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(Research Article)

Evaluation of chemical quality characteristics of water collected from some groundwater sources in Tabuk City during 2024

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Abstract

The evaluation of water quality for drinking purpose is differed from that of other purposes such as domestic uses, irrigation of for certain laboratory preparations. The aim of this study was to evaluate the chemical parameters of Tabuk groundwater compared to the local standards of drinking water quality. Samples were taken from 12 groundwater sources that are randomly selected to represent Tabuk City. Samples (500 ml) were taken from the main outlet pipe, and it were kept in clean and aseptic plastic containers. The chemical tests were conducted in the Laboratory, Food health and safety, municipality of Tabuk using the standard devices, methods and solutions. The obtained data were compared to the local quality standards of MEWA (2022). The results showed that, pH for all samples agreed with the local standard, as same as in EC, TDS and Hardness with exception of some samples. Also, the concentrations of Bicarbonate and nitrate for all samples did not exceed the upper standard limits, while sulfate and ammonia agreed with local limit of standard with some exceptions. The concentrations of fluoride and lead in all samples were far more below the upper limits, unlike the concentrations of chloride that more than 30-folds exceeded the upper limit in all samples. Lead is still far from its potential critical concentration. Ion most samples, the concentrations of Sodium and Potassium were below the upper standard limits. Moderate concentrations of Mg were recorded for most samples, but all samples contained low concentrations of Fe element far more than the upper required limit. The samples that did not agreed with the local standards should be investigated and the concentrations of Na, K, Mg and Fe should be considered seriously from their physiological requirements to human body.

Keywords: Quality; Chemical characteristics; Drinking water; Tabuk City; Groundwater

1. Introduction

The water element is an inorganic, polar, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms. It is vital for all known forms of life, even though it provides no calories or organic nutrients [1]. Lack of clean water supply, sanitation and hygiene are major causes for the spread of waterborne diseases in a community. The fecal–oral route is a disease transmission pathway for waterborne diseases [2]. Access to safe drinking water is one of the basic human rights and is critical to health. About 884 million people in the world still do not get their drinking water from safe sources; Sub-Saharan Africa accounts for over one third of this number. It is estimated that 80% of all illnesses in the world are related to use of unsafe and contaminated water [3].

The presence of calcium in water supplies results from passage through or over limestone, dolomite and other calcium containing deposits. Magnesium is a major contributor to water hardness and may also contribute undesirable tastes to drinking water. Water hardness is mainly caused by the presence of calcium and magnesium and is expressed as the equivalent quantity of calcium carbonate. A potential source of sodium in water supplies is the water-softening process which replaces calcium and magnesium (hardness) with sodium. Potassium ranks seventh among the elements in order

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of abundance. At levels above 0.3 mg/L, iron stains laundry and plumbing fixtures and causes undesirable taste. The precipitation of excessive iron causes a reddish-brown color in the water. Fe and Mn gives better taste to drinking water at their acceptable level [4].

Water conductivity is the ability to conduct an electrical current by aid of dissolved + or -ve ions.

Usually, pH denoted the status of acidity or alkalinity of water. Alkalinity is a water's acid-neutralizing capacity and is primarily a function of carbonate, bicarbonate and hydroxide content. Carbonates can only exist if the pH of the water exceeds 8.3. Bicarbonate is the major form of alkalinity. Sulfate occurs naturally in water and may be present in natural waters in concentrations ranging from a few to several thousand mg/L. Sources of nitrate in water include decaying plant or animal material, agricultural fertilizers, manure, domestic sewage or geological formations containing soluble nitrogen compounds [4][5].

2. Methodology

2.1. Study site

Tabuk City which locates at the Northwestern part of Kingdom Saudi Arabia is selected to conduct this study during 2024. 12 groundwater sources (wells that remarked as sample 1 - 12) were randomly selected to collect water samples.

2.2. Study design

A cross-sectional design was carefully followed to represent most parts of Tabuk City.

2.3. Sampling of drinking water

Samples were taken from 12 sources that are randomly selected. Samples were taken from the groundwater source through main outlet pipe. The quantity was 500 ml for each, and it was kept in clean and aseptic plastic containers. The collected samples were transferred to the Chemistry Laboratory, Food health and safety, municipality of Tabuk for testing their chemical properties.

2.4. Chemical characteristics of water

Chemical tests aimed to determine: pH, electrical conductivity (EC), hardness, total dissolved solids (TDS), ammonia, nitrate, HCO_3^-, SO_4^-, chloride, fluoride, Na^+, K^+, Mg^{++} and Fe^{++} in addition to lead (Pb) following the standard devices, methods and solutions.

2.5. The pH

The pH for the sampled waters were determined using a pH meter. The pH meter was calibrated by using the standard solution of pH (3.0, 7.0 and 10.0) at 30^{o}C and the pH of each drinking water sample was then recorded.

2.6. EC

This test was done by inserting the active pole of conductivity-meter in the water sample, and the resulted value was monitored in the device screen.

2.7. TDS

This test was also done using the conductivity-meter by changing setting of the device.

2.8. Hardness

In 250 ml conical flask, 1.0 ml ammonia buffer solution and 30 mg of Eriochrome black indicator were added to 25 ml of water sample and then the solution was tittered with 0.01 M EDTA solution until the color change to blue [6].

$$\text{Hardness (as mg } CaCO_3\text{/L)} = (V \times 0.01 \times 100 \times 1000)/\text{ ml sample}$$

V = volume of EDTA required for titration

2.9. Ammonia, nitrate, bicarbonate and sulfate

These tests were run using titrimetric methods described by Collins [7].

2.10. Na, K, Fe, Mg, Cl, F and Pb

The concentration of these elements was determined using flame photometer, volumetric and Atomic Absorption methods as was described by Vogel [6].

2.11. Data analysis

The obtained data were subjected to suitable statistical tools in order to evaluate the quality of Tabuk groundwater as drinking water compared to the local quality standards of MEWA [8].

3. Results

3.1. The pH, Electric conductivity (EC), TDS and Hardness

Table (1) showed that, pH for all samples were ranged between 7.49 – 7.94 and agreed with the local standard of MEWA (2022). EC for all samples agreed with the local standards (ranged between 679 – 793 µs/cm, while 4 samples (1, 2, 3, and 7) showed high values (1476, 5056, 1794 and 1681 µs/cm), respectively, and exceeded the local standards of EC (200 – 800 µs/cm). Total dissolved solids (TDS) for all samples were ranged between 357 – 959 ml/L, except sample (2) which exceeded (2800 mg/L) the local standard (100 – 1000 mg/L). Hardness for all samples agreed with the local standards (ranged between 261 – 288 mg/L, while 4 samples (1, 2, 3, and 7) as same as EC, showed high values (482, 1561, 534 and 584 mg/L), respectively, and exceeded the local standards of EC (≤ 300 mg/L).

Table 1 pH, Electric conductivity (EC), TDS and Hardness of the tested water samples

Sample No.	pH	EC	TDS	Hardness
1	7.65	1476	783	482
2	7.76	5056	2800	1561
3	7.79	1794	959	534
4	7.90	691	358	270
5	7.94	793	414	288
6	7.67	707	362	286
7	7.84	1681	894	584
8	7.82	679	357	264
9	7.82	771	395	275
10	7.49	758	395	264
11	7.56	711	367	261
12	7.68	736	386	281
Standard limits of MEWA	6.5 -8.5	200-800 µs/cm	100 -1000 mg/L	≤300 mg/L

3.2. Concentrations of Bicarbonate, Sulfate, Nitrate and Ammonia

Table (2) showed that, the values calculated for the concentrations of Bicarbonate (ranged between 104 – 276 mg/L) and nitrate (ranged between 1.0 – 4.6 mg/L) did not exceed the upper standard limits (400 mg/L and 250 mg/L), respectively. Sulfate concentrations ranged between 58 – 136 mg/L, which below the upper limit (250 mg/L), except for sample (2, 3, and 7) which exceeded the upper limits (698, 303 and 286 mg/L, respectively). Ammonia ranged between 0.16 – 0.50 mg/L for all samples except sample (10, 11, and 12) which slightly exceeded the upper limit (0.50 mg/L) by about 0.08 mg/L.

Table 2 Concentrations of Bicarbonate, Sulfate, Nitrate and Ammonia on the tested water samples

Sample No.	Bicarbonate	Sulfate	Nitrate	Ammonia
1	104	136	1.1	0.46
2	149	698	1.2	0.37
3	121	303	1.6	0.22
4	157	72.8	1.6	0.20
5	159	68.4	1.5	0.45
6	151	62.7	1.5	0.33
7	276	286	4.6	0.16
8	160	69	1.2	0.39
9	141	68	1.0	0.50
10	147	65	1.1	0.59
11	158	58	1.0	0.58
12	161	61	1.3	0.58
Upper Standard limits	400 mg/L	250 mg/L	50 mg/L	0.5 mg/L

3.3. Concentrations Sodium, Potassium, Magnesium and Iron

It was clear that, all samples contained sodium in concentrations below the upper limit (200 mg/L) of the standards, except sample (2) which is 3-folds more than the upper limit, as same as in potassium concentration. Sample (3) contained high concentration (13.7 mg/L) of K than the upper standard limit (8 mg/L). Moderate concentrations of Mg (less than 50 mg/L) were recorded for all samples, except sample (1, 2, and 7) that exceeded the upper limit (60.7, 229.4, and 94.3 mg/L) following the same order. It was also cleared that, all samples contained low concentrations of Fe element far more than the upper required limit (0.3 mg/L) as was shown in Table (3).

Table 3 Concentrations of Sodium (Na), Potassium (K), Magnesium (Mg) and Iron (Fe) in the tested water samples

Sample No.	Na	K	Mg	Fe
1	168	4.2	60.7	0.04
2	685	29.2	229.4	0.06
3	191	5.1	34.7	0.01
4	61.8	4.2	29.2	0.0
5	65.8	4.4	30.9	0.01
6	56.6	4.2	34.3	0.01
7	173	13.7	94.3	0.07
8	60.6	5.0	26.0	0.01
9	65	4.2	27.2	0.02
10	65.1	3.8	24.3	0.0
11	57.4	4.3	27.0	0.02
12	60.4	4.4	30.6	0.0
Upper Standard limits	200 mg/L	8 mg/L	50 mg/L	0.3 mg/L

3.4. Concentrations of Floride, Chloride, and Lead

Table (4) showed that, the concentrations of fluoride and lead in all samples were far more below the upper limits (1.5 mg/L and 0.01mg/L, respectively), unlike the concentrations of chloride that more than 30-folds exceeded the upper limit (0.5 mg/L) in all samples.

Table 4 Concentration of Floride (F), Chloride (Cl), and Lead (Pb) in the tested water samples

Sample No.	F	Cl	Pb
1	0.18	53.9	≤0.002
2	0.57	178	≤0.002
3	0.26	71.3	≤0.002
4	0.10	20	≤0.002
5	0.15	25.4	≤0.002
6	0.13	19.8	≤0.002
7	0.21	40.3	≤0.002
8	0.15	19.5	≤0.002
9	0.07	21.8	≤0.002
10	0.16	19.8	≤0.002
11	0.46	18.1	≤0.002
12	0.47	20	≤0.002
Upper Standard limits	1.5 mg/L	0.5 mg/L	0.01 mg/L

4. Discussion

The aim of this study was to evaluate the chemical parameters of the groundwater collected from Tabuk City compared to the local quality standards. During 2023, similar study was conducted in Tabuk, using multivariate statistical tools, remote sensing and geographic information systems for water priority determination, using some principal components (bifurcation ratio, ruggedness number, elongation ratio, drainage density, basin relief, circularity ratio, and relief ratio, showed indication of soil erosion that raised the needs to reduce infrastructure damage [9].

The results showed that, pH for all samples were agreed with the local standard, as same as in EC and Hardness for all samples except samples (1, 2, 3, and 7) that exceeded the local standards. TDS agreed with the local standard, except sample (2) which exceeded it.

During 2009, TDS values in water samples of the Saq aquifer from Tabuk area were 630 mg/L in the southwestern sector and 420 mg/L at the northeastern sector, and both are safe for irrigation purposes. Additionally, there was an obvious increase of the readily soluble soil salts [10]. Hardness indicates high mineral contents (mainly Ca^{+}) and cause deposit in water pipes. It may be temporary due to carbonate and bicarbonate or permanent due to sulfate and chloride [4].

The results also showed that, the concentrations of Bicarbonate and nitrate did not exceed the upper standard limits, while sulfate concentrations were below the upper limit, except for sample (2, 3, and 7) which exceeded the upper limits. Ammonia agreed with local limit of standard for all samples except sample (10, 11, and 12) which slightly exceeded the upper limit. The concentrations of fluoride and lead in all samples were far more below the upper limits, unlike the concentrations of chloride that more than 30-folds exceeded the upper limit in all samples

It was found that, the excess of sulfate in drinking water may result in a noticeable taste [5]. Also, fluoride concentrations in groundwater may get enhanced through the use of phosphatic fertilizers that can seep into the groundwater via irrigation return flows [11]. Chloride occurs naturally and unharmful, but excess concentration indicates wastewater pollution, while sulfate occurs naturally and unharmful, excess concentration indicates deposit of Na or Mg sulfate [4]. Concerning the abundance of Pb, it seemed to be far more than to be a potential hazard.

It was clear that, all samples contained sodium in concentrations below the upper limit of the standards, except sample (2) which is 3-folds more than the upper limit, as same as in potassium concentration. Sample (3) contained high concentration of K than the upper standard limit. Moderate concentrations of Mg were recorded for all samples, except sample (1, 2, and 7) that exceeded the upper limit. It was also cleared that; all samples contained low concentrations of Fe element far more than the upper required limit.

The concentrations of Na, K, Mg and Fe in the tested samples should be considered seriously from their physiological requirements to human body. Na and K are very important in contraction of muscles [12] and blood pressure [13], while Fe and K are very important in blood formation and clotting, respectively [12]. Mg contributes to the total hardness of water [5].

The major changes in the chemical composition of groundwater occurred firstly in the soil zone during the concentration of salts by evaporation and evapo-transpiration. The chloride ion indicated the increase of dissolved salts by these two processes. The same conclusion can be achieved from the Ca^{2+}+ $Mg^{2+}/HC0_3$ + Na_2SO_4 plots. Within the aquifer itself it is clear that the main dominant process was simple dissolution or mixing, thus the high rate of evaporation and the low rainfall concentrated the salts in the soil and when runoff occurred it leached the soil [14].

5. Conclusion

The pH for all samples were agreed with the local standard. Hardness as same as EC and TDS agreed with the local standards, except some samples. The concentrations of Bicarbonate, Ammonia, Sulfate and nitrate agreed with standard limits, except some samples. The concentrations of fluoride and lead in all samples were far more below the upper limits, unlike the concentrations of chloride that more than 30-folds exceeded the upper limit for all samples. Lead is still far from its potential critical concentration. All samples contained Na, K and Mg in concentrations agreed with the standards, except some samples. All samples contained low concentrations of Fe far more than the upper required limit.

The source of sample (1, 2, 3, and 7) should be investigated and the environmental treatment should be applied whenever required. The concentrations of Na, K, Mg and Fe in the tested samples should be considered seriously from their physiological requirements to human body.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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