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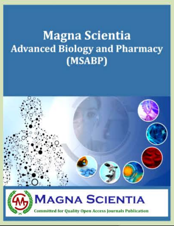

(RESEARCH ARTICLE)

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Quality of drinking water of Kosti city, White Nile State, Sudan, collected during February 2021

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Abstract

Lack of clean water supply, sanitation and hygiene are major causes for the spread of waterborne diseases in a community. This study was conducted, to determine the quality of drinking water collected from Kosti City, White Nile State, Sudan. In this study, the quality levels of drinking water (physical, chemical and the microbial), were determined following the standard methods. Five sites were selected to sampling drinking water during Feb. 2021. The results showed that, some of pH, HCO_3^-, Hardness, SO^-, Na^+ and Ca^{++} values were not fall within the standard ranges. Total Dissolved Solids (TDS), Cl and K^+ data agreed with standard ranges. CO_3 show a very strong +ve correlation (0.99) with Na and -ve correlation (-0.98) with HCO_3. *E. coli* were relatively high in comparison to standards (which should be zero). The study recommends evaluating the quality of the drinking water, and this should be routine work.

Keywords: Quality; Drinking water; Kosti City; White Nile State; Sudan

1. Introduction

Water is an inorganic, transparent, tasteless, odorless, and colorless chemical substance, which are the main constituent of Earth and the fluids of all known living organisms. It is vital for all known forms of life, even though it provides no calories or organic nutrients. Its chemical formula contains one oxygen and two hydrogen atoms, connected by covalent bonds, at an angle of 104.45° [1].

Lack of clean water supply, sanitation and hygiene are major causes for the spread of waterborne diseases in a community. The fecal–oral route is a disease transmission pathway for waterborne diseases [2].

The two main water sources used in Sudan are groundwater and surface water including from the White, Blue and River Nile. Groundwater is abstracted in Sudan from hand dug wells and boreholes, with handpumps, motorized pumps, or by hand by rope and bucket. Some urban areas rely entirely on groundwater, such as Kassala Town in Kassala State. Spring water is also utilized in some areas and in rural areas rainwater is also collected from earth dams or hafirs and some households also collects water from roof water harvesting (UNICEF and WHO. Safely managed drinking water – thematic report on drinking water. https://apps.who.int/iris/bitstream/handle/ 10665/325897/ 9789241565424-eng.pdf?sequence=1. accessed 2017 April).

In Sudan, only 68 percent of households have access to basic improved water, with disparities in access between rural and urban populations at 64 and 78 per cent respectively. There are also disparities between States, with just around a third of households having access to safe water in Red Sea, White Nile and Gedarif compared to 90% access in Khartoum and the Northern States. Lack of funding, inadequate management and community participation are

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among the main reasons behind the system's low functionality levels. An estimated 13 million people are still using unimproved drinking water sources (UNICEF, World Water Day. https://worldwaterday archive.unwater.rw1.co.za/2017/, accessed 2017 April, 4).

Waterborne diseases are conditions caused by pathogenic microorganisms that are spread in water. These diseases can be spread while bathing, washing, drinking water, or by eating food exposed to contaminated water. While diarrhea and vomiting are the most commonly reported symptoms of waterborne illness, other symptoms can include skin, ear, respiratory, or eye problems [2]. Waterborne diseases are impacted by a country's economy and also impact the economy by being costly to deal with.

Because of the range of humanitarian contexts that Sudan faces as well as on-going challenges from environmental degradation and climate change, there is a need to strengthen Disaster Risk Reduction (DRR). The DRR, suffering the lack of clarity on institutional responsibilities, lack of access to logistics for water safety monitoring and repair of supplies and networks and inadequate access to water treatment chemicals. Strengthening DRR and emergency preparedness would lead to more effective responses when new outbreaks, flooding or displacement contexts occur again in the future [3].

2. Material and methods

2.1. Study area

Actually, 5 different sites within Kosti city, White Nile State (which located in the southwestern part of Sudan, between 30^{o} 8'– 30^{o} 13' N and 28: 22 – 28 E, about 360 km from Khartoum, the capital of the Sudan) were selected for survey of drinking and rain water: Hassania, Andalus, Al-Shabie, Alsug, Alaabdein.

2.2. Sampling of drinking water

One objective of surveillance is to assess the quality of the water supplied by the supply administration. Samples were taken from five (5) sites that are selected within Kosti city. In each of the selected location, samples were taken from sources peoples usually used it for drinking. The quantity was 250 ml for each, and it was kept in cleaned plastic container in aseptic conditions. The collected samples were transferred to the Applied Chemistry Laboratory, Faculty of Engineering and Technology, University of Gezira, for their physical and chemical properties in addition to microbiological analysis.

2.3. Water quality tests

2.3.1. Physical properties

Most of physical parameters were simply observed, like odor and colour. Turbidity and solids are generally the most important physical parameters to measure, since high levels of turbidity are usually associated with high levels of microbiological contamination. Colour was leveled as transparent and less transparent; turbidity leveled as turbid or less turbid; odor described as muddy or less muddy or without, whereas solids were leveled as few solids or without. Each test was triplicate.

2.3.2. Chemical properties

Most chemicals in water were resulted from human contamination. According to UNICEF (World Water Day. https://worldwaterdayarchive.unwater.rw1.co.za/2017/, accessed 2017 April, 4), three chemicals: arsenic and fluoride, which can occur naturally, and nitrate, which is commonly used in fertilizer for agriculture, should be prioritized for testing (especially when planning new water supply projects). Chemical testing were run at the Applied Chemistry Laboratory to determine: pH, Cl, CO_3^-, HCO_3^-, hardness, total dissolved solids TDS, SO_4^-, Na^+, K^+ and Ca^{++} following the standard devices, methods [4, 5] and solutions. Each test was triplicate.

2.4. Microbiological properties

Microbiological contamination is the most serious public health risk associated with drinking water, which makes it the priority for water quality testing. Pathogens in water (bacteria, viruses, protozoa and helminthes) can cause a wide range of health problems. Testing for microbiological contamination specially *Escherichia coli* (*E. coli*) which is one of the standards for testing for microbiological contamination. A series of Petri dishes containing *E. coli* special media were prepared. Few drops of each drinking water samples were added to these Petri dishes. A positive control (sewage water) and a negative control (*E. coli*-free water) were also added. The Petri dishes were autoclaved at 30℃for 48 hours, after which the formed *E. coli* colonies were counted for each treatment (locations and controls). Data were presented as number of colonies for each drinking water collected from different locations within Kosti city.

2.5. Data analysis

The obtained data were subjected to suitable statistical tools in order to understand the quality of Kosti city drinking.

3. Results and discussion

3.1. Quality parameters for drinking water

3.1.1. Physical properties

The physical parameters of drinking water sampled during the winter at Feb. 2021 were presented in Table (1). The drinking water samples are less transparent and having the slight muddy odor accompanied with few turbidity and solids, compared to the control which is transparent, odorless and without turbid or solids. It was clear that, the physical properties of Kosti city drinking water were relatively less quality than control.

Table 1 Physical parameters of drinking water collected during (Feb. 2021) from different sites within Kosti city

Site	Colour	Odour	Turbidity	Solids
Hassania	Less transparent	Slight Muddy	Less Turbid	Few Solids
Andalus	Less transparent	Slight Muddy	Less Turbid	Few Solids
Al-Shabie	Less transparent	Slight Muddy	Less Turbid	Few Solids
Alsug	Less transparent	Slight Muddy	Less Turbid	Few Solids
Alaabdein	Less transparent	Slight Muddy	Less Turbid	Few Solids
Control	Transparent	Without	Without	Without

3.1.2. Chemical properties

During winner (Feb. 2021, Table, 2), pH ranged from 5.8 in Alsug samples to 7.3 in Alaabdein samples. The pH standard range (6.5-8.5). Concerning Chlorine Cl, the obtained data ranged between 7.09 mg/L in Alsug to 15.95 mg/L in Alaabdein samples, the standard range of Cl in drinking water was (5-35 mg/L).CO_3^- ranged between 0 (Nil) in Alsug, up to 66 mg/L in Andalus samples, while bicarbonate (HCO_3^-) was relatively high in Alsug (274.5 mg/L) and relatively few in Andalus samples (122.0 mg/L).

Table 2 Chemical parameters of drinking water collected during (Feb. 2021) from different sites within Kosti City

Site	pH	Cl (mg/L)	CO_3^- (mg/L)	HCO_3^- (mg/L)	Hardness (mg/L)	TDS (mg/L)	SO_4- (ppm)	Na^+ (ppm)	K^+ (ppm)	Ca^{++} (ppm)
Hassania	7.1	8.8	60	134.2	240	105	1.15	50	2.6	24
Andalus	7.05	8.8	66	122	240	105	0.98	50	2	40
Al-Shabie	7.1	10.6	36	210	240	105	0.95	40.2	2.3	68
Alsug	5.8	7.09	Nil	274.5	160	130	1.31	27.5	4.0	68.0
Alaabdein	7.3	15.95	30	189.1	160	110	0.74	40.2	2.7	68
Control	6.5-8.5	5-35	-	-	80-150	80-150	5-35	5-25	0.1-15	10-35

Concerning hardness, all samples (160-240 mg/L) were out of the standard range (80-150), unlike the TDS, in which, all samples were within the standard ranges (80-150 mg/L), but (SO_4^-) for all samples were less than the minimum standard level (5 ppm). Na^+ and Ca^{++} in all samples that collected from within Kosti city were exceed the maximum standard level (25 and 35 ppm, respectively), unlike K^+ in which all samples laid within the standard levels near the minimum level (0.1-15 ppm).

Correlation analysis (Table 3) revealed that, pH had strong negative (-0.94) correlation with TDS and a negative correlation (-0.88) with K, while chlorine had a considerable negative correlation (-0.90) with SO_4, CO_3 had a very strong positive correlation (0.99) with Na and negative correlation (-0.98) with HCO_3, bicarbonate ($HCNO_3$) had relatively strong negative correlation (-0.94) with Na, hardness had a considerable positive correlation (0.76) with Na and negative correlation (-0.76 and -0.75) with TDS and K, respectively, TDS had relatively strong positive correlation (0.96) with K, Na had a relative negative correlation (-0.86) with K.

Table 3 Correlation analysis of the Chemical parameters of drinking water

	pH	**Cl**	**CO_3**	**HCO_3**	**Hardness**	**TDS**	**SO_4^-**	**Na**	**K**
Cl	0.64								
CO_3	0.73	0.004							
HCO_3	-0.75	-0.10	-0.98						
Hardness	0.48	-0.34	0.81	-0.68					
TDS	-0.94	-0.34	-0.88	0.83	-0.76				
SO_4^-	-0.81	-0.90	-0.30	0.36	0.004	0.61			
Na	0.78	0.09	0.99	-0.99	0.76	-0.89	-0.36		
K	-0.88	-0.29	-0.87	0.82	-0.75	0.96	0.64	-0.86	
Ca	-0.30	0.37	-0.80	0.80	-0.64	0.49	-0.24	-0.80	0.40

3.1.3. Bacterial contamination

E. coli contaminated drinking water collected from different site during (Feb. 2021) from Kosti city were estimated and presented in Table (4). During this winter, it was noticed that, the colonies of *E. coli* per Petri dish (PD) were estimated to be more than 300 colonies/PD in Andalus and Alsug samples (the highest estimated colonies/PD), 288 colonies/PD in Hassania samples, 260 colonies/PD in A-Shabie samples, 168 colonies/PD in Alaabdein samples (the lowest estimated colonies/PD). It was noticed that, *E. coli* contaminated drinking water is relatively high during winter (Feb.) and this may be due to the low consumption and use of water during winter, that may cause a temporal stagnant or low flow of water within water pipe, that permit to *E. coli* to multiply more than during hot or rainy season, in which high demand and fast flow of water may occur, in addition to increase in temperature in water pipe that inhibit multiplication of *E. coli*.

Table 4 Estimated number of colonies of *E. coli*/Petri dish; for the drinking water collected during Feb. (2021) from different sites within Kosti city.

Site	***E. coli* colony/Petri dish**
Hassania	288
Andalus	>300
Al-Shabie	260
Alsug	>300
Alaabdein	168
Control	0

Similar study done by Siddig [6] to investigate the drinking water quality of Kosti city distributed via the pipeline of water network during the period August 2004 to July 2005. The obtained indicated that the turbidity level ranged from (10.5 – 62.5) thus exceeding the permissible level of WHO standards (5 NTU; Nephelometric Turbidity Units). The concentration of minerals such as chloride ranged from (6.6 10.6 mg/L), sulphate (8.0 - 14.0. mg/L), calcium (9.6 - 23.0 mg/L), alkalinity (61.7 - 87.5 mg/L), fluoride (0.28 - 0.49 mg/L), magnesium (3.2 - 7.0 mg/L), ammonia (0.01 - 0.023 mg/L), TDS (80.75 - 125.1) and hardness (34.33 - 82.23 mg/L). The iodine content ranged from (0.06 - 0.2 mg/L). All these values fall below thresholds value of national and international standards of WHO and Sudanese Standards and Metrology Organization (SSMO) standards.

A similar study was conducted by Homaida and Goja [7] in Ed-Dueim Town to investigate the microbial quality of drinking water. The results of the viable count of drinking water obtained from Polyvinyl chloride High Density (PVC.HD), Polyvinyl chloride Low Density (PVC.LD), and Asbestos pipes were ranged from 0.3×10^4 to 9.3×10^7 cfu/ml. Total coliform MPN values were ranged from 0.0 to 11MPN/100 ml. Faecal coliform 0.0 to 7MPN/100 ml, while for faecal streptococci MPN were ranged from 0.0 to 3/100 ml.

Lateef *et al*., [8] found that, the water quality parameters of the Shatt Al-Arab River, southern Iraq, measured from December 2018 to October 2019, revealed that, total dissolved solids ranged between 950 to 8500 mg/L, total hardness varied from 400 to 2394 mg/L as calcium carbonate ($CaCO_3$), the sulfate ranged from 149 to 1602 mg/L, and chloride ranged from 330 to 3687 mg/L. These values are great more than the values obtained from drinking water collected from Kosti City during Feb. 2021.

4. Conclusion

The quality (physical, chemical, and microbial) characteristics of Kosti city drinking water did not matched in all parameters the standard levels of drinking water.

Compliance with ethical standards

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Disclosure of conflict of interest

All authors (Abdelaal, Mutaman and Mazahir) declare no conflicts of interest regarding the publication of this paper.

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