Assessment of Well drinking Water Quality in Samrab, Dardog and Hattab Communities, Khartoum North, Sudan

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Abstract: *The quality of drinking water in some of the northern suburb communities of Khartoum North, Sudan was investigated with respect to electrical conductivity (EC), total dissolved salts (TDS), pH, major ions (Ca^{+2}, Mg^{+2}, Na^+, K^+, SO_4^{-2}, NO_3^-,HCO_3^-, Cl^-) and total iron, beside coliform bacteria (E.coli and streptococci) as an indicators of fecal contamination. The results obtained revealed that 20% of the samples were above the maximum limit of both $1.6dSm^{-1}$ and $1000mgl^{-1}$set by SSMO and WHO for EC and TDS, respectively. About 25% of the samples exceeded the maximum limit of 200 mg/l set by SSMO and WHO for Na^+. Most of the major ions and total iron were found within the recommended limits of the local, regional and international standards of drinking water. Microbiological analyses indicated that 55% of the samples were contaminated with coliform bacteria. It may be recommended that continuous assessment of drinking water quality, on routine basis, is imperative and a better management and monitoring are warranted to reduce the deterioration of aquifer water quality in the region.*
Keywords*: Water quality, contamination, major ions, coliform, standards.*

I. Introduction

During the last decade, it has been observed that groundwater is vulnerable to pollution due to the increasing urbanization and human activities. Consequently a number of cases related to water borne diseases were detected which may be linked to deterioration of water quality. Therefore, basic monitoring on water quality is deemed necessary to cope with the rising demand and hence the expected, pollution risk level of groundwater (Abdel Magid, 2016). A good number of water analysis experiments were regularly conducted by different groups of chemists and biologists in this regard (Abdel Magid *et al.,*1984; Abdel Magid, 1997; Redhaiman and Abdel Magid, 2002, Shomo, 2007; Abdellah *et al.*, 2013). Based on taste, Abdellah *et al.* (2013) suggested the following classification for groundwater on the basis of TDS level: 1) < 200 mg TDS/l as palatable water ; 2) 200 - 500 mg TDS/l as potable water ; 3) 500 - 750 mg TDS/l as none palatable water ; 4) 750 - 1000 mg TDS/l as salty taste water ; 5) 1000 – 1500 mg TDS/l as saline water ; and 6) > 1500 mg/l TDS as brine water . However, water used for drinking purposes should be free of suspended impurities, dissolved harmful salt and disease - causing microorganisms. The suitability of groundwater resources is determined by both the quality of the water and by the available yield. The chemical quality of groundwater depends primarily on the level of TDS (Abdellah *et al.,* 2014). Equivocal and undocumented concern indicated that potential health hazards may arise from drinking saline and bacteriologically contaminated water in the area of study since the drinking water is still distributed by vendors on donkey mounted water distribution carts (Plate 1 and 2). However, absence of current or previous aquifers study data for wells drilling, legislations and sanitary laws may accentuate the problem. The main objectives of this study are to evaluate the physico - chemical and the microbiological characteristics of well water samples collected from diverse drinking water sources in the study area and to compare the results obtained with the local (national), regional and international standards and guidelines.

II. Materials And Methods

Description of study area:

The area under study is located at the northern eastern part of Greater Khartoum State, Sudan. Wells under investigation were drilled in Samrab, Dardog, and Hattab suburban communities. Khartoum city the capital of Sudan is located in the central part of the country which is located between latitudes 15º26' and 15º45' N and longitudes 32º25' and 32º40' E, at an altitude of 405.6 m above sea level (Shakesby, 1991). According to Perry (1991), the main climatic conditions of Greater Khartoum are conditioned by its location on

the southern fringes of the Sahara, the city experiences four climatic seasons, the winter season extends from mid-November to March, with a minimum temperature ranging between 8ºC and 10ºC which falls to 5ºC during night, and maximum temperatures varying from 23ºC to 25ºC, and a relative humidity which may sometime be as low as 20 per cent, the hot, dry summer season is well in place by the end of March, the maximum temperatures may exceed 45ºC by the end of May, the rainy season covers the period from July to September, with August being the rainiest month. Generally, annual rainfall ranges between 110 and 200 mm. A short, hot (about 40ºC) transitional season occurs between mid-September and the beginning of winter.

Collection of water samples:

For the physico - chemical tests twenty drinking water samples were collected in clean plastic bottles after rinsing with the sampled tap (public stands water known locally as Sabeel drinking water) or well water at the collection site. For the bacteriological tests the water samples were collected in sterile glass bottles and immediately rushed to the laboratory in iced containers.

Laboratory work:

 Laboratory analyses were mainly carried out at the Dept of Soil & Environment Sciences, Faculty agriculture, University of Khartoum.

Chemical Examination:

The pH value was measured by pH-meter (Jenway. Model: 3510. England 2009)**.** EC (dS/m at 25ºC) was measured by EC-meter (Model: M35. Serial NO: 3405). Na^+ and K^+ were determined by flame photometer (Model: PFP7, Jenway-England) according to the APHA (1985,1998). Ca^{+2} and Mg^{+2} were determined by titration with Ethylene Di amine Tetra Acetic acid (EDTA) disodium salt (0.01N). Sulfate, nitrate, bicarbonate and chloride were determined according to Richards (1954). Total dissolved salts were determined by multiplying the EC value obtained by (640) according to Rhoades (1982).

Microbiological analyses:

The media and chemicals used in this study were purchased from Elrebooa CO. Ltd., Assouk-el-Arabi, Khartoum, Sudan. These media and chemicals were used to detect and enumerate different types of microorganisms according to Harrigan (1998) Before sterilization**,** glassware, to be used in the analysis, was washed thoroughly with deionized water and left to dry and then sterilized in a hot oven at 160ºC for at least 3 h (Harrigan and McCane, 1976). Instruments such as loops, needles, forceps, spoons and knives were sterilized by flaming directly after dipping in spirit.. The total viable count of bacteria was carried out by using the pour plate count method. For the determination of coliform bacteria in water samples, the multiple tube technique was used according to Harrigan (1998). This method is known as the dilution method or Most Probable Number (MPN) technique. The number of positive tubes was calculated from the MPN tables and the results were recorded.

Statistical analysis:

Statistical analysis of the data obtained were performed using calculator to estimate the mean and standard deviation. The means obtained for the various parameters were evaluated according to the current national (SSMO, 2002), regional (SASO, 1984) and international (USEPA, 1976 and WHO, 1993) drinking water standards and guidelines.

III. Results And Discussion
Groundwater samples of Samrab Community:

The results obtained for the Samrab community well water samples analysis (Table 1) revealed differences in the magnitudes of the various levels of the parameters studied: EC ranged from 0.28 to 0.64dSm^{-1} (TDS range =179.2 to 409.6 mgl^{-1}) with an average value of 0.45dSm^{-1} (TDS = 313.8mgl^{-1}. Comparison with the recommended standards and guidelines for drinking water salinity revealed that all of the samples studied are falling within the recommended limits of the national (local), regional and international standards . Likewise,, none of the following parameters, as shown in table 1, is above the guideline limits set by the respective standards : pH values ranged from 6.5 to 7.1 with an average value of 6. 8. Ca^{+2} concentrations ranged from 1.4 to 3.5mgl^{-1} with a mean value of 1.9mgl^{-1}, . Mg^{+2} concentrations ranged from 1.1 to 2.5mgl^{-1} with a mean value of 1.6mgl^{-1}.Na$^+$ concentrations ranged from 30 to141mgl^{-1} with a mean value of 77.3mgl^{-1}.K$^+$ concentrations ranged from 2.05 to 4.22mgl^{-1} with a mean value of 3.34 mgl^{-1}. Each of SSMO, SASO, USEPA and WHO standards has not set any guideline value or limit for K$^+$. Cl$^-$ concentrations ranged from 0.3 to 1.8mgl^{-1} with a mean value of 0.8mgtandardsl sl^{-1}. Tnd internationahe SO$_4$$^{-2}$ concentrations ranged from 0.0 to 16.5mgl^{-1} with a mean value of 5.7mgl^{-1}. The NO$_3$$^-$ concentrations ranged from 0.3 to 0.9 mgl^{-1} with a mean value of 0.6 mgl^{-1}. HCO$_3$$^-$ concentrations ranged from 2.6 to 4.6mgl^{-1} with a mean value of 4.0 mgl^{-1}. Each of SSMO, SASO, USEPA and WHO standards has not set any guideline value or limit for HCO$_3$$^-$.

Well water samples of Dardog Community:
The results obtained for the Dardog community well water samples analysis (Table 2) are more or less similar in magnitude to those obtained for Samrab community(Table 1) i.e. comparison with the standards and guidelines of drinking water revealed that all of the samples studied are falling within the limits recommended by the national, regional and international standards.

Groundwater samples of Hattab Community:
The results of the analysis of the water samples from Hattab community with respect to pH, Ca^{+2}, Mg^{+2}, K^+, Cl^-, SO_4^{-2}, NO_3^- and HCO_3^- are within the limits recommended by the respective standards (Table 3). However, the EC ranged from 0.88 to 18.0dSm^{-1} (TDS range = 563 to 11520 mgl^{-1}) with a mean value of 5.2 dSm^{-1} (TDS = 3296 mgl^{-1}) by the respective standards . Comparison with the standards and guidelines for salinity of drinking water revealed that 66.7% of the samples studied are falling above the standard limit of 1.6dSm^{-1} (TDS =1000 mgl^{-1}) set by SSMO, 50% of the samples are falling above the standard limit of 2.3dSm^{-1} (TDS =1500 mgl^{-1}) set by SASO while 100% of the samples are falling above the standard limit of 500mg l^{-1} set by USEPA guidelines and standards.

High salinity drinking water with TDS levels violating the maximum recommended levels (as that found in some wells of Hattab Community) is considered unsuitable for drinking but could be used for irrigation of crops with good salt tolerance (Al-Redhaiman and Abdel-Magid, 2002). Previous studies indicated that in some of the villages located to the extreme northwestern boundary of the study area the TDS levels were found to range between 1088 and 1952 mg/l (Abdel-Magid *etal.,* 1984). Abdellah *et al.* (2013,2014) reported a TDS level ranging between 97 and 2600 mg/l in the southern suburb of Omdurman City and between 128 and 1024 g in some wells in Grand Khartoum City. Moreover, Abdellah *et al.* (2012a) reported that, in the Al-Butana region, groundwater salinity tends to decrease by continuous discharge which replaced by fresh recharge from the low salinity Blue Nile water. Conversely, Al-Redhaiman and Abd-Magid (2002) and Munday and Andrew (2008) incriminated over exploitation and excessive water pumping among factors that may elevate salinity level in groundwater. Increasing levels of TDS in some groundwater areas are usually caused by the intrusion of high salinity water due to over-exploitation in aquifers adjacent to seawater or by the replacement of low salinity water with high salinity water in temperate climates (Drisckol, 1986). Sodium concentration (Na^+) ranged from 160 to 922 mg/l with a mean value of 424 mg/l thus revealing that about 83..3% of the samples studied are falling above the Standard limit of 200 mg/l set by both of the SSMO and WHO standards and guidelines. The WHO guideline for Na^+ (200 mg/l) is based on taste considerations rather than the impact on human health (Raveendran and Madany,1991; AL – Redhaiman and Abdel – Magid ,2002).

Microbiological analysis:
Table 4 shows the total count values as Log_{10} plate count per ml for the three study areas. It may be observed that only 25% of the samples studied showed negative total viable count. On the other hand, 55% of the samples were contaminated with coliform bacteria (35% of which are source well water samples and 20% are Sabeel (public water stands) water samples. The high total viable count of bacteria for the water samples in the study area indicates that the drinking water in the three communities is highly contaminated; the presence of coliform in the studied water samples is an indicator of fecal contamination , especially, in public water stands. This result agrees with a previous study by Abdella et al (2012b), which linked bacterial contamination in public water stands to a variety of factors : among these are the microbially contaminated hands of water consumers, children in particular ; handless cups used for drinking exacerbate bacterial transmission by the contaminated hands that are immersed to various depths into the bulk of the drinking water inside the container ; coverless water containers also facilitates the bacterial accession into drinking water; especially widely open clay-pots. Hamad and Dirar (1982) added that dust storms, unattended domestic animals and insects increase the potential for bacterial contamination as well. Moreover, the absence of the daily cleaning practice, prior to filling the water containers, allows growth of bacteria, algae and other microorganisms, especially in overlooked locations. The hoses that are usually used for filling the containers are another potential source of bacterial contamination (Abdel-Magid ,1997). The mechanism of pathogenic contamination in public water stands is independent of pollution at the groundwater source. Jensen *et al.* (2004) reported that drinking water of poor rural communities, even if it is obtained from 'safe' sources, it may become contaminated during storage in the house under non hygienic and non-sanitary conditions. Pathogenic effects on human life that are related to water were summarized by Abdellah *et al.* (2012b) into direct and indirect effects .

IV. Conclusions And Recommendations
Well drinking water quality in both Samrab and Dardog communities is suitable for human consumption since its physico – chemical characteristics are falling within the permissible limits recommended by the national, regional and international standards and guidelines. However, well drinking water in Hattab

community is highly saline and is, therefore, not suitable for human consumption. Bacteriological contamination is evident in the drinking water belonging to all of the three communities studied: 55% of the investigated drinking water samples were found to be contaminated with coliform bacteria since drinking water is distributed by random vendors throughout the study area. Therefore, it is imperative to consider connecting these communities to the municipally treated non - saline drinking water network supply. To avoid microbial contamination, distribution network pipes should be installed throughout the three communities.

Acknowledgement

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Plate (1): Water vendors are the main source of distributing drinking water in Dardog Community, Khartoum North suburb, Sudan.

Plate (2): Water reservoirs are widely spread in Hattab Community, Khartoum North suburb, Sudan.

Table (1): Physical and Chemical quality of drinking water samples (n= 8) in Samrab community as compared to the national, regional and international standards.*

Constituent/ Property	Mean	Range	Standard deviation	SSMO (2002)	(%) of Samples above	SASO (1984)	(%) of samples above	USEPA (1976)	(%) of samples above	WHO (1993)	(%) of samples above
EC(ds/m)	0.45	0.28-0.64	0.11	1.6	0.0	2.3	0.0	NS	_	NS	_
TDS(mg/l)	288.8	179-409.6	69.1	1000	0.0	1500	0.0	500	0.0	1000	0.0
Ph	6.78	6.53-7.06	0.17	6.5-8.5	0.0	6.5-9.2	0.0	6.5-8.5	0.0	<8	0.0
Ca^{+2}(mg/l)	2.13	1.4-3.5	0.67	NS	_	200	0.0	200	0.0	NS	_
Mg^{+2}(mg/l)	1.64	1.1-2.5	0.43	NS		150	0.0	150	0.0	NS	
Na^{+}(mg/l)	77.3	30-141	41.2	200	0.0	NS	_	NS	_	200	0.0
K^{+}(mg/l)	3.34	2.05-4.22	0.7	NS	_	NS	_	NS	_	NS	_
Cl^{-}(mg/l)	1.05	0.3-1.75	0.56	250	0.0	600	0.0	250	0.0	250	0.0
SO_4^{-2}(mg/l)	5.7	0.0-16.48	4.6	250	0.0	400	0.0	250	0.0	400	0.0
NO_3^{-}(mg/l)	0.53	0.3-0.9	0.2	50	0.0	<45	0.0	45	0.0	50	0.0
HCO_3^{-}(mg/l)	4.0	2.6-4.6	0.66	NS	_	NS	_	NS	_	NS	_

* SSMO: Sudanese standards & Metrology Organization, SASO: Saudi Arabian Standards Organization, USEPA: United States Environmental Protection Agency, WHO: World Health Organization guidelines, NS: No standard

Table (2): Physical and Chemical quality of drinking water samples (n= 6) in Dardog community as compared to the national, regional and international standards.*

Constituent/ Property	Mean	Range	Standard deviation	SSMO (2002)	(%) of Samples Above	SASO (1984)	(%) of samples above	USEPA (1976)	(%) of samples Above	WHO (1993)	(%) of samples above
EC(ds/m)	0.43	0.32-0.52	0.08	1.6	0.0	2.3	0.0	NS		NS	
TDS(mg/l)	274.13	204-333	51.52	1000	0.0	1500	0.0	500	0.0	1000	0.0
pH	6.97	6.33-7.45	0.34	6.5-8.5	0.0	6.5-9.2	0.0	6.5-8.5	0.0	<8	0.0
Ca^{+2}(mg/l)	1.87	1.4-2.2	0.25	NS	_	200	0.0	200	0.0	NS	_
Mg^{+2}(mg/l)	1.82	1.3-2.3	0.3	NS		150	0.0	150	0.0	NS	
Na^{+}(mg/l)	67.9	9.4-111	36.1	200	0.0	NS	_	NS	_	200	0.0
K^{+}(mg/l)	3.0	2-4.19	0.65	NS	_	NS	_	NS	_	NS	
Cl^{-}(mg/l)	0.9	0.3-1.5	0.56	250	0.0	600	0.0	250	0.0	250	0.0
SO_4^{-2}(mg/l)	4.8	0.0-12.36	4.4	250	0.0	400	0.0	250	0.0	400	0.0
NO_3^{-}(mg/l)	0.55	0.4-0.8	0.15	50	0.0	<45	0.0	45	0.0	50	0.0
HCO_3^{-}(mg/l)	3.72	2.6-4.4	0.65	NS	_	NS	_	NS	_	NS	_
Total coliform (MPN 100ml^{-1})	_	_	_	Negative	_	Negative	_	Negative	_	Negative	_

* SSMO: Sudanese standards & Metrology Organization, SASO: Saudi Arabian standards Organization, USEPA: United States Environmental Protection Agency, WHO: World Health Organization guidelines, NS: No standard

Table (3): Physical and Chemical quality of drinking water samples (n=6) in Hattab community as compared to the national, regional and international standards.*

Constituent/ Property	Mean	Range	Standard deviation	SSMO (2002)	(%) of Samples Above	SASO (1984)	(%) of samples above	USEPA (1976)	(%) of samples Above	WHO (1993)	(%) of samples above
EC(ds/m)	5.15	0.88-18	6.0	1.6	66.7	2.3	50	NS	_	NS	
TDS(mg/l)	3293	563-11520	3846	1000	66.7	1500	50	500	100	1000	66.7
pH	7.15	6.74-7.52	0.3	6.5-8.5	0.0	6.5-9.2	0.0	6.5-8.5	0.0	<8	83.3
Ca^{+2}(mg/l)	2.3	1.8-3	0.43	NS	_	200	0.0	200	0.0	NS	_
Mg^{+2}(mg/l)	5.1	1.9-12.5	3.6	NS		150	0.0	150	0.0	NS	
Na^{+}(mg/l)	424.6	160-922	286.16	200	83.3	NS	_	NS	_	200	0.0
K^{+}(mg/l)	6.62	3.45-16	4.63	NS	_	NS	_	NS	_	NS	_
Cl^{-}(mg/l)	2.05	1.75-2.5	0.27	250	0.0	600	0.0	250	0.0	250	0.0
SO_4^{-2}(mg/l)	5.5	0.0-16.48	5.32	250	0.0	400	0.0	250	0.0	400	0.0
NO_3^{-}(mg/l)	0.55	0.4-0.8	0.15	50	0.0	<45	0.0	45	0.0	50	0.0
HCO_3^{-}(mg/l)	6.9	3.8-12.6	3.39	NS	_	NS	_	NS	_	NS	_

* SSMO: Sudanese standards & Metrology Organization, SASO: Saudi Arabian standards Organization, USEPA: United States Environmental Protection Agency, WHO: World Health Organization guidelines,NS: No standard

Table4: Microbial loads of well water

Sample Source	Sample No.	Coliform MPN* Index Per 100ml	95% Confidence** Limits Lower	Upper	Fecal Coliform MPN Index Per 100ml	95% Confidence Limits Lower	Upper	Log$_{10}$ Plate** Count per ml
Samrab	1	>2400	_	_	7	1	21	5
	2	>2400	_	_	7	1	21	4
	3	1100	150	4800	<3	_	_	9
	4	93	15	380	<3	_	_	_
	5	23	4	120	<3	_	_	4
	6	9	1	36	<3	_	_	_
	7	4	<0.5	20	<3	_	_	3.6
	8	4	<0.5	20				4.8
Dardog	9	210	35	470	<3	_	_	10.6
	10	39	7	130	<3	_	_	50
	11	39	7	130	<3	_	_	7.5
	12	4	<0.5	20	<3	_	_	8.8
	13	<3	_	_	<3	_	_	3
	14	<3	_	_	<3	_	_	_
Hattab	15	>2400	_	_		<3	_	_
	16	>2400	_	_	4	<0.5	20	8
	17	460	71	2400	<3	_	_	_
	18	<3	_	_	<3	_	_	5.7
	19	<3	_	_	<3	_	_	3.6
	20	<3	_	_	<3	_	_	4.4

* MPN = Most Probable Number, ** - = Negative