Electronic Journal of University of Aden for Basic and Applied Sciences
EJUA-BA Vol. 3 No. 2 (2022)
https://doi.org/10.47372/ejua-ba.2022.2.158
ISSN: 2708-0684

RESEARCH ARTICLE

ASSESSMENT OF THE LEVEL OF PHYSICOCHEMICAL AND MICROBIOLOGICAL CONTAMINATION OF GROUNDWATER IN PARTS OF BIR NASSER AND BIR AHMED WATER FIELDS IN TUBAN DELTA IN ADEN AND LAHEJ GOVERNORATES - YEMEN

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Received: 07 June 2022 / Accepted: 24 June 2022 / Published online: 30 June 2022

Abstract

The objective of this study is to assessed the of groundwater pollution, in some of Bir Nasser and Bir Ahmed waters fields, in Tuban delta, which are considered as the main sources of drinking water and household purposes for consumers in Aden Governorate. In this study, 20 groundwater samples have been collected from the fields of Bir Nasser and Bir Ahmed, in the period from February until July 2021. The evaluation of groundwater quality in the study area was based on 19 parameters such as: Temperature (T), Turbidity, Hydrogen Ion Concentration (pH), Electrical Conductivity (EC), Total Dissolved Solid(TDS), Total hardness(TH), Total Alkalinity (TA), Calcium(Ca^{2+}), Magnesium (Mg^{2+})' Sodium (Na^{+1}), Potassium (K^{+1}), Iron (II) (Fe^{2+}), Sulfates (SO_4^{2-}), Chloride (Cl^-), Fluoride (F^-), Nitrate (NO_3^-), Nitrite (NO_2^-), Total Coliform (TC) and Fecal Coliform (FC). Groundwater suitability for a drink and domestic purposes was compared with the World Health Organization specifications (WHO 2004) and the Yemen's ministry of water and environment standards (YMWE,1999). The results showed that most of the physical, chemical and biological parameters are higher than the permissible limit by (WHO 2004), with the exception of pH and nitrite, which were found below the standard limit. Reasons for the high parameters values of some study areas were the presence of the investigated wells near the population centers that use cesspits to dispose of waste water, as well as the closeness of the wells to the agricultural lands that use chemical and animal fertilizers, in addition to random drilling of wells, and excessive pumping for groundwater. Therefore, there is a need for appropriate treatment measures before the consumption of these waters by the populace to avoid long term accumulated health problems of these pollutants.

Keywords: Physiochemical properties, Groundwater, Bir Ahmed, Bir Nasser, Tuban delta basin, Lahej, Aden.

1. Introduction

Groundwater resources play an important role in meeting the demand for water supply due to regional climate change and scarce or unsuitable surface water sources [1].s In this turn, water intended for human consumption should not contain organisms and chemicals in concentrations high enough to affect health.

Yemen's consumers water are mainly rely on groundwater, which suffers from the dangers of environmental pollution and threaten this resource, result of the lack of coverage of cities with sewage networks projects. Besides, dependence a large proportion of housing, hospitals and factories on the unlined cesspits whose wastewater seeps from it into the aquifers [2], n addition to , the desertification increase, the getting rid of the waste into the channels and streams of torrents, and the lack of rain [3].On the other hand, the amounts of extracted water from the ground are much higher than the amounts of recharge water for underground reservoirs, as well as population increases and migration from villages to the city lead to pressure on water resources and contribute to their depletion [4].

The situation in Aden governorate is not different from the rest of Yemen, as Aden governorate is completely dependent on groundwater from the Tuban delta, which extends between the governorates of Lahj and Aden, and the Bana Delta in Abyan governorate. The quality of groundwater in the Tuban delta is affected by many processes, such as the spread of random construction and the emergence of camps for displaced and marginalized people along and in the middle of the water fields during the war 2015 period. These communities and housing units use unlined cesspits to dispose of sewage, as well as the pollution resulting from the selection Random and erroneous dumps of waste near water basins. Also Lahj governorate is characterized as being agricultural, where the increasing use of organic fertilizers of animal source, as well as chemical fertilizers and pesticides in large quantities and without supervision, and the attendant leakage during irrigation operations into the underground reservoir.

Many researches and studies have been conducted on the physiochemical pollution of water in Aden, however, these studies were limited to test of water in schools and mosques, and bottled water in the city of Aden. [5-7]. In addition to some geographical studies that referred to the physiochemical examinations of the reservoirs of Bir Nasser, Bir Ahmed, Al-Barzakh, and Hashid [8-10]. But these studies were based on reports from the Public Authority for Water Resources or the local Water and Sanitation Corporation in Aden Governorate, as they are the two bodies responsible for supplying water to Aden Governorate, which stopped conducting periodic examinations of water sources in Bir Nasser and Bir Al-Manasra basins at Lahj governorate and Bir Ahmed in Aden governorate, since the 2015 war. Despite this, no attention was paid to conducting microbiological examinations of groundwater in the study area. In this paper, we present a report on the nature, sources and extent of groundwater pollution in the study area. Thus, this study aims to: 1) Determining the specifications of groundwater in the selected sites to determine its suitability as a source of drinking water by comparing the results obtained with the standards set for water quality in accordance with the Yemeni and international standard. 2) Evaluating the factors that affect the nature of water in the selected areas. The results of this study will be helpful for the decision makers at the Aden Water Supply Local and Sanitation Corporation (AWSLC) and National Water Resources Authority–Aden (NWRA-A) to deal with the polluted wells and protect the groundwater from contamination sources.

2. Materials and Methods

2.1 Description of study areas

The study area constitutes one of the hydrological systems of the Yemeni water resources, It is located geographically and administratively in the far southern tip of the Republic of Yemen, occupying parts of the governorates of Aden and Lahj, as it extends from the city of Aden which is located on the Gulf of Aden near the southern entrance to the Red Sea, with an area of about 750 square kilometers to the lands of the Tuban delta, which constitutes a range of flat land. From Fig (1) the study area is located between latitudes 12°.50'-13°.30' north of the equator and longitudes 44.55°-45.12° east of Greenwich line, This extension makes it within the semi-arid and dry region that extends throughout the entire region of the Arabian Peninsula, which is characterized by its low rainfall and high air temperature throughout the months of the year. According to the 2004 census, the population of the study area reached about 701,697 people [9-11].

2.2 Groundwater sampling:

Twenty samples were collected from different areas from the Nasser wells field in Lahj governorate and Ahmed wells field in Aden governorate, in addition to the Nasser wells reservoir and also the line of wells Dar Almanassera (C.L.DM), and all are located in Tuban Delta. Figure 1 and Table1 show a location map of the wells with latitude and longitude, Samples were taken from the wells that were examined in coordination with Aden Water Supply Local and Sanitation Corporation (AWSLC) and the National Water Resources Authority-Aden (NWRA-A), where these two institutions use the following symbols to denote the names of the wells: (BN) to refer to the wells of Nasser, and (BA) to refer to the wells of Ahmed. All selected wells are groundwater and are located adjacent to citizens' homes, where cesspits are used to dispose of sewage, and solid waste and garbage are dumped next to these wells. Samples were collected in the morning hours during the period from February 2021 until July 2021, with three iterations, each well was located using global positioning system (GPS) coordinates.

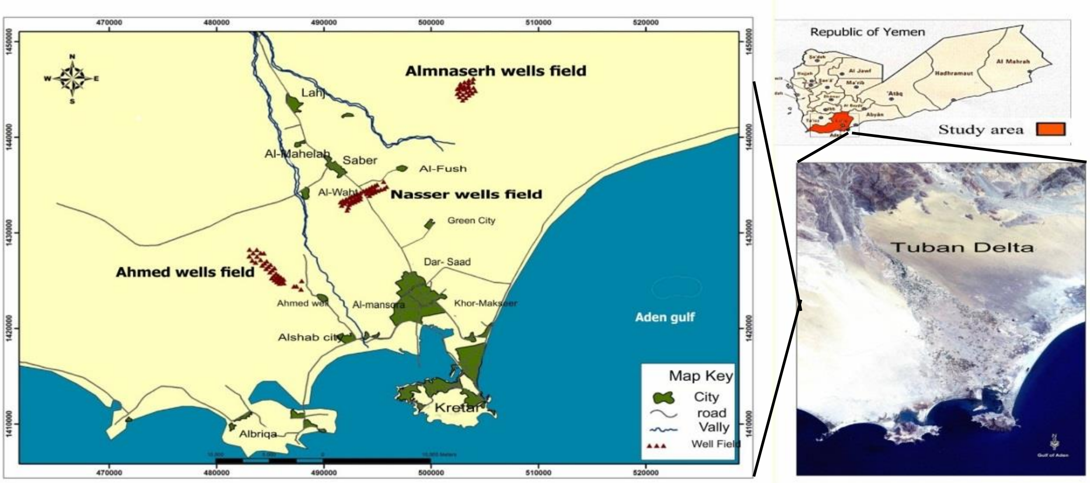

Fig1: Map showing of groundwater samples sampling locations from Bir Ahmed and Bir Nasser basins in Tuban delta.

2.3 Collection, transfer and analysis of samples

To collect samples for the purpose of physiochemical analysis, clean and sterile polyethylene containers were used that were washed with deionized water and dried at room temperature. The containers were then rinsed several times by the water source before the collection sample. After that the containers were filled with water to the top, taking care not to leave a void in the container. While, when water samples were collected for microbiological examination, non-reactive borosilicate glass containers, capacity of 250ml, were used that were carefully cleaned and rinsed, then rinsed with distilled water and sterilized. Taking into account the adequate vacuum left in the sample bottle to ensure ease of shaking the sample before the microbiological examination [12]. Samples were taken after the water was pumped from the well for a quarter of an hour and the electrical conductivity of the well water stabilized, so that samples could be taken directly from the aquifer, documented the location and procedure used for each sample taken. All samples were taken to the laboratory to measure physiochemical and biological parameters in an ice-box (4°C) because biological activity will continue after a sample has been taken, changes may occur during handling and storage to avoid unusual change in water quality, and prevent the growth of microorganisms, with care account not to allow the samples to freeze, and the sample bottle not be opened before the analysis, as well as the analysis started within six hours of collecting the samples [13]. After that, analyzes of samples were carried out in the laboratories of the Local Water and Sanitation Corporation in Aden Governorate (LWSCA), and the analyze was repeated in the water laboratories of the WITEX and PURE LIVE companies located, Suzuki round in Sheikh Othman District, Aden Governorate.

Physiochemical analysis

Temperature(T), pH, and Electrical conductivity(EC), were measured directly in situ using a graduated thermometer, pH-meter (HQ40d multi/ HACH), and EC-meter (HQ40d multi /HACH) respectively). While other parameters were analyzed in the laboratory, where Total hardness (TH), and Calcium ion were determined by EDTA titration methods using Eriochrom black T (EBT) and Muroxide as indicators respectively. Total Dissolved Solids (TDS), were measured by Digital TDS meter (HAANA-HI98192). Turbidity was measured by Spectrophotometer HACH (DR 900 model). Magnesium was measured by Calculation as from total hardness and calcium Hardness

$mg\frac{Mg^{+2}}{L} = \left(\text{TH as mg}\frac{\text{CaCO3}}{l} - \text{Ca H as mg}\frac{\text{CaCO3}}{\text{L}}\right) \times 0.243$ Where: Ca hardness = Ca ion × 2.5

Total alkalinity (TA) were estimated by Sulfuric acid Standard solution titration method, using phenolphthalein as indicator. Chloride (Cl^-), was measured by the silver nitrate, Titrimetric Method. While other parameters were analyzed in the laboratory, UV-Spectrophotometer HACH (DR 5000 model) was used for measuring of Nitrite (NO_2^-), Nitrate (NO_3^-), Iron (Fe^{2+}), Fluoride (F^-), and Sulfate (SO_4^{2+}). Cations (Na^+, and K^+) were measured by single channel emission, Flame Photometer (JENWAY -PFP7).

Biological analysis

Detection of Total and Fecal Coliform was done using Membrane Filtration technique 0.45µm pore size. Fecal coliforms and Total coliforms are detected using selective and differential culture medium. For the detection of total coliforms were used (mEndo agar broth medium), where Membrane filter is incubated at 35°C for 22-24 hours. for the detection of fecal coliforms were used (MFC agar broth medium), where membrane filter is incubated at 44.5°C for 22-26 hours.

The method of collection, preparation, preservation and analyzed were similar to those reported in previous studies [4, 12, 13, 14], and Standard methods for the examination of water and wastewater American Public Health Association [15]. The physicochemical and biological characteristics of groundwater samples were compared with the guideline values for drinking water as defined by [16] and [17].

2.4 Statistical processing of data

Statistical analysis was carried out using the statistical package for social sciences (IBM SPSS Statistics 20) The statistical tests applied were basic statistics (maximum, minimum, mean, standard deviation) and Pearson's correlation matrix (assuming p<0.01or p<0.05).

Table 1: Location Details with latitude and longitude of groundwater samples collected from Bir Ahmed and Bir Nasser basins in Tuban delta.

Name sample	Depth (m)	Year of Drilling	Latitude	Longitude	comments
BN-8	350	2008	12°58'14.2"N	44°56'50.2"E	
BN-10	350	2008	12°58'24.1"N	44°57'08.2"E	
BN-11	400	2009	12°58'28.7"N	44°57'17.0"E	
BN-12	350	2013	12°58'33.5"N	44°57'26.1"E	Old wells with less depth In 2013 they were re-drilled to greater depths.
BN-13	350	2013	12°58'39.67"N	44°57'34.46"E	
BN-14	350	2013	12°58'43.98"N	44°57'43.51"E	
BN-48	350	2010	12°58'47.1"N	44°57'28.1"E	
BN-41	350	2009	12°58'37.9"N	44°56'57.3"E	
BN-42	350	2008	12°58'37.1"N	44°57'06.7"E	
BN-29	350	2013	12°58'18.2"N	44°56'31.7"E	An old well with a depth of 70 meters, which is stopped working for a long time. In 2013 it was re-drilled to greater depths
BN-16	350	2013	12°58'05.3"N	44°55'46.7"E	Old wells with less depth. In 2013 they were re-drilled to greater depths
BN-17	300	2013	12°58'11.1"N	44°55'54.9"E	
BN-18	160	1984	12°58'15.6"N	44°56'04.2"E	
BN-46	300	2006	12°57'57.85"N	44°55'36.01"E	
BN.T	——	——	12°58'06.2"N	44°56'32.8"E	
C.L.BA	——	——	12°54'05.4"N	44°51'30.15"E	
BA-34	150	2005	12°54'26.79"N	44°50'58.27"E	
BA-43	150	2005	12°54'21.17"N	44°52'04.75"E	
BA-49	300	2013	12°54'46.67"N	44°50'57.78"E	A new well has been drilled in the Bir Ahmed field
C.L.DM	——	——	12°58'10.9"N	44°56'33.6"E	

BN: Bir Nasser, BA: Bir Ahmed, **BN.T:** Bir Nasser Tank**, C.L.BA:** Collection line Bir Ahmed, **C.L.DM:** Collection line Dar-Almanassera

3. Results and Discussion

3.1 Physiochemical parameters

3.1.1. The Temperature (T)

The temperature of the water is one of the most important characteristics that determines to a considerable extent the tendencies of changes in the groundwater quality [19, 20]. High water temperature enhances the growth of microorganisms and may increase problems related to taste, odor, color and corrosion [21]. Increased water temperature above 27°C is "unsuitable" for public use. At above 32°C, it would be considered "unfit" for public use [20, 22]. In the present study, as shown (Table 2) the water temperature values ranged between of 35.50 °C to 44.10 °C (with a mean value of 39.99 °C), The highest value was recorded in sample BA-49, while the lowest value was obtained in sample C.L.DM 35.5 °C. Temperature values of all measured samples were exceeded the permissible limits of WHO and YMWE (25°C), by 100%. The temperature of groundwater increases with depth because of the hydrothermal gradient in the area, which, in turn, is influenced by the volcanic activity among other tectonic factors [18]. The temperature values recorded in this study was close to a study conducted by [23] on groundwater in the of Al-Dhala city Yemen, who reported temperatures ranging from 28°C to 54°C with an average of 37.87 °C. On the other hand. These results are high compared to the results obtained by [24] to assess the quality of groundwater in the city of Sana'a, Yemen, and the temperature ranges from 20.90.

3.1.2. Turbidity

Turbidity in water is the reduction of transparency due to the presence of particulate materials such as fissures or clay, finely divided organic matter etc. It is important for both health and aesthetic reasons [25]. The existence of turbidity in water will affect its acceptability to consumers. The Turbidity value for all groundwater sampling sites were the range from 0.5 NTU to 11.31 NTU (with a mean value of 2.29 NTU). As shown in (Table 2). Groundwater samples BN13, and BN14 have high turbidity value that is above a value that is recommended by WHO, this indicates that it is necessary to treat water before used. On the other hand the results exhibit that concentration of turbidity in for all groundwater samples were lower than the standard limit of YMWE. The higher value obtained in the sample BN-

13, and BN-14, were maybe due to the presence of inorganic particulate matter in some groundwater [26]. The results of the current study coincide with that obtained by [20] for groundwater consumed quality assessment within Konso area, Southwestern Ethiopia the ranged turbidity was estimated from 1-8.5 NTU. [27] reported that the average turbidity in the groundwater wells of the Qom city Iran were 0.58 NTU.

3.1.3. pH

The pH of an aquatic system is an important indicator of water quality and the extent of pollution in the watershed. Unpolluted waters normally show a pH of about 7 and 8 [28-29]. pH usually has no direct impact on consumers. However, it is one of the most important operational water quality parameters. If the pH is above 7, this will indicate that water is probably hard and contains calcium and magnesium [30].

The pH content in the investigated water samples was ranging from 7.23 to 7.75 with (a mean value of pH 7.47). As shown (Table 2). The variations in pH are relatively small, however the pH range indicates that the groundwater samples are slightly alkaline in nature. The reason for this may be due to the melting of the Jurassic carbonaceous rocks found in the Tuban delta basins, and their dissolution in the waters feeding the groundwater reservoirs [9]. The pH values are within the recommended values of 6.5 to 9 by Yemen's Ministry of Water and Environment (YMWE, 1999) and (WHO, 2004). Results of the present study coincide with that obtained by [31] on the groundwater Dhamar city Yemen, concerning pH values mean was 7.50. And with the study conducted by [32], where the average pH of groundwater in Adhban , Sana'a, Yemen, was 7.51. In another research by [33] on the groundwater in Zabid city, Yemen, concerning pH values mean was 7.53. Which is consistent with the results of the present study.

3.1.4. Electrical Conductivity (EC)

EC is a measure of the ability of an aqueous solution to carry an electric current, dependent on the presence and total concentration of ions, their equilibrium, mobility, and temperature [20]. The results show that the measured conductivity of all water samples ranged from 1430.4µs/cm to 2830.50µs/cm, and the average conductivity value of all groundwater is (2004.68 µs/cm), (Table 2). EC values of sample C.L.DM was exceeded the permissible limits of YMWE (2500 µs/cm), while the remain 19 samples weren't exceeded the permissible limits of YMWE (2500 µs/cm). On the other hand, all groundwater samples were exceeded the permissible limits for WHO (1000 mg/l). The high EC values in all samples, may be due to the decrease in water table in the bottom of wells, where excessive pumping of well water causes the base movement of soil component or may be due to the increased effluent, domestic and agricultural wastes containing high dissolved solids [34]. [35] explained that agricultural, industrial and land use activities affect the mineral content and consequently on the EC of water. When comparing the results of the current study with previous studies about EC values, In a study carried out [36], The average of EC in groundwater in Wadi Siham Yemen were equal to 2676 mg/L. While the average of EC in the study of [23], in groundwater wells of Al-Dhalia city in Yemen, equal were 2449 mg/L. The values obtained in the above studies are similar those obtained in the present study.

Table 2: Results of physiochemical analysis of groundwater samples collected from Bir Ahmed and Bir Nasser basins, Tuban delta.

Mean concentrations of the target parameters (n=3)							
Name sample	T	Turbidity	pPH	EC	(TDS)	T.H	T.A
	^{0}C	NTU		(µS/cm)	Concentration (mg/l)		
BN-8	38.1	1.00	7.48	1910.11	1222.47	436.30	309.98
BN-10	38.9	1.30	7.43	1940.30	1241.79	419.43	297.55
BN-11	43.8	1.05	7.75	1724.50	1139.68	450.43	250.22
BN-12	38.4	1.21	7.45	1858.60	1433.80	400.60	266.60
BN-13	39.1	11.31	7.37	2200.61	1474.53	523.00	284.32
BN-14	41.3	10.31	7.49	2346.80	1410.53	543.70	275.00
BN-48	42.5	1.15	7.62	1519.22	972.30	293.76	202.50
BN-41	40.4	1.22	7.30	1790.44	1145.08	369.40	263.70
BN-42	41.2	1.29	7.35	1870.50	1195.84	413.00	278.10
BN-29	37.8	1.24	7.23	1880.60	1203.58	380.65	272.50
BN-16	40.2	1.31	7.28	1978.23	1269.78	412.76	316.40
BN-17	42.3	1.10	7.45	1521.60	987.14	274.98	294.11
BN-18	36.2	1.45	7.51	2071.50	1306.00	436.12	292.70
BN-46	40.1	1.27	7.38	1932.66	1236.90	395.70	252.50
BN.T	37.2	0.50	7.42	2240.60	1503.61	321.00	265.70
C.L.BA	39.86	1.52	7.50	2221.50	1421.76	437.90	219.50
BA-34	42.22	1.82	7.67	2330.45	1491.49	417.64	220.62

BA-43	40.7	1.85	7.70	2494.50	1596.48	441.02	232.43
BA-49	44.1	1.75	7.52	1430.40	910.34	383.74	186.95
C.L.DM	35.5	2.23	7.58	2830.50	1608.54	296.07	255.04
mean	39.99	2.29	7.47	2004.68	1288.58	402.36	261.82
min	35.50	0.50	7.23	1430.40	910.34	274.98	186.95
max	44.10	11.31	7.75	2830.50	1608.54	543.70	316.40
SD	2.37	2.94	0.14	346.98	202.00	69.03	35.11
YMWE 1999	25	1-15	6.5-9	450-2500	650-1500	100-500	150-500
WHO 2004	25	5.00	6.5-8.5	450-1000	1000.00	500.00	250.00
No. of sample unfit compared with WHO	20	2	0	20	17	2	15
Percent of samples more than WHO	100%	10%	0%	100%	85%	10%	75%

SD: Std. Deviation, **NTU:** Nephelometric Turbidity Unit

3.1.5. Total Dissolved Solid (TDS)

The range of TDS of analyzed water samples varied between 910.34 mg/l to 1608.54 mg/l, (with a mean value of 1288.58 mg/l), as shown in (Table 2). TDS concentration of sample C.L.DM has exceeded the admissible limits for YMWE (1500 mg/l), whereas the remaining 19 samples weren't exceeded the admissible limits for YMWE. On the other hand, all samples under study whit high TDS values of exceed exhibited the admissible limits WHO (1000 mg/l), Except for the three samples BN-48, BN-17, and BA-49, they have remained within the permissible limits. From the above results, the average TDS in the C.L.DM was 1608.54, the reason for this may be due to the lack of groundwater nutrition in that basin, and the excessive pumping of groundwater in it. The current results also showed that the values of TDS are also high in the Ahmed wells, which may be due to the location of this basin near the coastal areas, where the overlap of salty sea water with groundwater in the basin occurs. Except for well BA-49, which was newly drilled, with a depth of 350 meters. In general, the high TDS was maybe due to low levels of groundwater in most of the wells under study, due to the increased pumping of water to cover the demand for water supply in Aden, the lack of nutrition and the random drilling of groundwater wells in the areas near the water fields [8], Or may be due to the infiltration of excess of sewage wastes from the cesspits that are located near this wells. May be due to the presence of HCO_3^-, CO_3^{2-}, SO_4^{2-}, Cl^- and Ca^{2+}, which may originate from natural sources [37]. TDS concentrations in the current study are in close to with the study of [38], where mean values of TDS in drinking water wells of villages in Qom province Iran, are equal 1205 mg/l. On the other hand these results are low compared to the results obtained by [23] where TDS values was 1486 mg/l.

3.1.6. Total Hardness (TH)

TH is an important parameter of water quality, It is due to the presence of an increase of Mg, Ca and Fe salts. [34]. In this studied samples the TH values range from 274.98 mg/l in well BN-17 and 543.70 mg/l, in well BN-14, (with a mean value of 402.36 mg/l), as shown in (Table 2). Samples BN-13, and BN-14 exceeded the permissible limits for WHO and YMWE (500 mg/l), while the remaining other samples weren't exceeded the permissible limits for WHO and YMWE (500 mg/l). The increase in TH values for these two wells may be due to their location in the Bir Nasser basin near the houses that use cesspits to dispose of sewage water, which contain high concentrations of Ca^{2+}, SO_4^{2-}, Cl^- [34] and also the high concentrations of Ca^{2+}, Mg^{2+} and HCO_3^- in rock formations leads often to very considerable hardness levels in groundwater's. According to the Environmental Protection Agency [39] as shown in Table3. We can classify of studied samples based on TH.

Table 3: shows water classification on the basis of Hardness

Hardness mg/l $CaCO_3$	Water Class	Number of samples	% Samples
up to 50	Soft	0	0
51-100	Moderately Soft	0	0
101 - 150	Slightly Hard	0	0
151-250	Moderately Hard	0	0
251-350	Hard	4	20
> 350	Excessively Hard	16	80

From Table 3, it is clear that 80% of the studied samples are characterized by excessive hardness, while 20% of them were hard. Compared with the previous studies, In a study carried out by [15] in 2016, the average TH values of the groundwater in the villages of Qom province Iran, were 401 mg/l which is similar with the current study.

3.1.7. Total Alkalinity (TA)

TA is used to give an idea of the salts present in water samples [40]. The alkalinity of groundwater is mainly due to carbonates and bicarbonates [20]. The total alkalinity of analyzed water samples varied from 186.95 to 316.40 mg/l, (with a mean value of 261.82 mg/l) (as given in Table 2). The total alkalinity of all groundwater samples were below the permissible limit for YMWE (500 mg/l). While TA levels in fifteen samples were exceeded the permissible limits for WHO (250 mg/l), Except for the five samples BA-34, BA-43, BA-49, C.L.BA, and BN-48, that remained within the permissible limits. The highest amount of alkalinity was found in a BN-16 water sample. The lowest amount of alkalinity was found in a BA-49. The type of soil and sedimentary rocks which the hydroxide, carbonate and bicarbonates dissolve in the Tuban delta, is responsible for the alkalinity of water samples. Compared with the previous studies and in a study carried out by [14], the average total alkalinity values of the groundwater in the villages of Qom province Iran, were 213 mg/l, which is in line with the current study. Whereas it is lower than that reported by [40], While he studying the groundwater on the Velliangadu area in India, Where was the average alkalinity of 318 mg/l.

3.2 Major ions in water samples

3.2.1. Calcium (Ca^{2+})

The excess of (Ca^{2+}) causes concretions in the body such as kidney or bladder stones and irritation in urinary passages [36, 41]. The concentration of calcium (Ca^{2+}) in the tested samples was found in the range of 45.01mg/l to 89.13 mg /l (with a mean value of 73.94 mg/l) as shown in Table 4. All measured samples weren't exceeded the permissible limits of YMWE (200 mg/l). On the other hand Ca^{+2} levels in nine groundwater samples exceeded the permissible limits of WHO (75mg /l), while the remaining other samples weren't exceeded the permissible limits of WHO. High values in these samples may be due to the seepage of domestic wastes and effluent [42]. As these nine wells are located adjacent to the houses in the Bir Nasser Basin, which use cesspits to drain wastewater, also the BN-14 and BN-13 wells are located near the residential camp for the displaced and marginalized, While the other two wells are located in the Ahmed wells Basin. Or may be due to the geological, chemical and physical properties of the aquifer [43], Calcium can also originate as lime in agricultural fertilizers. Compared with the previous studies, in the study carried out by [44] in 2020, the average calcium values of the groundwater in the AL-Dhala basin in Yemen, were 74.94 mg/l, which is in line with the current study.

3.2.2. Magnesium (Mg^{2+})

Mg^{2+} contents in the studied samples ranged from 35.19 mg/L to 77.77 mg/l (with a mean value of 53.39 mg/l) as shown in Table 4. The results exhibit that the concentration of magnesium in in for all groundwater samples was lower than the standard limit of YMWE (30-150 mg/L). While Mg^{2+} levels in all samples exceeded the permissible limits for WHO (50 mg/l). The high levels of Mg^{2+} in all samples, especially wells 13 and 14 may be due to contamination by domestic wastewater from dwellings adjacent to wells in Bir Nasser and Ahmed basins, in addition, wells 13 and 14 are located next to the camp for the displaced and the marginalized. Or may be attributed to the variation in composition rocks. Water-rock interaction is the primary source of Ca^{2+}, Mg^{2+}, HCO_3^- in groundwater [22]. This result was in agreement with the average results obtained by [45] 69 mg/l in the Mardan in Pakistan. These results are also similar to the results obtained by [36] was 81 mg/l .

3.2.3. Sodium (Na^+)

Na^+ is a common constituent of natural waters, but its concentration is increased by pollution sources such as rock salt, precipitation raunoff. The addition of sewage waste containing soap solution and organic pollutant and detergent [46]. A proper quantity of sodium in the human body prevents many fatal diseases like kidney damages, hypertension, headache etc. [47]. In these studied samples, the values of sodium in all sampling points were ranged from 216.32 mg/l in BN-17 to 520.30 mg/1 in C.L.DM with a mean value of 291.91 mg/l (Table 4). According to YMWE standards, The permissible range of Sodium in water is (200-400 mg/l). And In this study the results exhibit that concentration of sodium in for all groundwater samples were lower than the standard limit of YMWE, except sample C.L.DM, while Na^+ levels in all samples were exceeded the permissible limits for WHO (200 mg/l). High values of sodium at all samples are attributed to the possible contamination by domestic sewages containing soap solution and organic pollutant [46, 30]. Especially these wells are locate near the city of Bir Nasser in Lahj governorate and Bir Ahmed city in Aden governorate, Where sewage containing soap can increase the proportion of sodium in groundwater. The agricultural by-products might be the other sources of the sodium content of the groundwater in the study area [48, 49]. Compared with the previous studies, the a study carried out by [36], sodium in groundwater in Wadi Siham). was equal to 352 mg/L. which corresponded to the current study. On the other hand According to the study of [38] the average of sodium was 245 mg/l, and in study carried out by [44], the average of sodium in groundwater in Al-Dhala Basin was 257.4 mg/l. The values obtained in the above studies were low than those obtained in the present study.

3.2.4. Potassium (K^+)

K^+ level in the body is vital as it maintains a balanced water level inside the body, controls blood pressure and plays a pivotal role in neural transmission and contraction of muscle, including involuntary cardiac muscle [50] .Potassium is found in low concentrations in natural waters since rocks that contain potassium are relatively resistant to weathering [41], but K^+ can be added to groundwater through anthropogenic sources of pollution such as excessive use of agricultural or animal fertilizers, or cesspits, waste products and sewage [49, 23]. The K^+ concentration recorded in this study ranged from 6.91 mg /l to 14.30 mg/l, (with a mean value of 9.30 mg/l), as shown in Table 4. K^+ levels in sixteen samples, weren't exceeded the permissible limits for WHO and

YMWE (12 mg/l). While the samples BN-16, BN-14, and BN-18, which are located in the Bir Nassir Basin and C.L.DM is located in the Al-Manasra Basin was exceeded the permissible limits for WHO(12 mg/l.). The high concentrations of K^+ in the three samples located in the Bir Nasser Basin are attributed to the possibility of contamination by domestic sewage water, as these wells are located next to houses that use cesspits to dispose of domestic sewage water. While Al-Manasra wells are located near agricultural areas that have been using various chemical and animal fertilizers for a long time without any supervision from the competent authorities. Compared with the previous studies, this result is high compared to the results obtained by [14], the average K^+ value of the groundwater in the villages of Qom province Iran, was 1.2 mg/l, and by [31] on the groundwater Dhamar city Yemen, the average K^+ value was 6.28 mg/l and by [33] on the groundwater in Zabid city, Yemen, K^+ mean was 1.8 mg/L.

3.2.5. Iron (Fe^{2+})

The current analysis results during 2021 showed the highest value of Fe^{2+} ion was 0.90 mg/l in sample BN-11 and the lowest value 0.02 mg/l in samples C.L.BA and BA-34 (with a mean value of 0.32 mg/l).). as shown in Table 4. where the seven samples located in the Bir Nasser Basin was in showed higher concentration than that recommended limit 0.3 mg/l which determined by WHO. While The results exhibit that concentration of iron in all samples were lower than the standard limit of YMWE (0.3-1mg/l). Results of the present study coincide with that obtained with by [41] on the Al-Sahool, Mitm and Al-Sayyadah valleys around Ibb city, Yemen, where concerning Iron values ranging from 0.018-0.64 mg/l).

3.3 Major ions in water samples

3.3.1. Sulfate (SO_4^{2-})

Gastrointestinal disorders in human, changes in some of the physical properties of water and corrosion in pipes is often the result of high sulfate concentrations, [14, 51]. The current analysis result revealed that the sulfate concentrations were the range from 200 to 505.13 mg/l, (with a mean value of 325.55 mg/l) (Table 4). SO_4^{2-} levels in fourteen samples was exceeded the permissible limits for WHO (250 mg/l) while the rest six samples were not exceeded the permissible limits for WHO. On the other hand, SO_4^{2-} contents of four samples (CLBA, BA-34, BA-43, and CLDM) were exceeded the admissible limits for YMWE (400 mg /l), All of them are located in the Bir Ahmed Basin and DM Basin, whereas the remaining 16 samples were not exceeded the admissible limits for YMWE. The high levels of SO_4^{2-} concentration in most wells may be due to the presence of these wells near homes that use cesspits to dispose of sewage, in addition to the presence of these wells in the stream of agricultural lands where farmers use animal and chemical fertilizers for agricultural purposes. Also sulfate enters groundwater from as the result of the chemical dissolution, dissolve sulfur-content minerals, and oxidize sulfates and sulfur. [23, 52]. The results of this study corresponded to those of [15], where sulfate levels in groundwater in the villages of Qom province were obtained as 317 mg/l. Also this result is low compared to the result obtained by [44] which was 479.64 mg/l. On the other hand, the result obtained in the current study is lower than the obtained by [33] on the groundwater in Zabid city, Yemen, SO_4^{2-} mean was 143 mg/l, and a study carried out by [31] on the groundwater Dhamar city Yemen, was SO_4^{2-} mean SO_4^{2-} 61.03 mg/l.

3.3.2. Chloride (Cl^-)

Chloride concentration is an indicator of pollution by wastewater [20]. Also the high chloride concentration is an indication of increase salinity of the groundwater. The chloride levels in unpolluted waters are often below 10 mg/l [29], but concentrations observed in this study was ranged from 205.43 mg/L to 613.41 mg/L, (with a mean of 311.49 mg/l) as shown in Table 4. Cl^- concentration in 17 samples exceeded the permissible limits for WHO (250 mg/l), while the remaining 3 samples were within the limit. On the other hand, all groundwater samples weren't exceeded the permissible limits for YMWE (250-600 mg/L), except CLDM sample exceeded the permissible limits for YMWE. Cl^- concentration in the present study was high than obtained by [33] where was the Cl^- concentration ranging from 36 to 282 mg/l in the groundwater Wadi Zabid, Hodiedah, Yemen. On the other hand, This result was lower than the result obtained by [44] the average of chloride in groundwater in Al-Dahlia Basin was 391.79 mg/L, which also was lower than the result (596 mg/l) obtained by [36]. Higher chloride concentration in 17 samples may be due to big discharge of sewage near the sampling sites, or may be due to contamination by fertilizers, this agrees with [53, 20]. Chloride concentration is higher in wastewater than in raw water because sodium chloride a common component of the human and diet, passes unchanged through the digestive system [28], or may be attributed to could be resulted from the mixing of fresh water with sea waters, because the excessive pumping of groundwater to cover the increase on water demand for Aden Governorate result of population increase and migration from the countryside to the city.

3.3.3. Fluoride (F^-)

From the result indicated in Table 4. The fluoride concentration was the rang from 0.015 mg/l to 2.4 mg/l , F^- levels in four samples BN.T, CLBA, BA43 and CLMD were exceeded the permissible limits for WHO and YMWE (1.5 mg/l), while the remaining sixteen samples were not exceeded the permissible limits for WHO and YMWE.

High fluoride concentrations was in some groundwater wells, mainly due to the geology strata (mineral composition) and physical properties (soil textures) [24, 44, 54]. In the present study, fluoride content in 80% of wells were below the authorized range and in 20% of wells were higher than national standards, these results are higher than the results (8%) in the Birjand and Qaen plain obtained by [55]. On the other hand, the results obtained in the current study are lower than the obtained by [44], reported high concentrations of F^-, included 71% of the groundwater in the AL-Dhala basin, Yemen. And also [4] reported high concentrations of F- by 82.9% of the groundwater in the Hidhran Al Burayhi Basin, northwest Taiz City, Yemen.

3.3.4. Nitrate (NO_3^-)

Highly concentrated wastes containing nitrogen compounds could have been oxidized to nitrate when discharged into the environment and found its way into groundwater via percolation. Major health implications of excess nitrate in water are hypertension in adults [56] and methaemoglobinaemia in infants [57]. The nitrate concentrations in the present study was the rang from 21.70 mg/L to 76.25 mg/L, (with a mean value of 58.04 mg/l), as shown in Table 4. NO_3^- levels in 13 samples were exceeded the permissible limits for WHO and YMWE (50 mg/L), whereas in the 7 remaining samples s), were not exceeded the permissible limits for WHO and YMWE.

The source of the NO_3^- high in the samples located in the Bir Nasser Basin, which are BN-11, BN-13, BN-14, BN-48, BN-41, BN-42, BN-29, BN-16, BN-18 and BN-46, and also the samples C.L.BA, BA-34 and BA-43 located in the Bir Ahmed Basin, may be due to the unplanned houses built near water fields, about a few meters from the samples sites, this the houses is use cesspits to get rid of sewage, also these wells are near of agricultural lands that use chemical and animal fertilizers for a purpose agriculture eg urea, nitrate or ammonium compounds. Excessive applications of fertilizers for agriculture and the seepage of untreated wastewater from cesspits are from the main causes of the high concentrations of nitrate, this agrees with [22, 37, 58, 59]. So the water in these areas needs immediate treatment to make safe for drinking. Results of the present study was low than that obtained by [59], where the concentration of nitrates was in Aqeel well (86 mg/l), and the Jameh well (82mg/l). Also it was low than that obtained by [60] in his study assessing chemical and microbial pollution of groundwater in the Sana'a Basin, who found the concentration of nitrates 76.27 mg/l. Also it is low then that obtained by [61] in the groundwater around Mai-Bela, Asmara, Eritrea, where the Nitrate concentration was ranged between 17.71 to 496 mg/l. but it is higher than that reported by [37] a mean value of 12.24 mg, in the groundwater samples of Gohana. Haryana.

3.3.5. Nitrite (NO_2^-)

Nitrate and nitrite ions are present in water streams in trace amounts but an excess amount of nitrate and nitrite ions is a possible indication of contamination from bio-sewage [62]. The nitrite concentrations in the present study were the rang from 0.010 mg/l to 0.054 mg/l, (with a mean value of 0.028 mg/l), as shown in Table 4. The nitrite levels in all samples weren't exceeded the permissible limits for WHO and YMWE (0.100 mg/l). The result in this study was higher than that obtained by[15] which the average of nitrite was 0.012 mg/l. Also it is higher than that the a study carried out by [13] which the average 0.0183 mg/l in the groundwater wells in Badra City, Iraq. But the result of this study is lower than that reported by [61], where the average of nitrite in groundwater of was 0.518483 mg/L. According to the environmental protection agency, [39] levels nitrite in unpolluted waters are normally low, below 0.03 mg/l. Values greater than this may indicate contamination by sewage, Accordingly, the levels of nitrite ion in samples BN-12, BN-14, BN-16, BN-17, BN-16, C.L.BA and BA-43 are high. The reason may be to the migration of polluted surface water to groundwater.

3.4 Microbiological analysis:

3.4.1. The total coliform (TC)

The total coliform group has been selected as the primary indicator for the presence of bacteria and disease causing organisms in drinking water. It is a primary indicator of suitability of water for consumption [52]. If large numbers of coliforms are found in water, there is a high probability that other pathogenic bacteria or organisms exist. The WHO and YMWE drinking water guidelines require the absence of total coliform in public drinking water supplies. As shown in Table 4, The results of the microbiological analysis for study samples showed signs of water pollution with total coliform, the range of between 0.00 to 18 CFU/100ml, (with a mean value of 7.20 CFU/100ml).

Total coliform of about 15 samples measured (75%) were higher than the maximum limits of drinking water by the WHO and YMWE (0 CFU/100ml), this is considered a dangerous indicator of the water pollution. The high levels of total coliform bacteria in most of the study samples may be due to the presence of these wells near the population centers that use cesspits to dispose of waste water, in addition to the presence of homes for shepherds and a camp for the displaced in the middle of the Bir Nasser field, the largest of the basins that feed Aden with water, and the attendant presence of water sewage, animal waste, and waste collection, which directly affects the drinking water that supplies Aden Governorate. Compared with the previous studies the present result for total coliforms was lower than that reported by [63] in his study on four groundwater wells of in Al-Houta city, Lahj Governorate, that the rang of total coliform were 7.5-15.1(CF/100ml), with contamination percentage 100%. Also it is lower than that reported by [23] on the groundwater in Zabid directorate Al-Hudaydah governorate, Yemen, where the TC was ranged between 10-161CF/100ml, (with a mean of 94.4 CF/100ml). On the other hand the present results for total coliforms are higher than that reported by [64] on groundwater in Al-Qatn city, Wadi Hadramout, Yemen, where found 50% of groundwater samples were contamination by total coliforms. Also it is higher than a study carried out by [65] on groundwater in the Amran Basin-Yemen, where the results showed that the average total coliform, 43.69 (CF/100ml). also it is higher than that reported by [52], on drink water of Wondo Genet Campus Ethiopia equal was 0.78 (CF/100ml).

Table (4): Results of the cation, anion and biological analysis of groundwater samples collected from Bir Ahmed and Bir Nasser basins, Tuban delta

Mean concentrations of the target parameters (n=3)												
Name sample	Ca^{2+}	Mg^{2+}	Na^{+1}	K^{+1}	Fe^{2+}	SO_4^{2-}	Cl^-	F^-	NO_3^-	NO_2^-	T.C	F.C
	Concentration (mg/L)										(cfu/100ml)	
BN-8	83.76	55.53	276.35	11.50	0.78	317.04	266.84	0.385	48.60	0.020	4.00	0.00
BN-10	78.60	54.17	293.42	7.68	0.74	355.21	325.09	0.910	42.60	0.010	5.00	0.00
BN-11	84.65	58.50	383.50	7.81	0.90	200.42	345.42	0.859	56.70	0.025	17.00	1.00
BN-12	71.50	52.80	286.93	7.25	0.77	330.14	276.11	0.640	46.80	0.034	5.00	0.00
BN-13	87.85	73.39	271.87	11.50	0.78	335.98	330.70	0.985	65.30	0.025	6.00	0.00
BN-14	89.13	77.77	303.84	14.30	0.76	380.43	368.50	1.050	76.25	0.035	8.00	0.00
BN-48	52.70	39.37	257.50	8.15	0.07	224.80	205.43	0.015	72.13	0.024	7.00	0.00
BN-41	71.61	46.26	263.00	7.99	0.13	240.00	249.92	0.450	60.80	0.025	0.00	0.00
BN-42	79.64	51.98	276.11	8.78	0.08	280.80	260.70	0.880	62.21	0.029	13.00	2.00
BN-29	70.76	49.55	263.75	6.91	0.11	247.11	261.00	0.560	59.58	0.014	18.00	9.00
BN-16	75.60	54.96	276.91	12.11	0.76	232.70	304.62	1.010	52.60	0.051	12.50	0.00
BN-17	45.01	39.61	216.32	7.11	0.11	200.00	213.31	0.530	46.70	0.054	1.00	0.00
BN-18	82.11	55.94	333.42	14.20	0.07	327.00	335.50	1.230	72.00	0.017	0.00	0.00
BN-46	78.76	48.31	255.90	7.69	0.05	286.71	279.27	0.720	66.95	0.024	0.00	0.00
BN.T	65.00	37.00	374.41	10.43	0.07	364.80	350.60	2.400	37.80	0.013	0.00	0.00
C.L.BA	71.23	63.14	338.76	7.01	0.02	455.63	326.23	1.600	74.50	0.035	12.00	0.00
BA-34	77.02	54.87	347.45	7.87	0.02	466.05	340.61	1.130	73.20	0.025	14.00	0.00
BA-43	79.40	58.93	359.09	7.27	0.03	505.13	310.21	1.515	75.50	0.050	9.50	0.00
BA-49	73.97	60.45	251.70	7.13	0.07	300.60	266.40	1.280	48.80	0.025	12.00	0.00
C.L.DM	60.50	35.19	520.30	13.26	0.07	460.44	613.41	2.240	21.70	0.022	0.00	0.00
mean	73.94	53.39	307.53	9.30	0.32	325.55	311.49	1.019	58.04	0.028	7.20	0.600
min	45.01	35.19	216.32	6.91	0.02	200.00	205.43	0.015	21.70	0.010	0.00	0.000
max	89.13	77.77	520.30	14.30	0.90	505.13	613.41	2.400	76.25	0.054	18.00	9.000
SD	11.24	10.98	67.56	2.57	0.35	91.92	84.43	0.59	14.72	0.01	6.03	2.04
YMWE 1999	75-200	30-150	200-400	8-12	0.3-1	200-400	200-600	0.5-1.5	10-50	0.100	0.00	0.00
WHO 2004	75.00	30.00	200.00	12.00	0.30	250.00	250.00	1.50	50.00	0.100	0.00	0.00
No. of Sample unfit compared with WHO	11	20	20	4	7	14	17	4	13	0	15	3
Percent of samples more than WHO	55%	100%	100%	20%	35%	70%	85%	20%	65%	0%	75%	15%

CFU/100ml: Colony forming units per 100 ml

3.4.2. Fecal coliform (FC)

The presence of fecal coliform bacteria indicates that a fecal source such as cesspool leakage, animal feedlot, etc, is in the vicinity. Their presence also indicates that the water may be contaminated with organisms that can cause disease which represents a serious and even deathly health concern [23].WHO and YMWE of recommended for drinking water that the count of the fecal coliform bacteria must be zero in 100 ml. From the results of the fecal coliform analysis of the groundwater samples in Table 4, the range was of between 0.00 to 9 CFU/100ml, (with a mean value of 0.6 CFU/100ml). Only three samples (BN-29, BN-11and BN-42) showed contamination of Fecal coliform, where exceeded the permissible limits for WHO and YMWE (zero in 100 ml), whereas the remaining samples weren't exceeded the permissible limits for WHO and YMWE. BN-29 well has the highest microbial load of (9 in 100 ml) while well of BN-11 has the low microbial load of (1 in 100 ml).

The high levels of fecal coliforms in samples (BN-29, BN-11 and BN-42) may be due to the location of these wells in the Bir Nasser Basin, where the BN-29 is locate near the garbage dump on the main road of Al-Fayoush Lahij, where the remains of dead animals and human waste are disposed of next to the site of this well, While the samples BN-11 and BN-42 are Near the residences adjacent to the basin, As these houses rely on cesspits to get rid of sewage; also, near these wells, those the housing for shepherds and yards for sheep and livestock, where waste is disposed of in a random manner next to those wells. Therefore these wells are not suitable for drinking unless they are treated.

When comparing the results of the current study with previous studies about fecal coliform values we find that, [63] indicated in his study on the water of four wells used for household purposes in Al-Houta city, Lahj Governorate, that the range of fecal coliform was 4.25-7.25 (CFU/100ml), with contamination percentage 75%. As well as [33] a field study was carried out to assess the suitability of groundwater for drinking and uses in Zabid directorate Al-Hudaydah Governorate Yemen, the study showed the presence of coliform Escherichia coli in (87.5%) of the samples. And in the study conducted by [41] for the purpose of assessing the contamination of groundwater wells located near the landfill in the Al-Suhoul area in Ibb governorate Yemen, that four of the wells are contaminated and that the leachate from the landfill adjacent to the wells has penetrated and polluted the groundwater resources in this area. Also [65] studied the quality of groundwater in the Amran Basin Yemen, the result showed that the average fecal coliform were 0.23 (CF/100ml). The values obtained in the above studies are higher than that those obtained in the present study.

3.5 Pearson correlation analysis

Table 4, shows positive correlation between water temperature and each of pH (r=0.39), NO_3^- (r=0.376), NO_2^-(225), and TC (0.488*),the significant correlation between water temperature and pH, turbidity, NO_3^-, NO_2^- as well as TC agrees with the knowledge that temperature affects other properties of water by speeding up chemical reactions [29, 66]. Positive correlations were found to exist between turbidity and TH (0.650**), Mg (0.700**), Ca^{+2}(0.446*), and K^+ (0.475*). As well as between pH and Na (0.508*). A very strong positive correlation exists between EC and TDS (0.934**) buttressed the fact that EC depends greatly on the amount of dissolved ions in water and between EC and cations Na^+ (0.763**) K^+ (0.485*) and between EC and anions SO_4^{2-} (0.825**) ,Cl^- (0.805**), F^- (0.700 **). This result is in agreement with earlier similar results reported by [33]. Electrical conductivity is reflection of the status of inorganic pollution and is a measure of TDS and ionized species in water [28]. Strong positive correlation between TDS and Sodium (0.668**) and anions SO_4^{2-} (0.810**) ,Cl^- (0.665**), F^- (0.652**). TDS gives an indication for the significant increasing of chemical ions. This result is agrees with similar results obtained by [33]. Also There is strong positive correlation between TH and cations Ca^{2+} (0.918**), Mg^{2+} (0.946**) and fe^{2+} (0.547*) and with NO_3^- (0.527*). This result is agrees with similar results obtained by [31]. Positive correlation between hardness and each of Ca^{2+} and Mg^{2+} is because of their importance in hardness of water. positive correlation between alkalinity and Fe^{+2} (0.547*) and K^+(0.472*) . Positive correlation was also found between Ca^{2+} each of Mg^{2+} (0.787**) and Fe^{2+}(0.493*). And between Mg^{2+} and Fe^{2+} (0.492*), and NO_3^- (0.544*). Strong positive correlation between SO_4^{2-} and Cl^- (0.578**) and F^- (0.662**). Also results shows that there is a significant relation between the NO_3^- and TC (0.333), and TC and FC (508*). As well as TC and FC (508*).

Table 5: Correlation coefficient matrix for different water quality parameters of groundwater samples collected from Bir Ahmed and Bir Nasser basins, Tuban delta

		T	Turb	PH	EC	TDS	TH	T.A	Ca^{2+}	Mg^{2+}	Na^{1+}	K^{1+}	Fe^{2+}	SO_4^{2-}	Cl^-	F^-	NO_3^-	NO_2^-	TC	FC
1	T	1																		
2	Turb	.020	1																	
3	PH	.339	-.071	1																
4	EC	-.548-*	.318	.197	1															
5	TDS	-.561-*	.301	.158	.934**	1														
6	TH	.070	.650**	.023	.252	.315	1													
7	T.A	-.482-*	.127	-.535-*	.071	.101	.188	1												
8	Ca^{2+}	-.024	.446*	.003	.250	.295	.918**	.210	1											
9	Mg^{2+}	.240	.700**	.058	.127	.173	.946**	.035	.787**	1										
10	Na^{1+}	-.405	-.049	.508*	.763**	.668**	-.064	-.150	.033	-.172	1									
11	K^{1+}	-.487-*	.475*	-.062	.485*	.362	.296	.472*	.309	.209	.350	1								
12	Fe^{2+}	.018	.397	-.054	-.074	.037	.547*	.520*	.493*	.492*	-.099	.280	1							
13	SO_4^{2-}	-.319	.189	.393	.825**	.810**	.250	-.275	.215	.223	.605**	.156	-.226	1						
14	Cl^-	-.483-*	.214	.282	.805**	.665**	.044	.017	.110	-.036	.903**	.537*	.031	.578**	1					
15	F^-	-.386	.035	.203	.700**	.652**	-.036	-.144	.023	-.061	.754**	.308	-.268	.662**	.733**	1				
16	NO_3^-	.376	.294	.151	-.032	-.007	.527*	-.273	.376	.544*	-.326	-.094	-.149	.093	-.411	-.325	1			
17	NO_2^-	.225	-.026	.139	.126	.058	-.186	.034	-.359	-.056	.085	.050	-.028	.052	.128	.092	-.068	1		
18	TC	.488*	.004	.138	-.139	-.124	.336	-.278	.280	.403	-.067	-.337	.136	-.051	-.166	-.134	.333	-.008	1	
19	FC	-.147	-.112	-.401	-.124	-.141	-.047	.086	-.015	-.076	-.146	-.242	-.131	-.259	-.160	-.201	.037	-.282	.508*	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Conclusions

- The average concentrations of pH (7.47), and NO_2^- (0.028) in all wells were within the standard limit for WHO, 2004 and YMWE (1999).
- The average temperature (39.99°C) in all groundwater wells was above from the standard limit for WHO, 2004 and YMWE, 1999 (by 100%).
- The average concentrations of EC (2004.68 μS/cm), Mg^{2+}(53.39 mg/l) and Na^{+1} (307.53 mg/l) in all groundwater wells (by 100%) were higher than the standard limit for WHO (2004) .
- The average concentrations of TDS (1288.58 mg/l) and Cl^-, (311.49 mg/l) in 85 % of the studied groundwater wells were higher than the standard limit for WHO 2004 .
- The average concentration NO_3^- (58.04 mg/l) in 65 % and the average concentrations F^- (1.019 mg/l) and the K^{+1},(9.30 mg/l) in 20%, were higher than the standard limit for WHO (2004) and YMWE(1999).
- The averaVge concentrations of Turbidity (2.29 NTU), and TH, (402.36 mg/l) were higher than the standard limit for WHO 2004 (by 10%). TH classified the studied samples according to the classification of the EPA, and it turned out that 80% of the studied samples were characterized by excessive hardness, while 20% of them were hard.
- The average concentration TA is (261.82mg/l) by 75% and The average concentration Ca^{2+} is (73.94mg/l) by 55%, and the average concentration Fe^{2+} is (0.32 mg/l) by 35%, and the average concentration SO_4^{2-} is (325.55 mg/l) by 70%, from the studied groundwater wells were higher than the standard limit for WHO 2004.
- The results of the microbiological analysis of total coliform and fecal coliform also indicated presence of high levels of contamination, where the results showed the presence of total coliform (7.20 cfu/100ml) in (75%) and fecal coliform (0.600 cfu/100ml) in (15%) of from the studied groundwater wells were above from the standard limit for WHO (2004) and YMWE(1999).
- The infiltration of wastewater to the bottom layers and contamination of groundwater can be recognized by the high concentration of wastewater indicator components such as TDS, NO_3^- , Cl^- and SO_4^{2-}, as well as microorganisms. The positive correlation between TC and FC also TC and NO_3^- confirms this conclusion.
- The results show that the values of TDS, EC, Cl and SO_4^{2-} of the CLDM exceeded the limits allowed by WHO (2004) and YMWE(1999).The reason may be due to the over-pumping of water from this field and the lack of rain feeding into the field.

- Results of statistical analysis showed a Positive link relationship between the total coliform and fecal coliform bacteria, as well as Positive link relationship between nitrate ions and total coliform bacteria.
- This result shows that the waters basins under study receives a very high amount of pollution from the surrounding areas, and if the similar condition continues for a longer period, these ponds may become completely contaminated.s

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مقالة بحثية

تقييم مستوى التلوث الفيزوكيميائي والميكروبيولوجي للمياه الجوفية في أجزاء من حقلي مياه بير ناصر وبير أحمد في دلتا تبن في محافظتي عدن ولحج - اليمن

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المُلخّص

الهدف من هذه الدراسة هو تقييم مصادر تلوث المياه الجوفية، في بعض حقول مياه بير ناصر وبير احمد، في دلتا تبن محافظة عدن ولحج، اليمن، والتي تعتبر المصادر الرئيسية لمياه الشرب والأغراض المنزلية للمستهلكين في محافظة عدن. في هذه الدراسة، تم جمع 20 عينة مياه جوفية من تلك الحقول، في الفترة من فبراير وحتى يوليو 2021. استند تقييم جودة المياه الجوفية في منطقة الدراسة إلى 19 مؤشر (parameter's) مثل درجة الحرارة (T)، العكارة، تركيز ايون الهيدروجين (pH)، الموصلية الكهربائية (EC)، إجمالي المواد الصلبة الذائبة (TDS)، العسر الكلي (TH)،القلوية الكلية (TA)، الكالسيوم (Ca^{+2})، الماغنسيوم (Mg^{+2})، الصوديوم (Na^{+})، البوتاسيوم (K^{+})، الحديد (Fe^{+2})، الكبريتات (SO_4^{--})، الكلوريد (Cl^{-})، الفلوريد (F^{-})، النترات (NO_3^{-})، النتريت (NO_2^{-})، القولونية الكلية (TC) والقولونية البرازية (FC). تمت مقارنة ملاءمة المياه الجوفية للشرب والأغراض المنزلية مع معايير منظمة الصحة العالمية (WHO 2004) ومعايير وزارة المياه والبيئة اليمنية (YMWE، 1999). أظهرت النتائج أن معظم القياسات الفيزيائية والكيميائية والبيولوجية أعلى من الحد المسموح به من قبل (WHO 2004)، باستثناء الرقم الهيدروجيني والنتريت، والتي تم العثور عليهم أقل من الحد القياسي. ترجع أسباب ارتفاع قيم ال parameters لبعض مناطق الدراسة إلى وجود الآبار المدروسة بالقرب من التجمعات السكانية التي تستخدم الحفر الامتصاصية للتخلص من المياه العادمة، وكذلك قرب الآبار من الأراضي الزراعية التي تستخدم الأسمدة الكيميائية والحيوانية، بالإضافة إلى الحفر العشوائي للآبار، لذلك هناك حاجة لتدابير العلاج المناسبة قبل استهلاك هذه المياه من قبل السكان لتجنب المشاكل الصحية المتراكمة على المدى الطويل لهذه الملوثات.

الكلمات المفتاحية: الخواص الفيزوكيميائية، المياه الجوفية، بير احمد، بير ناصر، حوض دلتا تبن، لحج، عدن.

How to cite this article:

Sh. M. K. Saleh and A. M. A. Al-Sallami, "ASSESSMENT OF THE LEVEL OF PHYSICOCHEMICAL AND MICROBIOLOGICAL CONTAMINATION OF GROUNDWATER IN PARTS OF BIR NASSER AND BIR AHMED WATER FIELDS IN TUBAN DELTA IN ADEN AND LAHEJ GOVERNORATES-YEMEN", *Electron. J. Univ. Aden Basic Appl. Sci.*, vol. 3, no. 2, pp. 101-116, June. 2022. DOI: https://doi.org/10.47372/ejua-ba.2022.2.158