EUROPEAN ACADEMIC RESEARCH
Vol. I, Issue 12/ March 2014

ISSN 2286-4822
www.euacademic.org

Impact Factor: 3.1 (UIF)
DRJI Value: 5.9 (B+)

Physico-chemical Quality of Boreholes Water Used as a Source of Public Supply in Arib (Ain Defla-Algeria)

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Abstract:

Water from boreholes in Arib (Ain Defla) South-Western Algeria was investigated to ascertain its quality status and suitability for drinking and domestic uses. 56 water samples were collected from four boreholes during March to June 2011. Various physico-chemicals were analyzed. Temperature, pH, Electrical Conductivity, turbidity, total hardness, alkalinity, calcium, magnesium, iron, manganese, nitrate, nitrite, chloride and sulphate were assessed among the entire samples collected. The results show that: temperature ranges from 18-23.7°C, pH range is 6.55-6.93. Turbidity ranges between 0.19-0.29. Conductivity ranges between 1848-2840 µS/cm, Alkalinity range is 23-257 mg L^{-1}, Total hardness is between 40 and 100mg L^{-1}, calcium (121.5-240 mg L^{-1}), magnesium (24-97 mg L^{-1}), Chloride concentration (189-543 mg L^{-1}), nitrate (8-30.5 mg L^{-1}), nitrite (0-0.02 mg L^{-1}) and sulphate concentration ranges between 27.5-2649 mg L^{-1}. Results show that some of the water samples considered in this work does compare favorably with WHO (2004) water standard for drinking and domestic usages while some other samples of boreholes water fall short of this standard.

Key words: Borehole, hydrochemical analysis, Arib-Ain Defla

Introduction:

Water is essential to maintain and sustain human life, animal and plant (Patil and Patil 2010). The availability of good quality water is an indispensable feature for preventing disease and improving quality of life (Patil et al. 2012).

Natural groundwater is usually of good quality, but this can deteriorate due to inadequate source protection and poor resource management (Pedley and Howard 1997).

The sources of contamination are numerous and include the land disposal of sewage effluents, sludge and solid waste, septic tank effluent, urban runoff and agricultural, mining and industrial practices (Sabatini 1994, Ikem et al. 2002, Al Khatib and Arafat 2009).

Contamination of groundwater has severe implications for public health, particularly in small communities and developing countries where groundwater is often the preferred source of drinking water (Bitton and Gerba 1984).

In Algeria, groundwater constitutes an important source of water supply for domestic and agriculture purposes. But, the overexploitation of aquifers and reduced natural recharge due to high urbanization and anthropogenic activity has caused a decrease in groundwater quality in many areas. Very little work has been done on the suitability of ground water for human consumption in the study area.

The main objective of this study was to determine the quality and suitability of ground water from boreholes in Ain Defla, South Western of Algeria for human consumption, by comparing the results obtained from its chemical and bacteriological analysis with WHO drinking water standards.

Study area:

The study area as shown in figure 1 is Arib which is a medium size community of Ain Defla which is located at 145 Km from

South West of Algiers. Geographically, the town is located on longitude 2° 3' 56.96"E and latitude 36° 17' 16.09"N, it shares a boundary with Tipaza in the North, Tissemsilt in the South, Chlef in the West and Blida in the East. The people of the community are majorly farmers.

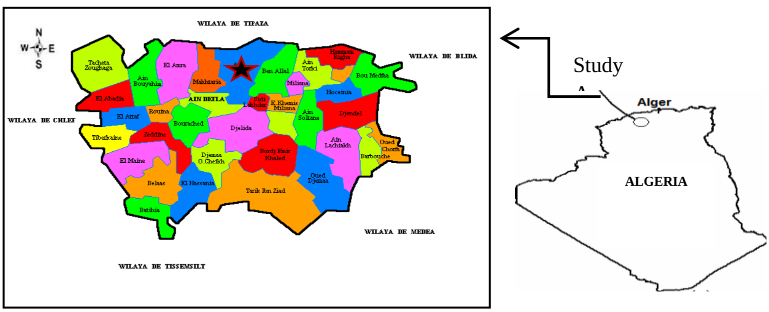

Figure 1: Showing the location of Arib area ★ in Ain Defla (Algeria)

Sample collection and analysis of water:

Four boreholes (BH) were sampled; their characteristics are shown in Table 1.

Boreholes	BH1	BH2	BH3	BH4
Depth (m)	65	70	120	58
Flow (lS^{-1})	40	30	20	20
Date of commissioning	1982	1982	1992	1994

Table 1: Characteristics of the Sampled Boreholes (Algérienne Des Eaux (ADE) 2010)

For each borehole, 56 water samples were collected from different boreholes located in Arib during March to June in the year of 2011. One liter were collected in sterilized polyethylene bottles, while a 0.5 liter sterilized bottle was used to collect sample for bacteriological analysis and stored at the temperature of 4°C. The analyses covered physical, chemical, and bacteriological parameters of the water samples from each borehole. The qualitative analyses were carried out at the ADE laboratories of Ain Defla. The physical parameters tested included: temperature, pH and turbidity. Chemical parameters analyzed were total hardness (TH), iron, nitrate, nitrite, chloride, sulphate, calcium and magnesium. The pH was determined using a pH meter by direct measurement, analog mercury thermometer was used for temperature measurements, and a turbidimeter was used for turbidity determination. The samples were also analyzed in the water laboratories for alkalinity, total hardness, iron, nitrate (NO_3), nitrite (NO_2), calcium, and chloride using standard methods for the examination of water (Rodier 1984, APHA 2005). All the results were compared with the World Health Organization (WHO 2004) values.

Results and Discussion:

The results and comparison of the sample parameters with the World Health Organization Standard for Drinking water quality are presented in Table 3.

Parameters	Range	Mean	WHO Standard values
Temperature °C	23.7- 18	21	25
pH	6.93 - 6.55	6.79	6.5 – 8.5
Turbidity NTU	0.29 – 0.19	0.18	5
Conductivity μSCM^{-1}	2840 - 1848	2397	1200
Alkalinity (mg L^{-1})	257- 23	219	250
Total Hardness T.H (mg L^{-1})	100 – 40	70.53	500
Calcium. Ca^{+2} (mg L^{-1})	240- 121.5	167	75
Magnesium Mg^{2+} (mg L^{-1})	97- 24	70	50
Chlorides Cl^- (mg L^{-1})	543 – 189	345	250

Nitrates NO_3^- (mg L^{-1})	30.5- 8	15	50
Nitrites NO_2^- (mg L^{-1})	0.02-0	0.02	0.5
sulphates SO_4^{2-} (mg L^{-1})	2649- 27.5	863	200
Iron (Fe^{+2}) (mg L^{-1})	0.08- 0	0.01	0.3
Manganese Mn^{2+} (mg L^{-1})	0.02-0	0.006	0.1

Table 3: Mean values of physic-chemical parameters in borehole water samples obtained from Arib area (Ain Defla) compared to the recommended World Health Organisation (WHO 2004) for Drinking Water Quality

The value of temperature in the study area ranged from 18-23.7°C. It is noted that high water temperature enhances the growth of microorganisms and may increase taste, odor, color and corrosion problems. Warm temperature gives rise to accelerated bacterial activities there by creating potentials of odor development through depletion of oxygen (Hoko 2008).

The PH values of samples range is 6.55-6.93 which conform to WHO standard for drinking water. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Ahmed et al. (2000) reported a pH range of 8.8-9.9 in groundwater in Sudan. A pH range of 6.5-8.5 is generally suggested by most guidelines and standards (OME 2003).

On the basis of pH, water is described as neutral if $6.8 < pH < 7.2$, weakly alkaline if $7.2 < pH < 7.8$. The water is weakly acidic if $6.8 > pH > 6.0$ and acidic if $6.0 > pH > 4.5$. pH of boreholes in the study area is however neutral going by the above water pH categorization.

Turbidity in drinking-water may be due to the presence of inorganic particulate matter in some groundwater or sloughing of biofilm within the distribution system. High turbidity value can protect microorganisms from the effects of disinfection thereby can stimulate bacterial growth (Hoko 2008). In this study, the turbidity of the water was found to range from 0.19 to 0.29 NTU against a WHO Guideline value of 5 NTU (WHO 1996).

The conductivity concentrations range was 1848- 2840 µS CM^{-1}. These values are much greater compared to those found by Hoko (2005), which were Gokwe South (70-1730 µS/cm), Nkayi (89-1459 µS/cm), Lupane (118-1034 µS/cm) and Mwenezi (222-9800 µS/cm). Larsen et al. (2002) found EC values of 346-1079 µS/cm in Matebeleland North, in Zimbabwe. Bernard and Ayeni (2012) found EC values of 126-143 µS/cm. The value is without WHO standard for drinking water (WHO 2004-2011).

Conductivity is affected by the presence of dissolved ions in water. The importance of EC is its measure of salinity, which generally affects the taste and therefore, impacts on the user acceptance of the water (Ahmed et al. 2000). In this study, the consumers do not generally accept the taste in the water and normally associate such water with possible wastewater pollution and the health risks.

The alkalinity of water may be caused by dissolved strong bases such as sodium. The alkalinity value ranged between 23-257 mg L^{-1}. When water has high alkalinity it is concluded that it is well buffered. It resists a decrease in pH when acidic rain snowmelt, enters it. If water has an alkalinity below about 100mg L^{-1} as $CaCO_3$, it is poorly buffered and pH sensitive. This could be harmful to the plants and animals that live there (WHO 2011).

Total hardness is the indicator of hydrogeology and aesthetic quality of water. Total hardness varied between 40 and 100 mg L^{-1}. These findings suggest that the water body is moderately hard and high medium productive during present study. Similar findings were also observed by Adebo and Adetoyinbo (2009) and Hiremath et al. (2011) in their studies. Water total hardness is imparted mainly by the calcium and magnesium ions, which apart from sulphate, chloride and nitrates are found in combination with carbonates.

Hardness caused by calcium and magnesium usually results in excessive soap consumption. In some instances, consumers tolerate water hardness in excess of 500 mg L^{-1}. Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg L^{-1} may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings. Soft water, with a hardness of less than 100 mg/l, may, have a low buffering capacity and so be more corrosive for water pipes. (WHO 2011). According to the classification of Durfor and Becker (1964), the analyzed of water of boreholes is hard.

Calcium contributes to the hardness of water and it is the fifth most common element found in most natural waters. The sources of calcium in ground water especially in sedimentary rocks are calcite, aragonite, gypsum and anhydride. The calcium concentration in the sampled borehole in the study area is very high 121.5 to 240 mg L^{-1} with the highest of value found in BH3 and the maximum allowable concentration according to WHO standard for drinking water quality 2004 is 75 mg L^{-1}. Ohle (1934) classified the water bodies into three categories on the basis of calcium richness: (i) poor, (ii) medium and (iii) rich. Thus as per the recommendations of Ohle (1934), most of the water samples are 'Calcium rich'. When calcium (Ca^{2+}) and magnesium (Mg^{2+}) occurred in high concentration, they result in the hardness and alkalinity of the water.

Magnesium is one of the most common elements in the earth's crust. It is present in all natural waters. It is an important contributor to water hardness.

The sources of magnesium in natural water are dolomites and mafic minerals (amphibole) in rocks. The solubility of dolomite in water depends on the composition. From this, we may conclude that the magnesium source in this area is from the carbonate rock (limestone) deposited in the area which change to dolomite due to dissolution of calcium and thus the source. In study area, magnesium concentration ranged between 24 to 97 mg L^{-1} with the mean of 70 mg L^{-1}, which is higher than the maximum allowable concentration 50 mg L^{-1} based on WHO (2011) standard. The high concentration of this magnesium was found mostly in water samples from BH1, BH3 and BH4.Results of present investigation shows that the magnesium contents in majority of samples does exceed the limit as prescribed by WHO.

Chloride in drinking-water originates from natural sources, sewage and industrial effluents (Canter and Knox 1985). In the study area, the concentration of chloride is higher and range between 189 to 543 mg L^{-1}, which is beyond the maximum allowable concentration of 250 mg/l (WHO 2004) which indicates pollution status of water body. The highest concentration was recorded in the Borehole BH1. However, chloride concentrations in excess of about 250 mg L^{-1} can give rise to detectable taste in water (WHO 2008, WHO 2011).

Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), but groundwater concentrations generally show relatively slow changes. Some ground waters may also have nitrate contamination as a consequence of leaching from natural vegetation.

The concentration range of 8-30.5 mg L^{-1} was observed which was below the WHO standard of drinking water permissible limit (WHO 2004, WHO 2011)

High nitrate concentrations in drinking water are associated with the development of methaemoglobinaemia in infants. This is a situation where nitrate is reduced to nitrite as nitrate itself does not cause this disorder. The nitrite combines with haemoglobin in red blood cells to form methaemoglobin, which is unable to carry oxygen and so reduces oxygen uptake in the lungs. Normal methaemoglobin level in blood is between 0.5 and 2.0%. As methaemoglobin does not carry oxygen, excess levels lead to tissue anoxia (i.e. oxygen deprivation). It is only when the methaemoglobin concentration in the blood exceeds 10% that the skin takes on a blue tinge in infants, the disorder known as methaemoglobinaemia or blue-baby syndrome. The progressive symptoms resulting from oxygen deprivation are stupor, coma and eventual death. Death ensues when 45-65% of the haemoglobin has been converted.

Although methaemoglobinaemia is well recognized and is unlikely to be a problem in areas with adequate medical facilities, it may be more important in the developing areas where such facilities are lacking. All the health considerations relating to nitrate are related to its conversion to nitrite. In the gastrointestinal tract, nitrite reacts with certain compounds in food under acidic conditions to produce *N*-nitroso compounds with amines and amides. Many of these compounds are known carcinogens. Although there is no epidemiological evidence to link nitrate directly with cancer in humans, increased concentrations of nitrite and N-nitroso compounds have been detected in people who secrete inadequate amounts of gastric acid, a group known to be particularly at risk from gastric cancer (National Academy of Sciences 1981, Tricker and Preussmann 1991, Fewtrell 2004).

Nitrite concentration in all boreholes never exceeds the drinking water norms proposed by the WHO. Observed values situate between 0 and 0.02 mg L^{-1}. This is in agreement with the study of Kholtei (2002) who analyzed the nitrite quality of the Berrechid aquifer in the central part of Morocco and who observed nitrite contamination levels situated between 0.0014 and 0.066 mg L^{-1}.

Sulphate occurs in water as the inorganic sulphate salts as well as dissolved gas (H_2S). Sulphate is not a noxious substance although high sulphate in water may have a laxative effect. The concentration of sulphate in study area is between 27.5-2649 with the mean value of 863 mg L^{-1}, the highest value was recorded in BH3. The concentration in all samples from

BH1, BH2, BH3 and BH4 are higher compared the maximum allowable limits of WHO (2006) standards. The high concentration of sulphate in these boreholes is likely due to the dissolution of gypsum. Excess amount of Sulphlate in water sample has cathartic effect on human health (Siddiqui and Waseem 2011).

Iron (Fe) concentrations in the ground water samples ranged from 0.00-0.08 mg L^{-1} and thus not exceed the maximum allowable limits (0.3 mg L^{-1}) for potable ground water according to WHO (2004) recommendation.

It is noted that anaerobic groundwater may contain ferrous iron at concentrations of up to several mg/l without discoloration or turbidity in the water when directly pumped from a Borehole. On exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish-brown color to the water. Iron also promotes the growth of "iron bacteria" which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping (WHO 2011).

The concentrations of manganese in the samples were ranged from 0.00-0.02 mg/l and thus not exceed the maximum allowable limits (0.1 mg L^{-1}). The concentration of manganese in the study area is acceptable for health purposes as toxicity is not a factor with manganese.

Conclusion:

Groundwater is generally said to be the safest water among the various sources of water for drinking and domestic purposes. However the present study clearly reveals that several factors like unscientific agricultural practices, domestic and industrial waste discharges, poor sanitization measures, geological formations etc. can affect the quality of boreholes water.

The excessive level of many physico-chemical parameters with respect to majority of the boreholes water samples studied in the present investigation render them unfit for human consumption and in certain cases (BH4) not even suitable for irrigation purposes. With respect to the water sample BH1, all the physico-chemical parameters considered for the present study were within the desirable limit. All other water samples exhibited excessive values for few or more physicochemical parameters compared to WHO standards.

More work need to be done in this area by means of extending the area of research to include the whole geographical location of Ain Defla in order to ascertain the extent of the conformity of boreholes to WHO safety standard.

Acknowledgments

The study was supported by the Ministry for Higher Education of Algeria in the project CNEPRU F00420120010: "Milieux aquatiques, écologie et pollution". The authors thank ADE of Ain Defla.

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