3). The average concentration values of both anions were 0.051 and 49.27 mg L^{-1}, while the STD values were 0.016 and 40.34 for NO_2^- & NO_3^-, respectively. It was observed that the concentration of nitrite of all samples were within the WHO and GSS limits of 3 mg L^{-1}. Further, most of groundwater samples had nitrate concentration within the WHO and GSS limits except that collected from the wells in HH4, ZF5 and HJ6 sites. Nitrite is a specific health concern in the human body as it changes haemoglobin in the blood to methaemoglobin. The high level of nitrate in groundwater is often caused by contamination from excessive use of fertilizers, animal waste and seepage of the human sewerage from private septic systems.

Table (3): The analytical results of groundwater quality parameters at each sampling location.

No.	Parameters	Samples								
		HF1	HF2	HR3	HH4	ZF5	HJ6	EH7	BH8	TE9
1	pH	7.3	7.9	7.6	8.1	8.1	8.2	8.5	8.1	8.2
2	Conductivity, µS cm^{-1}	3374	2539	2398	5469	8944	6000	758	754	7063
3	TDS, mg L^{-1}	2328	1752	1655	3774	6171	4140	523	520	4873
4	T. Alkalinity, mg L^{-1}	221	247	280	223	200	494	266	276	285
5	T. Hardness, mg L^{-1}	1102	893	1065	1523	2231	1987	245	247	1922
6	Turbidity, NTU	1.2	1.4	1.5	2.1	0.5	0.3	0.4	0.6	0.9
7	Color, TCU	4	11	18	21	12	8	8	9	14
8	Oder	No	No	No	No	No	No	No	No	No
9	Fluoride, mg L^{-1}	1.45	0.78	1.27	0.05	1.69	2.07	0.43	0.49	1.52
10	Chloride, mg L^{-1}	725	681	162	551	771	992	125	112	1091
11	Nitrite, mg L^{-1}	0.042	0.058	0.032	0. 30	0. 065	0. 026	0. 03	0. 033	0.071
12	Nitrate, mg L^{-1}	32	23	32	88	108	101	20	7	16
13	sulfate, mg L^{-1}	560	528	740	1315	1368	1320	73	77	1682
14	Ammonia, mg L^{-1}	0.0	0.18	0.07	0.01	0.0	0.02	0.01	0.02	0.02
15	Calcium, mg L^{-1}	1097	801	911	1279	2017	1802	189	533	1877
16	Magnesium, mg L^{-1}	5	92	154	244	214	185	56	286	45
17	Iron, mg L^{-1}	0.06	0.1	0.25	0.05	0.04	0.02	0.02	0.63	0.28
18	E.coli, MPN/100 ml	- ve	- ve	- ve	- ve	- ve	- ve	+ ve	+ ve	+ ve
19	T. Coliform	- ve	- ve	+ ve	- ve	+ ve	+ ve	+ ve	+ ve	+ ve

T. Alkalinity, mg L^{-1} (as: HCO_3), T. Hardness, mg L^{-1} (as: Mg,$CaCO_3$)

Table (4): Statistical data of the physicochemical parameters of groundwater samples along with WHO and GSS values.

GWQ	Actual analytical values				WHO Standards		No.	GSS Standards		No.
Parameters	Min	Max	Mean	STD	MDL	MPL	SAPL	MPLBW	MPLUW	SAPL
pH	7.3	8.5	7.982	0.3995	6.5	9.2	0	6.5	8.2	1
EC, µS cm^{-1}	754	8944	4272.455	3019.427	-	1500	7	200	1600	7
TDS, mg L^{-1}	520	6171	2947.909	2083.307	500	1000	7	500	1000	7
TAlk, mg L^{-1}	200	494	289.636	100.646	100	300	1	70	200	8
TH, mg L^{-1}	245	2231	1244.636	750.958	100	500	7	200	500	7
Turb., NTU	0.3	2.1	1.027	0.648	0.3	4.0	0	2.0	5.0	0
Color, TCU	4	21	11.818	5.812	0	15	2	0	15	2
F^-, mg L^{-1}	0.05	2.07	1.079	0.718	1.0	1.5	3	1.5	1.5	3
Cl^-, mg L^{-1}	112	1091	583.0	379.022	200	600	5	100	700	4
NO_2^-, mg L^{-1}	0. 026	0. 30	0.051	0.016	0.9	3.0	0	0.2	3.0	0
NO_3^-, mg L^{-1}	7	108	49.272	40.337	10	50	3	50	50	3
SO_4^{2-}, mg L^{-1}	73	1682	856.182	610.093	200	400	7	150	250	7
NH_3, mg L^{-1}	0.0	0.18	0.0464	0.0656	0.0	2.0	0	0.5	1.5	0
Ca^{2+}, mg L^{-1}	189	2017	1155.64	666.248	75	200	8	65	200	8
Mg^{2+}, mg L^{-1}	5	286	142.909	102.641	30	150	5	10	150	5
Iron, mg L^{-1}	0.02	0.63	0.191	0.224	0.3	2.0	0	0.3	0.3	1

Note:**GWQ**: Ground Water Quality, **STD**: Standard Deviation, **WHO**: World Health Organization, **MDL**: Maximum Desirable Limit, **MPL**: Maximum Permissible Limit, **SAPL**: Samples Above Permissible Limit, **GSS**: Gulf Standard Specifications, **MPLBW**: Maximum Permissible Limit for Bottled Water, and **MPLUW**: Maximum Permissible Limit for Unbottled Water.

Sulfate ion is a non-toxic anion commonly found in fresh water resources, but its high levels put a theater to human health. The sulfate concentration (SO_4^{2-}, mg L^{-1}) in the studied locations ranged from 73 to 1682 mg L^{-1} with an average value of 856.18 mg L^{-1}. These detected values exceeded the maximum allowable limits of both WHO and GSS (400 and 250 mg L^{-1}). Moreover, sulfate is not a health concern below the maximum allowable limit for drinking water but may have a laxative effect at high level, which can lead to intestinal discomfort and consequently dehydration. The presence of high sulfate content may be due to breakdown of organic substances of weathered soils, human activities, and usage of fertilizers and sulfate leaching [30]. Finally, it could be concluded that the mean molar concentration of determined anions following the decreasing order: $NO_2^- < F^- < NO_3^- < Cl^- < SO_4^{2-}$ based on the mean analyzed values.

3.1.3. Major cations

The concentration of major cations such as Ca, Mg and Fe in the collected groundwater samples was determined and data are discussed below.

The concentration of major ions defines the general hydrochemistry of groundwater. The results indicate that all major ions (Ca, Mg and Fe) in groundwater samples varied widely, suggesting high variability in their concentrations. Calcium is naturally abundant in the Earth crust. It is necessary for the human body, and sufficient intake is required for the usual growth and human health. A higher concentration of Ca in groundwater is causing hardness of water. Calcium concentration (Ca^{2+} mg L^{-1}) in the study area ranged from 189 to 2017 mg L^{-1} with an average of 1155.6 mg L^{-1}. Almost collected groundwater samples had Ca^{2+} content exceeded the allowable limits of the WHO and GSS of 200 mg L^{-1}, Table (4). Out of nine samples, only one sample that collected from the wells in EH7 site had Ca^{2+} content within the guidelines.

The major elements, like magnesium, are essential for human at permissible limits, but at higher concentrations, they may cause kidney stone, hypertension and other diseases. The Mg results varied from 5 to 286 mg L^{-1} with an average value of 142.9 mg L^{-1}. The Mg concentration values of five samples crossed the maximum permissible level of both WHO and GSS standards of 200 mg $L^{-1.}$ The higher concentration of Mg, in the study area, may be due to the rocks weathering containing ferro-magnesium element, carbonates rocks or organometallic matter. Generally, calcium and magnesium cause the greatest portion of hardness occurring in natural waters that is objectionable from the viewpoint of water use.

Iron is the second most abundant metal in the earth's crust. It can enter our bodies by drinking water or food and it is necessary to conserve the body metabolism. Iron is usually present in water as soluble ferrous (Fe^{2+}) form. It is easily oxidized to the insoluble ferric (Fe^{3+}) on exposure to the air. Actually, the content of iron in groundwater varies depending on the geological nature of the surrounding area. The concentration of iron (Fe^{2+}, mg L^{-1}) in the study area was varied from 0.02 to 0.6 mg L^{-1} with an average value of 0.191 mg L^{-1}. The obtained results ensure that the concentration of Fe in the study area was within the limits of WHO and GSS guidelines. Experimentally, the results confirm that the abundance of the major analyzed cations in the study area, Tathleeth, follow the order: Ca > Mg > Fe. Finally, the concentration of ammonia in all collected groundwater samples had values ranged from 0 - 0.18 mg L^{-1}. The average concentration value was 0.046 mg L^{-1}, while the STD value was 0.0656, respectively. These determined values are below the permissible limit set by WHO and GSS, Table (4).

3.2. Bacteriological analysis

The coliform group of bacteria is the principal indicator of suitability of water for domestic, industrial or other uses. The density of coliform group is the criteria for the degree of contamination and is considered as a basis for bacteriological water quality standard. In an ideal situation, all water samples taken from a studied system should be free from coliform organisms. In practice, it is not always attainable; therefore, the following standard for water quality has been recommended [37].

The organisms used as indicator of water pollution are *E*. coli and the coliform group as a whole. *Escherichia coli (*or simply *E. coli*) is a facultative anaerobe, gram-negative rod bacteria that lives in the intestinal tracts of warm-blooded animals. *E. coli* is used to verify the water quality and applied as an indicator of biological contamination. Detection of *E. coli* in drinking water indicates that water has been contaminated with fecal material that may contain pathogens (i.e. disease causing microorganisms such as certain type of bacteria, viruses and protozoa). Pathogens can cause a range of diseases, involving nausea, vomiting, diarrhea cholera, typhoid, viral hepatitis A and dysentery). The WHO guidelines for *E. coli* bacteria allow the most probable number (MPN) of 10 per 100 mL [30]. The groundwater contamination from fecal coliform bacteria is generally caused by percolation from contamination sources (domestic sewage and septic tank) into the aquifers and because of poor sanitation.

The T. Coliform and *E. coli* counts in the collected groundwater samples changed between +ve and –ve, Table (3). The sample collected from the sites HF1, HF2 and HH4 showed –ve counts for both T. Coliform and *E. coli*. In contrast, +ve counts for both T. Coliform and *E. coli* were detected in the sites EH7, BH8 and TE9. Further, the analysis of the samples collected from the HR3, ZF5, and HJ6 showed +ve counting for T. Coliform and –ve counting for *E. coli*. Thus, from the microbiological perspective, the groundwater collected from the sites EH7, BH8 and TE9 is not safe for drinking use and needs some degree of treatment before consumption.

3.3. Quality assessment

3.3.1. Contamination index (*CI*)

The parameters of each individual groundwater sample beyond the permissible limits were combined to obtain contaminated index *CI*. The *CI* is the grouping of all parameters, which are considered hazardous when used for drinking purposes. The contaminated index results of groundwater samples of the study area varied from 0.0 to 22.61, Table (5). The value of *CI* showed that two sites of nine were zero and were considered of good quality for human consumption. Further, Three groundwater samples (HF1, HF2 and HR3) showed moderate contamination with $CI < 3$, while the samples collected from the sites HH4, HJ6 and TE9 were highly contaminated and had $CI > 3$.

Table (5): The contaminated index (*CI*) of the different collected groundwater samples for drinking purposes.

No	Sample	Contamination index
1	HF1	2.6
2	HF2	0.21
3	HR3	2.07
4	HH4	12.16
5	ZF5	22.61
6	HJ6	17.88
7	EH7	0.0
8	BH8	0.0
9	TE9	17.64

3.3.2. Water quality index (*WQI*)

The effective weight values and the relative weight values, calculated using equation (2), for each water quality parameter are given in Table (6). In addition, the values of water quality index for all studied locations are present in Table (7). The calculated *WQI* values ranged from 35.5 to 244.65. Consequently, the groundwater quality of the studied locations for drinking usage is ranged from the “Excellent” to “very poor". The results reveal that out of nine studied locations, one location (EH7) was classified as the “Excellent water” class (*WQI* less than 50) and one locations (BH8) as a “Good water” class (*WQI* less than 100). Additionally, the four sites HF1, HF2, HR3 and HH4 were classified as a “Poor water” class (*WQI* 100.1 - 200). Finally, three groundwater samples that collected from the locations ZF5, HJ6 and TE9 were classified as a “very poor water” class (*WQI* 200.1 - 300) and no samples as a “water unsuitable for drinking purpose” class, Table (7). This reflects the presence of anthropogenic pollution sources in the surrounding area, such as industrial activities.

Table (6): The unit weight and relative weight of each parameters used for WQI calculations.

Parameter	Unit weight (w_i)	Relative weight (W_i)
pH	4	0.068965517
EC, μS cm^{-1}	4	0.068965517
TDS, mg L^{-1}	4	0.068965517
TAlk, mg L^{-1}	3	0.051724138
TH, mg L^{-1}	3	0.051724138
Turb., NTU	3	0.051724138
Color, TCU	2	0.034482759
F^-, mg L^{-1}	5	0.086206897
Cl^-, mg L^{-1}	5	0.086206897
NO_2^-, mg L^{-1}	4	0.068965517
NO_3^-, mg L^{-1}	4	0.068965517
SO_4^{2-}, mg L^{-1}	5	0.086206897
NH_3, mg L^{-1}	3	0.051724138
Ca^{2+}, mg L^{-1}	3	0.051724138
Mg^{2+}, mg L^{-1}	3	0.051724138
Iron, mg L^{-1}	3	0.051724138
	$\sum w_i = 58$	$\sum W_i = 1.0$

Table (7): The values of *WQI* calculated for each individual groundwater sample and their classification for drinking purposes.

No	Sample location	Code	*WQI* value	Classification
1	Hajis Fuhayd 1	HF1	118.75	Poor
2	Hajis Fuhayd 2	HF2	101.08	Poor (slightly)
3	Hadi Romiah	HR3	109.82	Poor (slightly)
4	Hajis Hassan	HH4	175.41	Poor
5	Zafir Fahad	ZF5	244.65	Very poor
6	Hawayzi Jafin	HJ6	215.25	Very poor
7	Eyd Hamda	EH7	38.50	Excellent
8	Bandar Hawizi	BH8	56.73	Good
9	Tahus Eubayd	TE9	215.30	Very poor

3.3.3. Magnesium hazard index (*MHI*)

Magnesium ion concentration plays an important role in productivity of soil, so that it is used to determine whether the water is suitable for irrigation or not. If magnesium hazard index (*MHI*) is less than 50, then the water is safe and suitable for irrigation [35]. The determined values of *MHI* ranged from 0.45 to 34.92 with an average value 133.36. It was found out that all samples collected from the study area had magnesium hazard values less than 50 and could be classified as suitable for irrigation use, Table (8).

Table (8): The magnesium hazard index of the different collected groundwater samples for irrigation consumption.

No	Sample	Magnesium hazard
1	HF1	0.45
2	HF2	10.30
3	HR3	14.46
4	HH4	16.02
5	ZF5	9.59
6	HJ6	9.31
7	EH7	22.85
8	BH8	34.92
9	TE9	2.34

4.Conclusion

In this paper, the suitability of groundwater samples that collected from Tathleeth, Asir region, Saudi Arabia for domestic and agricultural purposes was investigated. The water quality index (WQI) with the respect to the WHO & GSS was used for groundwater quality assessment. Sixteen physico-chemical parameters were selected to calculate WQI in addition to the microbiological analysis. The results clarify that all the wells in the study area have pH values almost below the maximum allowable level. Out of 9 analyzed locations, 7 locations exceeded the WHO and GSS guideline values for the parameters EC, TDS,TH, SO42- and Ca2+. Moreover, almost the studied locations exhibited assessing values within the WHO and GSS guidelines for the other traced quality parameters. The microbiological analysis showed +ve results for T. Coliform and E. coli. in some locations while the others were –ve. Therefore, the samples should be properly disinfected before being used for drinking purpose. The contamination index (CI) and water quality index (WQI) results showed that there is a location was classified as “Excellent water” class, and another one as a “Good water” class, four locations as a “Poor water” class, and three as a “very poor water” class for human drinking purposes. The MHI result indicated the suitability of the groundwater’s quality in the study area for irrigation consumption.

Acknowledgement

The author wishes to express its appreciation to all whose efforts made the production of this paper. Many thanks are directed to the Central Laboratory for Water Analysis - Abha, for its continued support.

References

[1] Raju N. J., Seasonal evaluation of hydro-geochemical parameters using correlation and regression analysis. Curr. Sci., 91(6): 820–826 (2006).

[2] Zhu J., Yu L., Xu T., Wei, X., Yang, K., Comparison of water quality in two catchments with different forest types in the headwater region of the Hun River, Northeast China. J. For. Res. 30(2): 565-576 (2019).

[3] Memon A. H., Ghanghro A. B., Jahangir T. M, Lund G. M., Arsenic contamination in drinking water of District Jamshoro, Sindh, Pakistan. Biomed. Lett. 2(1): 31–37 (2016).

[4] Liu C. W, Lin W. S., Shang C, Liu S. H.., The effect of clay dehydration on land subsidence in Yun-Lin coastal area, Taiwan. Environ. Geol., 40(4–5): 518 –527 (2001).

[5] Abbasnia, A., Yousefi, N., Mahvi, A. H., Nabizadeh, R., Radfard, M., Yousefi, M., & Alimohammadi, M., Evaluation of groundwater quality using water quality index and its suitability for assessing water for drinking and irrigation purposes: Case study of Sistan and Baluchistan province (Iran). Human and Ecological Risk Assessment: An International Journal, 25(4): 988–1005 (2019).

[6] Magesh, N. S., & Chandrasekar, N., Evaluation of spatial variations in groundwater quality by WQI and GIS technique: A case study of Virudunagar District, Tamil Nadu, India. Arab J. Geosci., 6: 1883–1898 (2013).
[7] Kumar, S. K., & Chandrasekar, N., Hydrogeochemical study of shallow carbonate aquifers, Rameswaram Island, India. Environ. Monit. Assess., 184: 4127–4138 (2012).
[8] Nagarajan, R., Rajmohan, N., Mahendran, U., Senthamilkumar, S. Evaluation of ground water quality and its suitability for drinking and agricultural use in Thanjavur city, Tamil Nadu, India. Environ. Monit. Assess., 171: 289–308 (2010).
[9] Daghrah, G. A., Al-Sa'ed, R., Treated wastewater impact on Al Qilt Catchment area-Palestine. Asian J. Earth Sci., 2: 58-70 (2009).
[10] Daghrah, G. A., Water quality study of Wadi Al Qilt-West bank-Palestine. Asian J. Earth Sci., 2: 28-38 (2009).
[11] Close, M. F., Effects of septic tank effluent on chemical quality of alluvial gravel aquifers. New Zealand J. Marine Freshwater Res., 23: 275-286 (1989).
[12] Ali, A. J., Al-Shereideh, S. A., Rukah Y. A., Al-Qudah, K., Aquifer ground water quality and flow in the Yarmouk river basin of Northern Jordan. J. Envir. Syst., 26: 265-287 (1998).
[13] Al-Kharabsheh, A., Ground-water quality deterioration in arid areas: A case study of the Zerqa river basin as influenced by Khirbet Es-Samra wastewater (Jordan). J. Arid. Environ. 43: 227-239 (1999).
[14] Thomas, M., The effect of residential development on ground-water quality near Detroit, Michigan. J. Amer. Water Resour. Assoc., 36: 1023-1038 (2000).
[15] Tomer, M. D., Burkart, M. R., Long-term effects of nitrogen fertilizer use on ground water nitrate in two small watersheds. J. Environ. Qual., 32: 2158-2171 (2003).
[16] Laghari, A., Chandio, S. N., Khuhawar, M. Y., Jahangir T. M., Laghari, S. M., Effect of wastewater on the quality of ground water from Southern parts of Hyderabad city. J. Biol. Sci., 4: 314 – 316 (2004).
[17] Muhibbullah, M., Momotaz, S., Chowdhury, A. T., Use of agrochemical fertilizers and their impact on soil, water and human health in the Khamargao village of Mymensingh district, Bangladesh. J. Agron., 4: 109-115 (2005).
[18] Munoz-Carpena, R., A. Ritter and Y.C. Li, Dynamic factor analysis of groundwater quality trends in an agricultural area adjacent to Everglades National Park. J. Contaminant Hydrol., 80: 49-70 (2005).
[19] Scanlon, B. R., Reedy, R., Stonestrom, D. A., Prudic, D. E., Dennehy, K. F., Impact of land use and land cover change on groundwater recharge and quality in the southwestern US. Global Biol., 11: 1577-1593 (2005).
[20] El-Saeid, M. H., Al-Turki, A. M., Al-Wable, M.I., Abdel-Nasser, G., Evaluation of pesticide residues in Saudi Arabia ground water. Res. J. Environ. Sci., 5: 171-178 (2011).
[21] El-Naqa, A., Al-Momani, M., Kilani, S., Hammouri, N., Groundwater deterioration of shallow groundwater aquifers due to overexploitation in northeast Jordan. CLEAN Soil, Air, Water, 35: 156-166 (2007).
[22] Hammouri, N., El-Naqa, A., GIS based hydrogeological vulnerability mapping of groundwater resources in Jerash area Jordan. Geofisica. Int., 47: 85-97 (2008).
[23] Nkolika, I.C., Onianwa, P.C., Preliminary study of the impact of poor waste management on the physicochemical properties of ground water in some areas of Ibadan. Res. J. Environ. Sci., 5: 194-199 (2011).
[24] Thivya, C, Chidambaram S, Rao MS, Thilagavathi R, Prasanna MV, Manikandan S., Assessment of fluoride contaminations in groundwater of hard rock aquifers in Madurai district, Tamil Nadu (India). Appl. Water Sci. 7: 1011-1023 (2017).
[25] Jain, C.K., Bandyopadhyay A., Bhadra A., Assessment of groundwater quality for drinking purpose, district Nainital, Uttarakhand, India. Environ. Monit. Assess. 166: 663–676 (2010).
[26] Azizullah, A., Khan Khattak M.N., Richter P., Water pollution in Pakistan and its impact on public health—a review. Environ. Int. 37: 479–497 (2011).
[27] Chakraborti, D, Rahman M.M., Ahamed S., Dutta R.N., Pati S., Mukherjee S.C., Arsenic contamination of groundwater and its induced health effects in Shahpur block, Bhojpur district, Bihar state, India: risk evaluation. Environ. Sci. Pollut. Res. 23(10): 9492-9504 (2016).
[28] General Authority for Statistics (GAS), Saudi Arabia, Population Characteristics surveys (2017).
[29] American Public Health Association (APHA), Standard methods for the examination of water and wastewater. 21st ed., Washington, USA (2005).

[30] World Health Organization (WHO), Guidelines for drinking water quality, Geneva (2011).
[31] Backman B., Bodis D., Lahermo P., Rapant S., and Tarvainen T., Application of a groundwater contamination index in Finland and Slovakia. Environ. Geol. 36: 55-64 (1998).
[32] Ibrahim M. N., Assessing groundwater quality for drinking purpose in Jordan: Application of water quality index. J. Ecol. Eng., 20(3): 101–111 (2019).
[33] Ramakrishniah C. R., Sadashivam C., Ranganna G., Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. E-J. Chem. 6 (2): 523 – 530 (2009).
[34] Sahu, P., Sikdar, P. K., Hydrochemical framework of the aquifer in and around East Kolkata Wetlands, West Bengal, India. Environ. Geol., 55(4): 823–835 (2008).
[35] Szabolcs I., Darab, C., The influence of irrigation water of high sodium carbonate content of soils. Proc. Int. Congress Trans., 2: 803 – 812 (1964).
[36] Sawyer, C.N., McCarty, P.L., Parkin, G.F., Chemistry for Environmental Engineering and Science (5th Ed.). Boston: McGraw-Hill Education (2003).
[37] Jain C. K., Bandyopadhyay A., Bhadra A., Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. Environ. Monit. Assess. 166: 663–676 (2010).