RUFORUM Working Document Series (ISSN 1607-9345), 2018, No. 17 (2): 269-277.
Available from http://repository.ruforum.org

Research Application Summary

Environmental, physical and microbial parameters of harvested rain-water supply system of El Obeid drinking water

Abdelrahman, A. M.[1], Hana, M. J.[2] & Mohamed H.M.[3,4]

[1]Departments of Biochemistry and Food Sciences, Faculty of Natural Resources and Environmetal Studies, University of Kordofan, P.O. Box 160, Elobeid, Sudan

[2]Plant Protection, Faculty of Natural Resources and Environmental Studies, University of Kordfan, P.O. Box 160, Elobeid, Sudan

[3]Forestry and Range Science, Faculty of Natural Resources and Environmental Studies, University of Kordofan, P.O. Box 160, Elobeid, Sudan

[4]Faculty of Natural Resources and Environmental Studies, University of Kordofan, P.O. Box 160, Elobeid, Sudan

Corresponding author: abuabda75@Yahoo.com

Abstract

This study was carried out to identify some environmental pollutants, physical and microbiological parameters of harvested drinking water supply of Elobeid town, North Kordofan, Sudan during the rainy season of 2016. Water samples were collected from five points (Bagara, Elain, Air-port, Elmoderia streams and Elobeid station) and assessed for environmental pollutants. Physical parameters (turbidity, electrical conductivity and total dissolved solid) were determined according to standards methods. Microbiological parameters (total viable count of bacteria, total coliform bacteria and faecal coliform bacteria Escherichia coli) were determined using the pour plate and the most probable number techniques. Analysis of variance was used and Duncan's Multiple Range test performed for means separation. Results showed that water steams and other surface water drinking sources contained environmental pollutants (human, plants and animals residues). Results indicated that the highest mean values of water turbidity (166.0 NTU) and total dissolved solids (164.7 mg/l) were recorded from the Air-port stream while maximum electrical conductivity (235.3 µs/cm) was reported from Elobeid Station. Analysis of microbiological parameters revealed that Elmoderia stream had the highest total viable count of bacteria (27400 colony forming unit/ml), although the maximum mean value of most probable number for total coliforms bacteria (2400 cfu/ml) were reported at both Elain and Bagara streams. Faecal coliforms E. coli was found at Elain, Bagara and Air-port streams but not recorded at Elobeid Station and Elmoderia Stream. The study concluded that the main problem of Elobeid surface drinking water supply were human and animal pollutants. It is recommended that surface drinking water sources be protected by fencing to reduce contamination.

Keywords: Drinking water, Elobeid town, environmental pollutants, microbiological parameters, physical parameters, Sudan

Résumé

Cette étude a été réalisée pour identifier certains polluants environnementaux, paramètres physiques et microbiologiques de l'eau potable collectée dans la ville d'Elobeid, Nord Kordofan, Soudan pendant la saison des pluies de 2016. Des échantillons d'eau ont été collectés en cinq points (ruisseaux de Bagara, Elain, Aéroport, Elmoderia et station Elobeid), pour y évaluér les polluants environnementaux. Les paramètres physiques (turbidité, conductivité électrique et le solide total dissous) ont été déterminés suivant les méthodes standards. Les paramètres microbiologiques (nombre total de bactéries viables, les bactéries coliformes totales et les bactéries coliformes fécales Escherichia coli) ont été déterminés à l'aide des techniques de la plaque et de nombres probables. L'analyse de la variance et le test multiple de Duncan ont été effectués. Les résultats ont montré que les vapeurs d'eau et d'autres sources de consommation d'eau de surface contenaient des polluants environnementaux (résidus humains, végétaux et animaux). Les résultats ont aussi indiqué que les valeurs moyennes les plus élevées de turbidité de l'eau (166,0 NTU) et de solides totaux dissous (164,7 mg / l) ont été enregistrées dans le ruisseau de l'Aéroport tandis que la conductivité électrique maximale (235,3 µs / cm) a été signalée à la station Elobeid. L'analyse des paramètres microbiologiques a révélé que le ruisseau d'Elmoderia avait le nombre total de bactéries viables le plus élevé (27400 unités formant colonie / ml), bien que la valeur moyenne maximale du nombre plus probable des bactéries coliformes totales (2400 cfu / ml) ait été signalée dans les ruisseaux d'Elain et de Bagara. Les coliformes fécaux E. coli ont été trouvés dans les ruisseaux d'Elain, de Bagara et d'aeroport, mais n'ont pas été enregistrés dans la station Elobeid et dans le ruisseau Elmoderia. L'étude a conclu que le principal problème d'approvisionnement en eau potable de surface d'Elobeid était les polluants humains et animaux. Il est recommandé que les sources d'eau potable de surface soient protégées par des clôtures pour réduire la contamination.

Mots clés: eau potable, ville d'Elobeid, polluants environnementaux, paramètres microbiologiques, paramètres physiques, Soudan

Introduction

Sudan is one of the largest countries in Africa and lies mostly in the arid region where water is scarce. However, the country is considered to be rich in water resources (Ginawi, 1994). Over 70% of the population and the majority of livestock live around the river Nile. The recent drought, coupled with civil war, have led to human migration to urban centers resulting in overuse of the available and limited urban facilities, including water and sanitation systems. The economy of the country is largely agro-pastoral and hence provision of water for both human population and livestock herds imposes the major constraint for all developmental activities (Mukhtar, 1998). In the Sudan, the rural population constitutes about 80% of the country's inhabitants. This population mostly uses untreated water directly from sources. Such sources include traditional surface wells, deep bores, rivers, intermittent rainy season streams (Khors), natural rain ponds and artificial rain water catchments (Hafirs) (Abdel Magid *et al*., 1984).

Previous studies in the Sudan have only dealt with certain aspects of water pollution problems. Detailed considerations have come to light as a result of the work done by researchers such as Abdel Magid *et al*. (1984) and Dirar (1986) on the pollution of water from the Nile and from wells in Khartoum area. The recent research done by Mohammed (2012) on El Obeid drinking water supply systems showed that the water treatment measures adopted by the North Kordofan State Water Corporation (coagulation,

sand filtration and disinfection by chlorination) did not guarantee acceptable levels of water disinfection. The main problem with Bara underground water was high salinity, while the harvested rain water system suffered from high turbidity and elevated microbiological counts. To alleviate these problems, blending of the two water systems and subsequent treatment to reduce microbiological load were suggested. The present study evaluated the environmental and microbiological contamination of the drinking water of El Obeid city. The specific study objectives were (i) to enumerate the environmental pollution and contamination which are used primarily to identify environmental changes that may affect water quality, and (ii) to enumerate some health indicators (physical and microbial parameters) associated with harvested rain water of El Obeid drinking water supply system.

Materials and methods

Study area. The city of El Obeid lies in central Sudan and is the capital of North Kordofan State. It lies at latitudes 13^0-13.15^0 N and longitudes 30.08^0-30.15^0 E. The city's population is approximated at 345126 inhabitants (CBS, 2011). The city receives drinking water from two different sources, i.e., surface harvested rain water system and Bara underground water system. The harvested rain-water system supplies about 70% of the city's water demand and it comes from Bagara and Alain streams. In that system, water is stored in earthen embankments using harvested water system. The Bara underground water system consists of four catchment areas (Khors) which supply 11 Hafirs. Two of the catchments are located about 28 km away from the city. These are Bagara stream (supplying five hafirs with a total capacity of 7240000 m^3) and Alain stream (supplying two hafirs with a total capacity of 4628000 m^3). Water from both catchments finally flow into Alain station. At Alain station, water is pumped (using 500 m^3/hrs pumps) through three asbestos pipelines (10, 10 and 12 inch diameters). One of these lines (10-inch) has recently been replaced with a cast iron line. The policy is to replace any damaged asbestos line with cast iron or polyvinyl chloride (PVC) line. Water travels 9 km from Alain station to Alain half station. Here 500 m^3/hr pumps are used to discharge water via three different pipelines to Bano station (a distance of 11 km). At Bano station, an additional source (Bano hafir) with a capacity of 1000000 m^3 joins. Water continues to travel from Bano station to finally reach El Obeid station, travelling a total distance of 28 kilometers or more. At El Obeid station, three other hafirs join, two receiving water from the air-port stream, and the third (Tiran hafir with a total capacity of 250000 m^3) receiving water from Elmoderia stream. At El Obeid station water is treated by coagulation (adding aluminum sulphate or polyaluminum chloride, PAC), and flocculation prior to filtration with sand filters and disinfection by adding chlorine gas or powder. The treated water is then pumped into an iron cistern via a pump at 300 m^3/hr, and is then distributed mainly to the western part of the city through pipelines (Fig. 1), (Mohammed, 2012).

Information regarding the sources of water, the distribution system and the quantity supplied by each source was collected from North Kordofan State Water Corporation and visits were paid to the earthen embankments, Khors and Hafirs to decide on sampling points (Mohammed, 2012).

Sampling point and collection. Water samples were collected during the rainy season and carried out according to the methods described in APHA (1980) and Harrigan (1998). Five sampling points were selected in the harvested rain-water system and include: Bagara stream, Alain stream, Air-port stream, Elmoderia stream, and Treated water at El Obeid station. Water samples for microbiological examination were collected in sterile screw-cap bottles (capacity 500 ml) under aseptic conditions. All samples were examined in the laboratory of microbiology, Faculty of Natural Resources and environmental studies, University of Kordofan, immediately after removal.

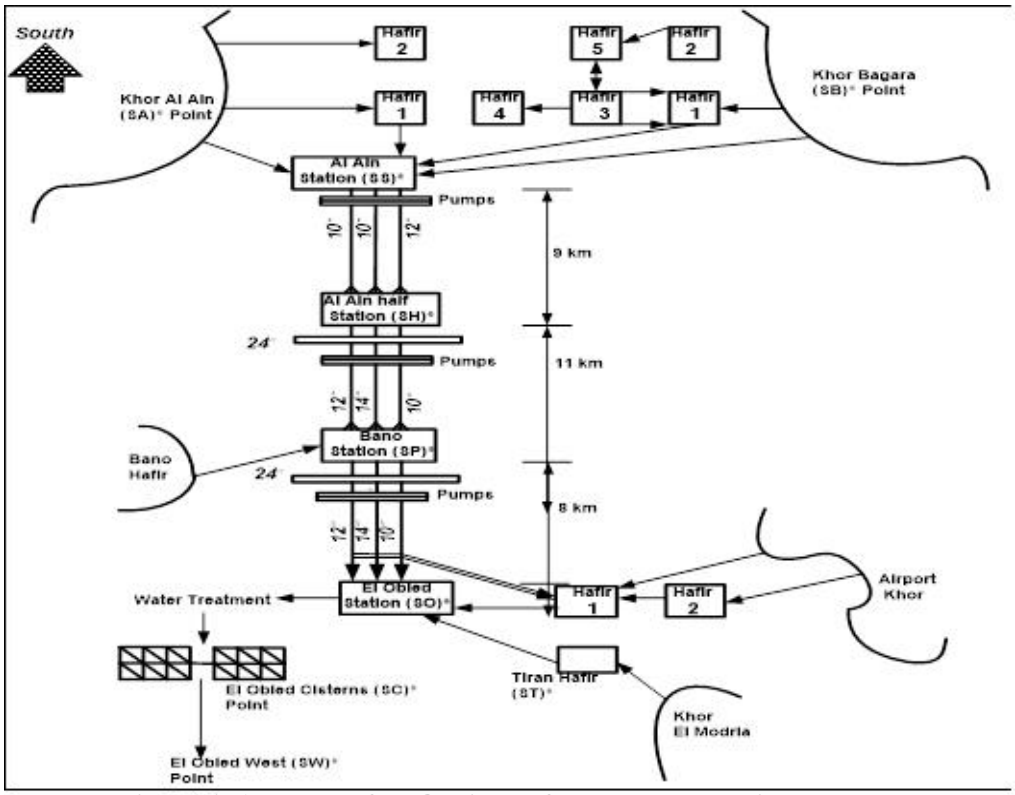

Figure 1. A sketch of El Obeid surface harvested rain-water system.

Environmental and physical parameters The documentation of water sources pollution. Water sources pollution was documented by a Digital 8 Handycam Sony Camera (700X) (Plates 1, 2, 3, 4, 5 and 6).

Turbidity. Turbidity measurements were made by the nephelometric method (APHA, 1998) using a HI 93703 Microprocessor Portable Turbidity Meter (HANNA Instruments, Hungary).

Plate 1. Human wastes

Plate 2. Water carried animal and human wastes

Plate 3. Animal's residues

Plate 4. Animal's residues

Plate 5. Human residues

Plate 6. Water with plants residues

Electrical conductivity (EC). Electric conductivity (µs/cm) was measured directly at 25°C using a HQ14d Conductivity Meter (Hach Instruments, USA).

Total Dissolved Solid (TDS). The TDS were measured directly at 25°C using a HQ14d Conductivity Meter (Hach Instruments, USA).

Microbiological examination

Total viable counts of bacteria (TVC). Total viable counts (TVC) were done using the pour plate technique (Harrigan, 1998). One mL of each 3-fold dilution of the water samples was aseptically transferred, in duplicate, into sterile Petri-dishes. Ten mL of molten Plate Count Agar (Labmate, UK) (45-46°C) were poured into each dish. The dishes were then thoroughly mixed to facilitate distribution of the sample throughout the medium. The medium was allowed to solidify and the plates were incubated

aerobically in an incubator (Human Gmbh, Germany) at 37°C for 48 hours. A colony counter (Labtech digital colony counter, India) and a hand-tally were used to count the viable bacterial colonies. Counts were expressed as colony-forming units (cfu) per ml.

Total coliforms and faecal coliforms. The Most Probable Number (MPN) technique was used for the enumeration of coliforms and faecal coliforms of all samples according to APHA (1980). The 3-tube most probable number test was used for the enumeration of total coliforms (TC), faecal coliforms (FC). MacConkey Broth (s.d. fine-chem. Ltd., India) was used for the presumptive test for coliform bacteria and results were confirmed by culturing positive tubes into Brilliant Green Bile Broth (Himedia, India) tubes. Both media were incubated at 37°C for 48 hours. EC Broth (Merck, Germany) was used for the enumeration of faecal coliforms after incubation at 44.5°C for 24 hours. Further confirmation of faecal coliforms was done by isolation on EMB agar (Difco, USA) and carrying out of the indole test (WHO, 1984).

Statistical analysis. Statistical analyses were carried out in M-STAT software. Data were subjected to analysis of variance (ANOVA) and performed according to the method described by Gomez and Gomez (1984). Means were separated by the Duncan Multiple Range test.

Results and discussions

Environmental and physical parameters. The water sources pollution was documented during the rainy season 2016 from the main water sources which include Bagara stream, Alain stream, Air-port stream and Elmoderia stream. Water is polluted by animal and human waste, residues and dead animals and plants. Theese pollutants contain coliform bacteria, faecal coliforms bacteria, worms, protozoa, insects that may carry disease causing micro-organisms, and spores that may cause food poisoning. The study revealed high levels of turbidity, electrical conductivity (EC) and total dissolved solids. In addition it revealed high levels of microbial load of total viable counts of bacteria (TVC) and other pathogenic bacteria. These most likely came from human and animal excreta.

Water turbidity. The results of the study showed that turbidity of the harvested rain-water of El Obeid drinking water supply system was high compared to the standards level (5NTU). Table 1 shows turbidity values of the different water sources. These were 75.5, 41.6, 43.2, 166.0 and 21.5 NTU for Alain stream, Bagara stream, El Obeid station, Air-port stream and Elmoderia stream, respectively. The highest turbidity was recorded at Air-port stream (166.0NTU), and was mainly due to clay, silt, organic particulates or plankton and other microscopic organisms.

Table 1. Water turbidity, Electric conductivity (EC) and Total dissolved solid (TDS) in different sources

Water resources	Turbidity (NTU)	E.C. (ás/cm)	T.D.S. (mg/l)
Alain stream	75.5b	177.8a	24.4b
Bagara stream	41.6b	200.9a	140.7a
El Obeid station	43.2b	143.9b	100.7a
Air-port stream	166.0a	235.3a	164.7a
Elmoderia stream	21.5b	204.9a	143.6a

*Each value in the column is a mean of three replicates. *Means in the column share same superscript letters showed no significant differences as separated by Duncan's Multiple Range Test

Water electrical conductivity (EC). The electrical conductivity (EC) of the harvested rain-water was also generally high (Table 1). Electrical conductivity values for Alain stream, Bagara stream, El Obeid station, Air-port stream and Elmoderia stream were 177.8, 200.9, 143.9, 234.3 and 204.9 µs /cm, respectively.

Water total dissolved solid (TDS). The results of the study showed that the amount of total dissolved solids (TDS) in the Alain stream, Bagara stream, El Obeid station, Air-port stream and Elmoderia were 124.4, 140.7, 100.7, 164.7 and 143.6 mg/l, respectively (Table 1).

Microbiological examination

Water total viable count of bacteria. As would be expected, the total viable bacterial counts (TVC) in the harvested rain-water of El Obeid drinking water supply system of five sampling points was generally higher than that in the Sudanese and United States of America microbiological standards for drinking water. Table (2) showed that the mean values of total viable count of bacteria in Alain stream, Bagara stream, El Obeid station, Air-port stream and Elmoderia stream water were 7740, 14633, 5107, 15767 and 27400 cfu/ml, respectively. The highest total viable count of bacteria (TVC) (27400 cfu/ml) was recorded at the Elmoderia stream. This stream came from army camps and other public and settlement areas near the city.

Water total coliforms and faecal coliforms (E**.** *coli***).** Table 2 shows the most probable number (MPN) of total coliforms and faecal coliforms in the different sampling points in the harvested rain-water of El Obeid drinking water supply system. The total coliforms count was also generally higher compared to the Sudanese and United States of America for microbiological standards limits of drinking water. Mean coliforms counts varied from 0.0 cfu/ml at El Obeid station and Elmoderia stream to 4 cfu/ml at Air-port stream and higher at Alain and Bagara streams (2400 cfu/ml). No faecal coliforms (*Escherichia coli*) were reported in the El Obeid station and Elmoderia stream but were present in the other sources. The Air-port stream was more contaminated compares to others points.

Table 2. Total viable bacterial counts of water in different resources

Water resources	Bacterial counts (cfu/ml)	Total coliform (cfu/ml)	Detection of E. coli
Alain stream	7740b	2400a	+ve
Bagara stream	14633b	2400a	+ve
El Obeid station	5107b	Null	+ve
Air-port stream	15767b	4b	+ve
Elmoderia stream	27400a	Null	+ve

*Each value in the column is a mean of three replicates. *Means in the column share same superscript letters showed no significant differences as separated by Duncan's Multiple Range Test

Relationship between environmental, physical and microbiological parameters. According to the results of this study, higher levels of environmental pollutants (Human and animals wastes and residues) and physical parameters (turbidity, electrical conductivity and total dissolved solid) were associated with higher levels of microbiological parameters (Table 3).

Table 3. Comparison between different physical and biological parameters

Water resources	Parameters				
	Turbidity NTU	E.Cμs / cm	T.D.Smg / l	Bacterial counts cfu / ml	Total Coliform cfu / ml
Alain stream	75.5	177.8	124.4	7740	2400
Bagara stream	41.6	200.9	140.7	14633	2400
El Obeid station	43.2	143.9	100.7	5107	0
Air-port stream	166.0	235.3	164.7	15767	4
Elmoderia stream	21.5	204.9	143.6	27400	0

Conclusion and recommendations

In this study, environmental pollution, physical and microbiological parameters of the surface harvested rainwater system were evaluated. The harvested rain water system was environmentally polluted and exhibited high levels of turbidity, electrical conductivity (EC) and total dissolved solid (TDS) . Values for these parameters were not in conformity with local and international standards. Wayer also contained a high total bacterial load, characterized by the incidence of coliforms and faecal coliforms. According to the European Union and Sudanese microbiological guidelines for drinking water, the harvested rainwater supplied to the city of El Obeid is unfit for human consumption. It thus requires treatment before it can be safe for domestic use.

Accordingly, the following recommendations have been made: (i) fencing and cleaning of the Hafirs and streams before the rainy season to keep away animals, (ii) further investigations on the relationship between certain environmental factors and incidence and load of pathogenic bacteria in the harvested rainwater.

Acknowledgement

This paper is a contribution to the Sixth African Higher Education Week and RUFORUM 2018 Biennial Conference

References

Abdel Magid, H.M., Ibrahim, I.S. and Dirar, H.A. 1984. Chemical and microbiological examination of well and Nile water. *Environmental International* 10: 259-263.

APHA. 1980. Standard Methods for the Examination of Water and Waste Water, 17th .Ed. American Public Health Association Inc., Washington, DC.

CBS.2011. Central Bureau of Statistic. 5th Population and Housing Census, 2008, Analytical Report, North Kordofan State. Ministry of the Cabinet, Khartoum, April 2011.

Dirar, H.A. 1986. Coliform bacteria counts in the Nile water at Khartoum. *Environmental International* 12: 571-576.

El Tom, A.M. 1997. Microbiology of Port-Sudan Water Supply. Ph.D. Thesis, Faculty of Agriculture, University of Khartoum.

Ginawi, M.M.H. 1994. Water quality in household cisterns. M.Sc. Thesis, Institute of Environmental Studies, University of Khartoum.

Gomez, K. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, USA.

Harrigan W.F. 1998. Laboratory Methods in Microbiology. Academic Press, London and New York.

Harrigan W.F. and MacCance, M.E. 1976. Laboratory Methods in Microbiology. pp. 257-303 Academic Press, London and New York.

Mohammed, A. A. 2012. Microbiological and physico-chemical evaluation of the drinking water supply systems of El Obeid City, Sudan. Ph.D Thesis, Faculty of Agriculture University of Khartoum.

Mukhtar, A.R. 1998. Water supply provision in Sudan, Khartoum: Standards for drinking water, Workshop 20-22 February 1999. World Health Organization and Sudanese Standards and Metrology Organization, Khartoum.

WHO. 1984. Guidelines for drinking water quality. 2. World Health Organization, Geneva.