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Assessment of Drinking Water Quality at Source and Point of use of Alazhari City

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Abstract

The present paper is aimed to assess the drinking water quality at source (ground water wells) and the point of use (Taps) at Al-Azhari city. The physicochemical and biological analysis of drinking water was carried out and results were compared with permissible limits established by the World Health Organization (WHO) and the Sudanese Standards and Metrology Organization (SSMO). The parameters subjected to the study were pH, TDS, EC, hardness, alkalinity, chloride, Mg, Ca, K, Na as well as bacteriological analysis. All the physicochemical parameters of drinking water samples collected from Al-azhari city are within permissible limit set by WHO and SSTO. Tap6 recorded relatively higher conductivity value (1040 µS/cm). The pH of the water ranged from 6.6 to 8.3 and TDS varied between 145.6 to 728 mg/l, EC varied between 224 and 1040 µS/cm, hardness varied between 84 and 262 mg/l, alkalinity varied between 20 to 576.2 mg/l, chloride varied between 9 and 99.93 mg/l. The heavy metals concentrations were 0.004 to 45.67, 18.4 to 68.93, 0.1 to 12.81, and 1.1 to 190 mg/l for Mg, Ca, K and Na respectively. The microbiological analysis had shown that all household waters except Tap2 were contaminated with E-coli. The absence of E. coli in wells 4, 5 and 6 and its presence in Taps4, 5 and 6 concluded that water in its way to households carry pollution through water distribution system.

Keywords: drinking water, water quality, standards, bacteriological and physiochemical parameters, Alazhari city.

تقييم جودة مياه الشرب من المصدرومن نقاط الاستخدام بمدينة الأزهري

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مُسْتَخْلَص

تهدف هذه الورقة لتقييم جودة مياه الشرب من المصدر (مياه الآبار) وعند نقاط الاستخدام (الحنفيات) لمدينة الأزهري. تم تحليل الخواص الفيزيوكيميائية والبيولوجية ومقارنة النتائج مع القيم المسموح بها في معايير منظمة الصحة العالمية والمعايير السودانية. المعاملات التي خضعت للدراسة هي التركيز الهيدروجيني والمواد الذائبة الكلية، الموصلية الكهربائية، العسر، القاعدية، الكلورايد، الماغنيسيوم، الكالسيوم، البوتاسيوم، الصوديوم بالإضافة إلى التحليل البكتريولوجي. كل الخواص الفيزيوكيميائية لعينات مياه الشرب المأخوذة من مدينة الأزهري في الحدود المسموح بها وفقاً لمعايير منظمة الصحة العالمية والمعايير السودانية. الموصلية الكهربائية للحنفية 6 أعلى قليلاً من الحدود المسموح به (1040 µS/cm). حدود التركيز الهيدروجيني 6.6-8.3 ، المواد الذائبة الكلية 145.6-728 ملجم / لتر، EC 224-1040 ميكرو سيمنز/ سم ، العسر يتراوح بين 84 و 262 ملجم/ لتر ، القاعدية 20 إلى 576.2 ملجم / لتر ، الكلورايد يتراوح بين 9 إلى 99.93 ملجم / لتر ، تركيز المعادن الثقيلة 0.004 إلى 45.67، 18.4 إلى 68.93 ، 0.1 إلى 12.81 ، 1.1 إلى 190 ملجم /لتر للماغنيسيوم ، الكالسيوم ، البوتاسيوم ، الصوديوم على الترتيب. التحليل المايكروبيولوجي أوضح أن كل المياه المأخوذة من المنازل ملوثة بالأيكولاي ماعدا الحنفية 2. غياب الأيكولاي في الآبار 4 ، 5 ، 6 و وجوده في الحنفيات 4 ، 5 ، 6 يوضح أن سبب التلوث هو الشبكة الناقلة للمياه.

كلمات مفتاحية:مياه الشرب، جودة المياه، المعايير، المعاملات البكتريولوجية والفيزيوكيميائية ، مدينة الأزهري.

Introduction

Water is the single most important substance known in the world it is elixir of life without its life is not possible, it represents a fundamental requirement for all life activities, it is essential to man, animals and plants.That water intended for human consumption must be free from chemical substances and micro-organisms in amounts which would provide a hazard to health is universally accepted (Eshraga, 2005). Water quality is the physical, chemical, and biological characteristics of water in association to the set of standards. These parameters directly related to the safety of the drinking water to human use.

One of the major types of monitoring is a research monitoring, which may be defined as: Measurements specifically related to research investigations (McNelis, 1973, and FAO, 1979). McNelis (1973) reported that monitoring is a necessary element of water quality considerations providing quantitative and qualitative data on existing circumstances and trends. As a result, water resources management (WRM) has been undergoing a change worldwide, moving from a mainly supply-oriented, engineering-biased approach toward a demand-oriented, multisectoral approach, often labeled integrated water resources management. (Daniel P. Loucks, 2016). The main objective of this study is to assess the physicochemical and the microbiological characteristics of drinking water at source and point of use from selected points of Alazhari city and to compare the results obtained with the WHO and SSMO standards.

Study Area

Alazhari city is located at the southern part of greater Khartoum city, Khartoum city the capital of Sudan is located in the central part of the country the state lies between longitudes 31.5 to 34 °E and latitudes 15 to 16 °N. Khartoum state is surrounded by river Nile State in the north-east, in the north-west by the Northern State, in the east and southeast by the states of Kassala, Qadarif, Gezira and White Nile State, and in the west by North Kurdufan. The weather is rainy in the fall, and cold and dry in the winter. Average rainfall reaches 100–200 mm in the north-eastern areas and 200–300 mm in the north-western areas. The temperature in summer ranges from 25 to 40 °C from April to June, and from 20 to 35 °C in the months of July to October. In winter, the temperature declines gradually from 25 to 15 °C between March and November. Wells under investigation were drilled in Al-azhari and Al-salma suburban communities (Figure 1).

Figure1: Location of the sampling stations of the wells

Methodology

Samples were collected from 12 locations; 6 from the source (groundwater wells) and other 6 from point of use (Taps). All samples were analyzed for 10 parameters, namely pH, electrical conductivity, TDS, total hardness, total alkalinity, chloride, calcium, magnesium, potassium and sodium. For the determination of coliform bacteria in water samples, the multiple tube technique or Most Probable Number (MPN) technique was carried out. In this study, all laboratory tests were carried out in accordance with Standard Methods[1]. Analysis of samples has been done at laboratories of the department of water and environmental engineering, Sudan University of science and technology, and UNESCO chair, Omdurman Islamic University.

Results and Discussion

The detailed respective analysis of physiochemical and biological quality parameters to ground water samples and the point of use are discussed as following:

pH

The pH value of water is a measure of acidity or alkalinity. The range goes from 0-14, with pH is 7 being the solution is neutral. When the concentration of hydrogen ions exceeds that of hydroxide ions, a pH value is less than 7 and hence water is acidic. Conversely, when the concentration of hydroxide ions exceeds that of hydrogen ions, the water is alkaline and has a pH value greater than 7. In this study, the results of the pH analysis of groundwater and tap samples are presented in Table 1. From the Table 1 the data showed that the pH of the water ranged from 6.6 at GW5 to 7.6 at GW4 and GW6 while levels recorded in tap waters ranged from 7.1 at Tap1 and Tap5 to 8.3 at Tap6.

Table1: pH at different sampling wells and taps:

Parameter	GW1	GW2	GW3	GW4	GW5	GW6	WHO	SSMO
pH	7.4	7.3	7.4	7.6	6.6	7.6	6.5-8.5	6.5-8.5
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	7.1	7.2	7.6	7.4	7.1	8.3		

All pH values are within the WHO and SSMO acceptable limit. The acceptable range of pH for drinking water quality is 6.5 to 8.5. The pH of drinking water has no immediate direct effects on human health but has some indirect health effects by bringing changes in other water quality parameters such as solubility of metals and survival of pathogen (Zabed *et al*., 2014).

Total Dissolved Solids(TDS)

Total Dissolved Solids (TDS) are inorganic compounds and small amounts of organic compounds that are dissolved in water. These solids include minerals like calcium, magnesium, sodium, salts and some traces of organic compounds such as decaying plant and animal matter. Particle is considered dissolved if it can pass through a filter of 2.0 micron size (1 micron = 1/1000 of a millimeter). Particles that are larger than 2 microns are called a suspended solid.

Table 2: TDS at different sampling wells and taps

Parameter	GW1	GW2	GW3	GW4	GW5	GW6	WHO	SSMO
TDS (mg/l)	377	306.8	275.6	345	275.6	291	1000	1000
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	386	276.3	145.6	275.6	221.6	728		

From the Table 2 the TDS values were found to be varied from 275.6 at GW3 and GW5 and 377 mg/l at GW1. Regarding tap water, the obtained results varied between 145.6 to 728 mg/l at Tap3 and Tap6 respectively. All water samples drawn from wells and taps were found within safe limits of WHO and SSMO guidelines. According to World Health Organization, TDS concentration of 1000 mg/litre is considered acceptable for water consumers; high concentration of TDS often has a bad taste and high-water hardness. A very low concentration of TDS may also be unacceptable because of its flat, insipid taste of water, the United States guidelines for TDS is 500 ppm (mg/l). EPA in USA includes TDS as secondary standards (SMCL) (Secondary Maximum Contaminant Levels).

Electrical conductivity EC

Conductivity is a measure of the ability of water to conduct electrical current; it is directly related to the total dissolved salt content of water. In this study EC ranged between 424 to 628 µS/cm at

GW5 and GW4 respectively for samples collected from wells, and ranged from 224 to 1040 µS/cm at Tap3 and Tap6 respectively for samples collected from tap water (Table 3). All water samples were found within the safe limits of SSMO guidelines (1000µS/cm) but samples collected from GW4, Tap1 and Tap6 were exceed the limit of WHO guidelines (500 µS/cm).Tap6 recorded relatively higher conductivity value (1040µS/cm), this value is greater than the WHO and SSMO guidelines (500 and1000µS/cm respectively), this might be due to the high level of soluble salts such as carbonates, chlorides, sulphates and nitrates and cations such as potassium, magnesium, calcium and sodium. It is well known that the conductance of water increases with salts and total dissolved solids (Meybeck, 1997)

Table 3: Electrical conductivity at different sampling wells and taps

Parameter	**GW1**	**GW2**	**GW3**	**GW4**	**GW5**	**GW6**	**WHO**	**SSMO**
EC (µS/cm)	460	472	424	628	424	451	500	1000
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	776	425	224	424	341	1040		

Hardness

Hardness is defined as the total concentration of calcium and magnesium cations contained in water. The hardness of water is mainly due to the presence of inorganic compounds such as carbonates, bi-carbonates, chlorides and sulphates of calcium and/or magnesium in dissolved form picked up from rocks and soils. In this study the hardness values of the source ranged between 84 to 262 at GW3 and GW6 respectively (Table 4). Regarding samples collected from taps the harness concentration varied between 135 to 220 mg/l at Tap4 and Tap1 respectively (Table 4). Several epidemiological investigations over the last 50 years have demonstrated a relation between risk for cardiovascular diseases and drinking water hardness or its content of magnesium and calcium (WHO, 1984). The total hardness level is not supposed to exceed 500 mg/l according to WHO and SSMO standards, hence all water samples drawn from source and taps meet WHO and SSMO maximum allowable levels. Based on Thomas classification (1953), it can be said that, all samples may be classified as hard water (180 mg/l and above), except GW2, GW3, Tap2, Tap4 and Tap6 may be classified as medium hard (60 to 179 mg/l).

Table 4: hardness at different sampling wells and taps

Parameter	GW1	GW2	GW3	GW4	GW5	GW6	WHO	SSMO
Hardness (mg/l)	215	172	84	216	236	262	500	500
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	220	164	188	135	184	136		

Alkalinity

Alkalinity is defined as the capacity of water to neutralize acid. Alkalinity of water is mainly caused by the presence of hydroxide ions (OH^-), bicarbonate ions (HCO^{3-}), and carbonate ions (CO_3^{2-}), or a mixture of these ions in water. Bicarbonates represent the major form of alkalinity.In higher alkalinity water, more acid can be added without considerable change in the pH and water of low alkalinity needs less acid to change pH.

Table 5: Alkalinity at different sampling wells and taps

Parameter	GW1	GW2	GW3	GW4	GW5	GW6	WHO	SSMO
Alkalinity (mg/l)	190	358.87	336.1	196	576.2	176	1000	1000
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	185	54	278.9	20	164.9	439.2		

The EPA Secondary Drinking Water Regulations (called a secondary maximum contaminant level or SMCL) limit alkalinity only in terms of total dissolved solids. In this study the alkalinity values varied between 176 and 576.2 mg/l in wells GW6 and GW5 respectively and varied between 20 and 439.2 mg/l (Table 5), these findings were within the range suggested by WHO and SSMO standards. Strong alkaline water has an objectionable "soda" taste. The high levels of either acidity or alkalinity in water may be an indication of industrial or chemical pollution.

Chloride

Table 6: Chloride at different sampling wells and taps:

Parameter	GW1	GW2	GW3	GW4	GW5	GW6	WHO	SSMO
Chloride (mg/l)	85.97	99.93	39.98	36	69.98	9	250	250
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	97.9	63.98	29.99	81.9	55.98	63		

Chloride occurs naturally in groundwater, streams due to rock containing chloride, other sources might be agricultural runoff, domestic and industrial wastewater. Chloride ions Cl^- in drinking water do not cause any harmful effects on public health. Small amounts of chlorides are essential for ordinary cell functions in animal and plant life but high concentrations may indicate contamination by sewage or animal waste, high chloride concentration in freshwater (more than

250 mg/L) can also cause an unpleasant salty taste for most people. WHO and SSMO standards for public drinking water require chloride levels that do not exceed 250 mg/L. In this study, the levels of chloride for the wells varied from 9 to 99.9 mg/l at GW6 and GW2, respectively. The levels for tap water varied from 29.99 to 97.9 mg/l at Tap3 and Tap1 respectively as shown in Table 6. Therefore, all wells and tap water samples were observed to meet WHO and SSMO acceptable levels.

Heavy metals

Table 7: Heavy metals at different sampling wells and taps:

Parameter	GW1	GW2	GW3	GW4	GW5	GW6	WHO	SSMO
Mg (mg/l)	3.42	28.25	14.18	28.8	45.67	16.32	150	150
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	0.004	28.17	25.65	25.12	34.94	9.72		
Ca (mg/l)	60.92	41.62	26.65	38.4	48.1	18.4	200	200
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	68.93	48.1	25.65	32.06	40.24	38.4		
K (mg/l)	7	2.05	12.81	4.1	0.25	3	NS*	12
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	7	0.28	10.67	0.32	0.1	9.728		
Na (mg/l)	75.45	2.84	2.7	38	3.27	41.5	200	200
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	75.45	1.98	3.24	1.1	63.17	190		

* No Standard

The term heavy metals refer generally to any metallic chemical element that has a relatively high density; heavy metals are natural components of the Earth's crust. Heavy metals can enter a water supply by industrial and domestic waste, or even from acidic rain breaking down soils and releasing heavy metals into surface water and groundwater. Some heavy metals are essential to human health if their level remains within the specified range recommended by WHO. They maintain the metabolism of the human body. However, at higher concentrations they can pose a threat to human health and poisoning. In this study, four heavy metals, magnesium (Mg), calcium (Ca), potassium (K), and sodium (Na) were determined by atomic absorption photometers in wells and tap waters of Al-azhari city and results are shown in Table 7. The data showed that the magnesium concentration of groundwater ranged from 3.42 to 45.67 mg/l at GW1 and GW5 respectively and for tap water the concentration varied from 0.004 to 34.94 mg/l at Tap1 and Tap5 respectively. The results indicate the water is free of magnesium pollution according to WHO and SSMO maximum allowable levels (150 mg/l). Calciumlevels found to be within the safe limits of WHO and SSMO

standards (200mg/l). It varies between 18.4 and 60.92 mg/L at GW6 and GW1 respectively and for tap water, the concentration varied from 25.65 to 68.93 mg/L at Tap3 and Tap1respectively. Potassium concentrations in water samples from wells ranged from 0.25 to 12.81 mg/L at GW5 and GW3, respectively, whilst levels recorded in tap waters ranged from 0.1 to 10.67 mg/L at Tap5 and Tap3 respectively. Concentrations of potassium were found to be within SSMO maximum allowable levels (12 mg/l) except slight excessive value at GW3 (12.81 mg/l). No standard or guideline has been established by WHO for potassium parameter. The **so**dium concentrations recorded in samples from wells ranged from 2.7 to 75.45 mg/L at GW3 and GW1 respectively. Samples from point of use recorded sodium values that ranged from 1.1 to 190 mg/L at Tap4 and Tap6, respectively. All sodium ion concentration had levels within the acceptable WHO guidelines value of 200 mg/l.

Microbiological quality

Microbiological characteristics are used to describe pathogenic microorganism such as bacteria, protozoa and viruses. Pathogen is any living organism that causes disease. Bacterial examination of water is very important, since it indicates the degree of pollution. Microbiological analysis of the water samples was performed by determination of most probable number technique of coliform bacteria in 100 ml of water sample. Because animals can transmit pathogens that are infective to human, the presence of E. coli must not be ignored (WHO, 1993). E. coli shouldn't be detected according to the WHO and SSMO standards. The results of the microbiological analysis of groundwater and tap samples are presented in Table 8. In this study, no coliform was detected from samples collected from well 2, 4, and 6. The study has confirmed the presence of E-coli in well1, 3, and 5. The highest count was found in well 3 (1100/100 ml) showing that the great risk of using water of this well, it is not suitable for human consumption; action should be taken by authority. The second highest number of bacteria was found at Tap5 (460/100ml). Although well 1, Tap1, Tap4, and Tap6 showed a smaller number of bacteria (3-43 /100 ml) but same attention should be taken to prevent bacteriological pollution. The microbiological examination of water in this study showed that the water network distribution system is the source of contamination of Tap4, 5 and 6, therefore, detailed studies should be undertaken along the distribution lines starting from their source to the households to find out the actual points of contamination and their sources in distribution system.

Table 8: Microbiological analysis of the water samples of wells and Taps:

Parameter	**GW1**	**GW2**	**GW3**	**GW4**	**GW5**	**GW6**	**WHO**	**SSMO**
E. coli MPN/100	3	0	1100	0	0	0	0	0
	Tap1	**Tap2**	**Tap3**	**Tap4**	**Tap5**	**Tap6**		
	3	0	1100	4	460	43		

Conclusion

All the physicochemical parameters of drinking water samples collected from Al-azhari city are within permissible limit set by WHO and SSTO, slight excess of EC recorded at Tap6. Regarding the biological parameters, a high microbial indicator count was detected in the water source well 3, water from this well is not suitable for human consumption. All household water samples except Tap2 were found to be unsatisfactory as they contained coliforms. The absence of E. coli in wells 4, 5 and 6 and its presence in Taps 4, 5 and 6 concluded that water in its way to households carry pollution through pipes and other distribution installations.

Recommendations

1. Water from the source GW3 is highly contaminated with E. Coli, this well is not suitable for human consumption, an urgent action should be taken by authority for proper drinking water treatment.
2. Detailed studies should be undertaken along the distribution lines starting from the source to the households to find out the actual points of contamination and their sources in the distribution networks and more study of parameters that have an effect in water quality.
3. Before a new source of drinking water supply is selected, it is important to ensure that the quality of the water satisfactory for drinking.
4. The old pipelines of the network must be replaced by a new one and distribution system must be periodically treated by chloride to prevent contamination by microorganisms.
5. Sources of ground water wells should be sited a constructed so as to be protected and to prevent public access and animals.
6. The statistical tools developed, for further studies required to be extended to larger areas covering several water resources and proposing water quality models. In addition to

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