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Research Paper

PHYSICO-CHEMICAL CHARACTERISTICS OF GROUNDWATER IN LAHJ GOVERNORATE, YEMEN

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Water is considered the main component of human life and without which life is nothing. Because of being so, the matter of its purity is regarded as an important aspect to be taken into account. Groundwater contains various constituents such as micro-organisms, gases, inorganic and organic materials at different concentrations, which may constitute undesirable pollutants when they are not within the WHO standards for drinking water. This study aims to analyze the physic-chemical characteristics of groundwater in Lahj Governorate, Yemen. Twenty groundwater samples were collected from different wells. Parameters were conducted to evaluate the quality of groundwater for drinking purposes. These parameters include: pH value, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS) TH, TA, CL, SO_4, Ca, Mg, Na, and K. These were used as measuring tools in the field of water sampling. According to the parameters, the results of the study showed that some samples comply with WHO standards and Yemeni standards whereas others are not. On the basis of the results, the validity extent of such samples in the study area is determined.

Keywords: Groundwater, Physicochemical parameters, Lahj governorate

INTRODUCTION

Water is considered the main component of life. Human continuous existence depends mainly on its availability. Therefore, good drinking quality is of a vital importance to human. Groundwater is considered as a source of water which is mainly depended on for drinking. So, purity of this water is regarded of a paramount importance since it is in touch with human life. For this reason, an examination of groundwater is demanding and needed since any changes in its properties and characteristics lead to its damage and pollution especially if they are out of the permissible limit specified by the local and the world standards such as World Health Organization (WHO) standards. To put it simply, any changes out of the permissible extent in the physicochemical characteristics of this water are regarded as one of the risks threatening human life. This study is aimed to analyse the physicochemical characteristics of the groundwater in Lahj Governorate, Yemen using the criteria of different

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parameters including pH value, Temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), TH, TA, CL, SO_4, Ca, Mg, Na, and K. A brief discussion of groundwater and pollution is given followed by specifying the area, the materials and methods, and the results of the study.

GROUNDWATER AND POLLUTION

Groundwater contains various constituents such as micro-organisms, gases, inorganic and organic materials at different concentrations which may constitute undesirable pollutants when they are not within the WHO standards for drinking water (So Ngele *et al.*, 2014). Water pollution has been suggested to be the leading worldwide cause of death and diseases (Adegbola Adedayo *et al*., 2012). So, we must provide good quality of drinking water and preserve the health of citizens from exposure to pollutants particularly because 80% of the diseases spread in the developing countries is as a result of the contamination of drinking water due to the absence of proper drainage system and the arrival of waste after decay into the groundwater (Thawabah Naji Saleh, 1996). Groundwater became unpurified and there is no case in which it does not contain stuck materials and other dissolved rates. Therefore, it is considered that all the processes and interactions that affect water from the moment of condensation in the air until its exit from wells are responsible for the physical and chemical characteristics of the groundwater (Dradka Khalifa, 1987). The contamination of drinking water leads to a major damage and has direct effects on human health. Groundwater is the most important source of domestic, industrial agricultural water supply in the world and it reflects inputs from the atmosphere, soil, and water rock reactions as well as pollutant sources such as mining, clearance, agriculture, domestic and industrial wastes. The quality of groundwater is constantly changing in response to daily, seasonal and climatic factors. So, continuous monitoring of water quality parameters is highly crucial because changes in the quality of water have far-reaching consequences in terms of its effects on man and living organisms (Ackah *et al.*, 2011).

In Lahj Governorate, groundwater is used for drinking and to satisfy the needs of the different water-using sectors, namely irrigated industrial, municipal use and agriculture use. Direct underground disposal of municipal and industrial wastewater by means of disposal facilities presents a potential threat of groundwater contamination. Systematic assessment of the physicochemical parameters, their sources and controlling hydrochemical processes are essential in maintaining the suitable ecosystem. Groundwater chemistry can be modified by variety of anthropogenic sources such as waste disposal facilities, industrial pollution, and many others (Sajil Kumar and James, 2013). Nowadays, water pollution happens to be one of the major environmental topics. Rapid industrialization arising from modern and sophisticated technology has introduced many synthetic materials into the environment. Drinking water is considered safe if it contains some dissolved impurities at concentrations within permissible limit of a given standard such as World Health Organization (WHO) Standard (Adejo Bagudo *et al.*, 2013).

STUDY AREA

The study area is Lahj Governorate which is located in the south – west of the Republic of

Yemen, between the longitudes (43-46) E, and between latitudes (12-14) N, about 337 km^2 from the capital Sana'a. It has an area of about 12.650 km^2 (Figure 1). The population of Lahj governorate, according to the 2011 census of population, is about 875, 000. In Lahj governorate, there are 15 districts Figure 2. The city of Al-Hota is the capital of the governorate (National Information Center, 2011). Figure 3 shows the map and location of the collected samples for the studied area.

MATERIALS AND METHODS

Twenty representation groundwater samples were collected from the groundwater wells of Lahj governorate during the year 2014. The samples were collected from the wells in plastic container of 500 ml capacity and they were preserved by using nitric acid position 65% by adding 3 ml for every 1000 ml. The physic-chemical analysis of groundwater samples was carried out by adopting standard methods given by APHA. Twelve parameters were analysed for quality assessment including Temperature, pH, Electrical Conductivity, Total Dissolved Solids, Total Hardness, Alkalinity, Chloride, Calcium, Magnesium, Sodium, Potassium, and Sulphates. All filed meters and equipment such as model 3540 pH, conductivity meter, Flam photometer, UV-VIS spectrophotometer and Electronic

Figure 1: Map of Lahj, Yemen

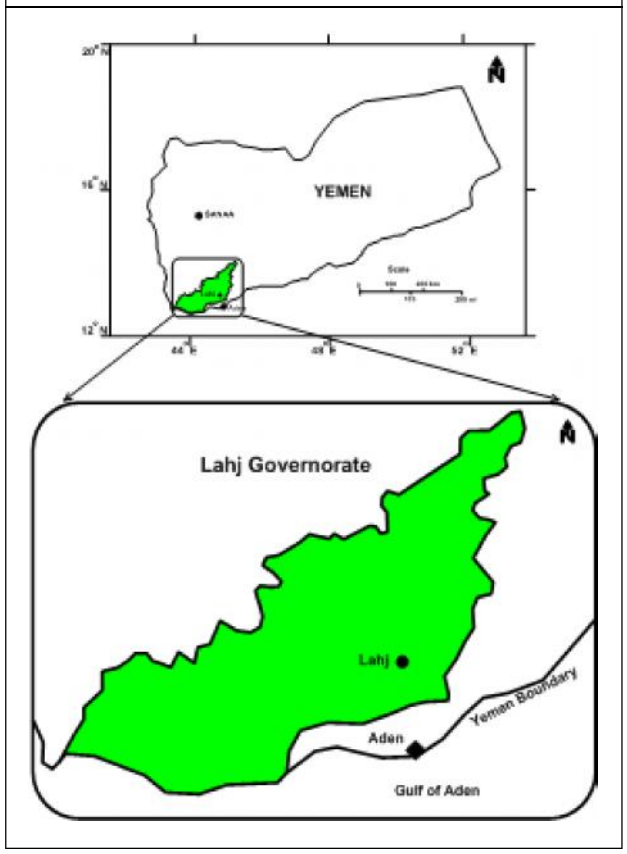

Figure 2: Map of the Districts of Lahj Governorate

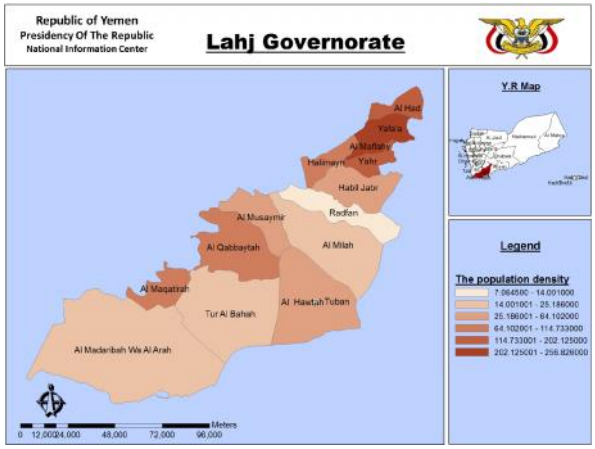

Figure 3: Location Map of Study Area, Lahj, Yemen

balance were calibrated and checked according to the manufacturer specification (APHA.1985; and Pathare *et al.*, 2014).

RESULTS AND DISCUSSION

The present study was undertaken with the aim of analysing certain physico-chemical characteristics of the groundwater samples from Lahj governorate. The parameters showed that some samples of the groundwater are within the permissible limits for drinking water. The other few samples concentrations exceed the desirable limit at some sites and needs treatment before its use. The results and the measuring parameters in the study area are shown in Table 1.

As shown in Table 1, the results obtained have been described and discussed as follows:

Temperature: The results of the filed temperature varied between 25C to 33C with an average of 28.85C. A high degree of temperature of water leads to the speeding up of the chemical reactions and reduces the solubility of gases. It also increases the bad taste and odor. Furthermore, it raises the metabolic activity of the organisms in water (Trived and Goel, 1984). The higher temperature values of the water samples in the study area can be due to the climatic condition of the area which is characterized by higher temperatures during the dry season.

Table 1: Physico-Chemical Parameters of Groundwater from Lahj Governorate

Parameter	Minimum	Maximum	Means
T	25	33	28'8
pH	6.8	8.5	7.5
EC	723	8115	2451.8
TDS	470	5274.8	1600.35
TH	250	2090	744.5
Ca	24.05	617.23	203.88
Mg	7.3	552	157.8
Na	69	625	324.84
K	4	13.9	8.1
TA	50	650	336.75
SO_4	12	260	95
Cl	206	1704	602.35

pH: The pH values of the groundwater samples ranged from 6.8 to 8.5 with an average of 7.5. The safe limit of the pH lies between 6.5 and 8.5 according to WHO and Yemeni standards specified for drinking water. The results indicate that almost all the groundwater samples of the study area are within the recommended limits for human consumption for most domestic and industrial uses. According to the pH parameter, the samples are within the permissible limit and do not cause any problem.

Total Dissolved Solids (TDS): This feature can be used as an alternative measurement of the electrical conductivity as it gives an idea of the total concentration of ions dissolved in the solution (Mohesen AL-Gahri and Ahmed Saeedan, 2000). The permissible limit of the Total Dissolved Solids (TDS) lies between 650 mg//-1500 mg// according to the WHO standards and the Yemeni National Water Resources Authority (NWRA) standards. When TDS is less than 300 mg/l, it is described as excellent. When it is between 300 and 600 mg/l, it considered good whereas the increase of salt or TDS above 600 mg// water is characterized by salinity and described as salty. However, when the TDS is more than 1200 mg// water is regarded as unacceptable (World Health organization, 1989). The concentration of TDS of the groundwater samples ranged from 470 mg//to 5274.8 mg// with an average of 1600.35 mg//. The TDS in this study indicate that

water samples 2, 3, 4, 5, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19 are within the permissible limit and in the samples 1, 6, 10, 11, 20 it is higher than the limit according to WHO and (NWRA) (NWRA, 2000; and WHO, 2004).

Electrical Conductivity (EC): All the types of water reaching the power supply increase the conductivity of ionic concentration. The conductivity values ranged from 723 µS/cm to 8115 µS/cm with an average of 2451.8 µS/cm. The World Health Organization adopted the electrical conductivity between 450-1500 µS/cm and the electrical conductivity according to the Yemeni National Water Resources Authority (NWRA) standards ranges from 450-2500 µS/cm. The results showed that water samples 1, 6, 10, 11, 20 are of very high level of Electrical Conductivity (EC) because of the high level of total dissolved solids in the same samples.

Total Alkalinity (TA): The concentration of total alkalinity ranged from 50 mg// to 650 mg//, with an average of 336.75 mg// in the study area. This indicates that almost all the groundwater samples of the study are within recommended limit according to WHO with the exception of one sample (WHO, 1993). Alkalinity is an estimate of the ability of water to resist a change in pH when added to acid (Mahanada *et al.*, 2013).

Total Hardness: The hardness of natural water depends mainly on the presence of dissolved calcium and magnesium salts. The concentration of total hardness ranged from 250 mg// to 2090 mg// with an average of 744.5 mg// in the study area. The results of TH indicates that water samples 1, 5, 8, 10, 11, 12, 14, 17, 18, 19, 20 are of higher concentration of TH and falls beyond the maximum permissible limit and the rest of the samples are within the permissible limit. The guideline value for drinking water recommended by WHO and (NWRA) for water hardness is 500 mg//. High value of hardness can be attributed to decrease water volume because of the lack of rain in the study area, and to the disposal of untreated or improperly treated sewage and industrial wastes.

Sodium Na: The concentration of sodium ranged from 69 mg// to 625 mg // with an average of 324.84 mg// in the study area. The permissible limit of sodium in potable water is 200 mg// according to the WHO standards and the local permissible limit in the Yemeni standards is 400 mg//. The results of sodium indicate that water samples No. 1, 5, 10, 11, 20 contain higher concentration of sodium. High variation of concentration of Na+ in the groundwater is due to exchange action among minerals.

Potassium K: The concentration of potassium ranged from 4 mg// to 13.9 mg// with an average of 8.1mg// in the study area. Drinking water contains lower concentration of potassium ions than the concentration of sodium ions. The values are below the local permissible limit according to the Yemeni standard which is 12 mg//. The results indicate that the water samples 1, 11 contain higher concentration of potassium in the study area.

Calcium Ca: The importance of calcium stems from the fact that it helps teeth to build and maintain. It is considered one of the most important positive ions in drinking water. The increase of its concentration leads to a change in the taste of water. This makes the consumers do not prefer this water. The concentration of calcium ranged from 24.05 mg// to 617.23 mg// with an average of 203.88 mg// in the study area. Calcium concentration in drinking water is

between 10-100 mg// and reaches 200 mg// according to the WHO standards and the Yemeni standards. The results of calcium indicate that water samples 1, 11, 12, 14, 17, 18, 19 contain higher concentration than the permissible limit.

Magnesium Mg: The concentration of Mg ranged from 7.3 mg// to 552 mg// with an average of 157.8 mg// in the study area. Some of the samples were within the permissible limit, except samples 10, 15, 16, 17, 18, 19, 20 which contain higher concentration than the permissible limit. When water contains magnesium sulphates by 1000 mg// it is considered a strong purgative for adults, while the lowest concentration affect children. Magnesium concentration in drinking water is between 30 mg//-150 mg// according to the WHO standards and the Yemeni standards.

Sulphates: Sulphates are considered of the few negative toxic ions. In high concentrations, these can cause diarrhea, dehydration and bowel infections. Sulphates often have adverse effects if they are accompanied by a high concentration of magnesium ions. The concentration of sulphate ranged from 12 mg// to 260 mg/l with an average of 95 mg// in the study area. The results indicated that values of sulphates in all the samples are within the permissible limit according to the WHO standards and the Yemeni standards where the limit lies between 200-400 mg//.

Chloride: The concentration of chloride ranged from 206 mg// to 1704 mg// with an average of 602.35 mg// in the study area. The concentration of chlorides in groundwater decreases in the rainy areas and increases in the dry ones. High concentration of chloride ions in drinking water leads to non-acceptance by consumers as the taste thresholds for chloride lies between 200-300 mg// based on taste consideration (World Health Organization, 1984), and the permissible limit in Yemeni standards is 600 mg//. The results indicated the presence of higher concentrations of chloride in some samples 1, 10, 11, 14, 17, 18, 19, 20. The rest of the samples were within the local permissible limit in Yemen.

CONCLUSION

The physico-chemical analysis showed that there are differences in the concentration of groundwater samples in the study area. The results showed that the values of pH content of all groundwater samples are within the permissible limit for drinking water given by WHO. Some groundwater samples contain higher EC, TDS than local permissible limit for drinking water. The majority of the groundwater samples contain sodium, calcium and magnesium within the permissible limit given by Yemeni standards. Potassium content of all groundwater samples was shown to be below the permissible limit except two samples which show higher content than the permissible limit given by Yemeni standards. The results showed that the majority of the groundwater samples contain sulphates content below the permissible limit. The total alkalinity values for most of the groundwater samples are within the permissible limit whereas some values of the total hardness and chloride are higher than the permissible limit. Some of the values of groundwater in the study area indicate that water quality is suitable for drinking purposes.

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