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Microbial Analysis and Safety of Drinking Water in Northern and Southern Darfur

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Abstract

Twenty four samples of drinking water raw and treated {16 from Northern Darfur (ND) and 8 from Southern Darfur (SD)} were collected at random. The sources of water included wells, dams, hafirs, water stations, and rest houses. Microbial analysis included total bacterial count, Coliforms and fungi. Drinking water microbial analysis showed that well (4) and (5) free from Coliforms, thermo tolerant *E. coli*, total bacterial count and fungi. They are suitable for human consumption according to WHO and Sudanese Standards of Drinking Water. Values of Coliforms were high for wells (1, 2,3,6,7 and Shigrat Elwadi (Tendulti) deep well), Dams 1and 2, Maleet village and government rest house with Coliforms range of 0.5- 6.5/ml. water is not fit for human consumption. Microbiological analysis of Coliform of raw water drawn by hand pump from deep wells in Hay El Gabal, Hay Elganayin and Yau yau shallow wells Rope and Bucket ranged 1.2/ml-7 Coliform and is not suitable for human consumption. Water from Manawashi Hafir, Goz Badeen Rahad, Nyala Khor, Nyala Water Station and Nyala Government House had high Coliforms range from 3/ml- 25.5/ml. it is not suitable for human consumption according to WHO and Sudanese Standards. In spite of this fact out- break of serious water borne-diseases had never been reported.

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It is observed that microbiological analysis of sample of drinking water from wells (4) and (5) of ND are the only sources meeting the WHO and Sudanese Standards for indicator organisms. The rest of the samples of water collected from different sources in ND and SD need treatments for their suitability for human consumption according to international and national microbiological standards.

Keywords: microbiological; analysis; drinking water; Northern and Southern Darfur.

1. Introduction

Water throughout the history of man had been a source of life and death [1]. It is praised and blamed for good health and human ills [2]. The function of water in human body to serve as solvent, medium for nutrients and waste to form cells , regulation of temperature and biological reactions. On the other hand it is the source of waterborne diseases (cholera, typhoid, hepatitis); water-washed (gastroenteritis diarrhea); water- insect vector (malaria, yellow fever) and water- based (Schistomiasis, guinea worm).

Water is essential for humans, animals, agriculture, vegetation and aquatic life. The United Nations and WHO [3] agreed upon the rights of humans, the access to clean, and sufficient drinking water according to their needs. Water is indispensible, irreplaceable for life. Carelessness leads to pollution and contamination of surface water, streams, lakes and underground water [4].

Microbiological Parameters of Water Quality:

Most of the pathogens potentially transmitted by water are ingested by gastrointestinal tract of humans and animals are excreted in feces of infected humans and animals [3].

Indicators of Water Safety for Humans:

Drinking water standards dated back to 1912 when US Public Health Act was established. The Safe Drinking Water Act (SDWA) was established 1974 [1]. Standards for drinking water suitable for human consumption had been set and Coliform bacteria group which includes *Escherichia coli*, Citrobacter, Entrobacter, and Klebsiella [5]. The present standard of WHO and Sudanese Standards stated that drinking water should be free of Coliforms and thermo tolerant *E. coli*. The authors [6] stated that the great distribution of Pseudomonas in bottle water in Greece needs to be considered in regard to water quality legislation. Similar observations had been reported by authors [7] stated that two parameters of fecal Coliform and *Pseudomonas aeruginosa* would be more reliable and rapid method for monitoring quality of water. WHO and the Organization for Economic Co-operation and Development (OECD) stated that inadequate drinking water supply quality and poor sanitation are among the world's major causes of morbidity and mortality. Las Vegas, Nevada in spring 1994 demonstrated the need for better understanding of the effectiveness of indicators and treatment processes in controlling water-borne pathogens outbreaks in water that does not meet the safety standards by guidelines for traditional index and indicator bacteria. Multiple indicators are needed for microbial and non- microbial. Technologies in the pipe line, advanced molecular technologies should be encouraged for rapid detection of microbial contamination [8].

Water Sources:

Water sources are divided into atmospheric, surface and underground. The major parts of the hydrological or water cycle are precipitation, infiltration, percolation, surface run off, evaporation and transpiration. Water resources in ND and SD consist of surface water, dams. Hafirs, Rahads, khors and quick running wadies.

The second source is ground water, dug wells (shallow and deep) and deep bores. In developed countries e.g. USA depends on ground water. In developing countries all villages depend on shallow dug wells, pumped deep wells. If the ground water of the well is contaminated, it is very difficult to restore it. So it had to be shut [1].

Contamination of Water Sources in ND and SD:

The raw untreated and treated surface and ground water are locally contaminated by man, animals and birds. The author [10] sited by author [9] stated that water which have higher fecal Coliforms (FC) count than fecal streptococci (FS) are likely contain wastes of human origin, if FC/FS is greater than 4. If less than 0.7 it is of animal origin. The author [9] evaluating microbiological harvested stored drinking water (hafirs in west of Northern Kordufan) stated that all samples showed the presence of Coliforms. The load of Coliforms was greater than the fecal indicators. The Coliforms range from 0- 920/i00ml. Seasonal variation showed the highest No. of Coliforms occurred in autumn compared with summer. Protected hafirs showed the lowest number of Coliforms compared to open ones. Authors [15] cited by [9] stated that microbiological quality of water in vessels at home is lower than that at the source, suggesting that the contamination is wide spread during collection, transport, storage and using of drinking of the water.

Treatment of Contaminated Drinking Water:

The author [1] stated that several drinking wells across the USA had been shut due to the contamination of the ground water formation.

Ground water of open wells could be closed and treated before the distribution to consumers. Surface water of dams, hafirs, Rahads and wadies should be treated before distribution. Water Stations should be treated before being distributed. Author [1] stated that permissible disinfectants should be used.

Microbiological Analysis of Drinking Water in the Sudan:

Several Sudanese scientists conducted microbial analysis on drinking water. The authors [11] conducted chemical and microbiological of wells and Nile water. Author [12] studied Coliforms bacteria in the Nile water at Khartoum. Author [13] surveyed microbes in drinking water in Khartoum. Author [14] carried out a comprehensive microbiological analysis in different parts of the Sudan. Author [9] carried out microbiological analysis of surface water (hafirs in Northern Kordufan).

Information on the microbiological analysis and safety of drinking water is lacking in Northern and Southern Darfur.

The objectives of his research are:

- The microbiological examinations of surface and underground drinking water from various sources and assessment of its safety for human consumption.
- Preparation of baseline data of water microbiology for authorities and policy makers.
- Establishment of a model which could be used for other states.
- Suggestions of means of improvement and safety of drinking water.

2. Materials and Methods

2.1 Study area

1. Northern Darfur State (ND).

2. Southern Darfur (SD).

2.2 Drinking water sources

They were described by authors [16].

2.3 Sampling

Twenty three samples of drinking water were collected from Northern (15) and Southern Darfur (8). The sources included wells, dams, hafirs, Rahads, khor, water stations and rest houses (table 1 and2).

2.4 Microbiological analysis

Coliforms group was used as an indicator organism for the assessment of the contamination of drinking water as stated by WHO and the Sudanese Standards. The following analysis was conducted: Coliforms Most Probable Number technique (MPN/ml) [17], Total Bacterial Count Pour Plate Technique were used [18,19]. Yeast and mould spread plate technique was used according to [22] (table 3).

3. Results

Results of the microbial analysis of underground drinking water are presented in tables 4, 5 and 6. Table 4 showed the analysis of Shigrat Elwadi (deep wells) and Hagar Gado wells 1- 7. Wells 4 and 5 are free of Coliforms as expressed in MPN. Their water is suitable for human consumption according to WHO and Sudanese Standards.

The use of Coliforms as an indicator for drinking water had been questioned as inadequate by WHO and OECD. Author [8] stated that there is need for better microbial monitoring parameters. Author [6] reported that the great distribution of Pseudomonas in bottled water in Greece need to be considered in legislation of water quality. Similar observation had been noted by authors [7]. They stated that two parameters of fecal Coliforms

and *Pseudomonas aeruginosa* would be more reliable and rapid for monitoring the quality of drinking water. Author [24] stated that the presence of *Pseudomonas aeruginosa* in drinking water is not desirable. It is an opportunistic pathogen and can produce enterotoxin.

Table 1: Northern Darfur State Sources of Drinking Water Locations

Location	Source of supply
Underground wells:	
Shigrat Elwadi well (Deep well)	Underground water
Hagar Gado well (1)	Underground water (Deep bores)
Hagar Gado well (2)	Do-
Hagar Gado well (3)	Do-
Hagar Gado well (4)	Do-
Hagar Gado well (5)	Do-
Hagar Gado well (6)	Do-
Hagar Gado well (7)	Do-
Dams and Hafirs:	
Golo Dam (1)	Rain water
Golo Dam (2)	Rain water
Maleet Dam	Rain water
Jadeed Al Sail Hafir	Rain water
Water Station, Village and Rest House:	
El Fashir (water station 1)	Raw water
El Fashir (water station 2)	Rain water
Maleet village	Rain water
El Fashir government House	treated tap water

The results of water microbiological analysis of Shigrat EL Wadi deep well (Water Station) showed Coliforms value of 1.0/ml MPN, $\log_{10}$/ml 1.477 total bacterial counts and absence of fungi. The water of this well is treated. Wells 1, 2, 5, 6, 7 are open wells scattered in radius one square Km and they are close to Hagar Gado mountain and khor Tendulti. They are open wells and water withdrawn by hand using rope and bucket. The

wells 1, 2 and 5 showed low Coliforms range of 0.5/ml- 1.1/ml MPN, total bacterial count (TBC) range 0- $\log_{10}$ 0.602 and absence of fungi. Wells 6 and 7 showed Coliforms counts of 2.5/ml and 2.6/ml MPN and $\log_{10}$ 0.845 for well 6 and Nil for well 7. No fungi were detected in any of them. It is observed that no fungi were detected in any well. The author [1] reported that when underground water wells are contaminated in USA the wells are usually shut down. USA is an industrial country and had been classified with China as the biggest pollutants [16]. In ND the contamination reported may be due to humans and animals or a near by contaminated stream. Closing of these open wells, piping and treatment of water will improve its quality and reduce the present level of Coliforms (0.5/ml- 2.6/ml MPN).

Table 2: Southern Darfur State Sources of Drinking Water Locations

Location	Source of Supply
Nyala Town Deep Shallow Wells:	
Hay El Gabal well (H.P- D.W)	Underground water
Hay Elganayin (H. P.- S.W)	Khor Nyala
Yau yau (S.W. R.B)	Khor Nyala
Hafir, Rahad and Khors:	
Manawashi Hafir	Surface- Rain water
Goz Badeen Rahad	Surface- Rain water
Khor Nyala	Surface water
Nyala Water Station and Rest House:	
Nyala Water Station	Treated water
Government Rest House	Tap water

The results of analysis of drinking water of Golo, Maleet Dams and Gadeed Alsail Hafir are presented in table 5. Golo Dam (1) and (2) are protected. They supply El Fashir town by drinking water. Treatment of water is required at the outlet of the Dams before distribution for drinking. Maleet Dam is open. It had to be protected, its water treated before distribution for drinking. Similarly Gadeed Alsail Hafir should be protected, treated and distributed. Coliforms in Golo Dams 1 and 2 ranged 3/ml- 3.5/ml MPN, TBC $\log_{10}$ 1.74- 1.845 and absence of fungi. Maleet Gadeed Alsail Hafirs values of Coliforms were 6.5ml and 6.2 ml MPN, TBC $\log_{10}$ 1.929 and $\log_{10}$ 1.845respectively. Traces of fungi were observed in Maleet Dam while non in Gadeed Alsail Hafir.

Microbiological analysis of treated tap water in ND is presented in table 6. Low values of Coliforms MPN were reported in El Fashir Station 1, Station 2 and Maleet village, 1.5/ml in each one. The TBC ranged $\log_{10}$ 1.01-1.845. Traces of fungi were observed in EL Fashir water station 1 and 2 while non in Maleet village. El Fashir Government Rest House taps water recorded 1.9/ml MPN Coliforms, TBC log10 1.697 and Nil for fungi.

Table 3: Microbiological Methods and Analysis for Drinking Water

Parameter	Method and Technique	Reference
Total Coliforms	Membrane Filtration (MF) (Sample 100 ml)	USEPA approved &ISO Standard 7704: (1985) [17]
Total Colony Count	Membrane Filtration (MF) (Sample 5ml)	ISO Standard No.9308- 1- (1990) [18] ISO Standard No. 9308- 2- (1990) [19]
Fecal Streptococci	Modified Membrane Filtration (MMF) (Sample 100ml)	ISO Standard No. 7899-1-1984 [20] ISO Standard No. 7899-2-1984 [21]
Yeast and Molds	Spread Plate Method	Colwell and Morissetti Method 1969 [22]
Total Bacterial Count	Pour Plate Method	Harrigan and McCance (1969) [23]

Table 4: North Darfur Microbiological Analysis for Drinking Water from underground wells

Source of sample	TBC $\log_{10}$/ml	Coliforms MPN/ml	Fungi cfu/ml
Shigrat Elwadi (deep well)	$\log_{10}$ 1.477	1	Nil
Hagar Gado well (1)	Nil	1.1	Nil
Hagar Gado well (2)	$\log_{10}$ 0.477	0.5	Nil
Hagar Gado well (3)	$\log_{10}$ 0.602	0.6	Nil
Hagar Gado well (4)	Nil	Nil	Nil
Hagar Gado well (5)	$\log_{10}$ 0.698	Nil	Nil
Hagar Gado well (6)	$\log_{10}$ 0.845	2.5	Nil
Hagar Gado well (7)	Nil	0.6	Nil

Table 5: North Darfur Microbiological Analysis for Drinking Water from Hafirs and Dams

Source of sample	TBC log_{10}/ml	Coliforms MPN/ml	Fungi /ml
Golo Dam (1)	log_{10} 1.845	3	++
Golo Dam (2)	log_{10} 1.740	3.5	++
Maleet Dam	log_{10} 1.929	6.5	traces
Gadeed Alsail Hafir	log_{10} 1.845	6.2	Nil

Table 6: Microbiological Analysis for Treated Drinking Water from taps in ND

Source of sample	TBC log_{10}/ml	Coliforms MPN/ml	Fungi /ml
El Fashir Water Station (1)	log_{10} 1.010	1.5	trace
El Fashir Water Station (2)	log_{10} 1.740	1.5	trace
Maleet Village	log_{10} 1.845	1.5	Nil
El Fashir Government Rest House	log10 1.697	1.9	Nil

The present method of water treatment in El Fashir 1 and 2 had to be improved and appropriate disinfectant used. The microbiological analyses of drinking water in SD are presented in tables 7, 8, 9.

Hay Elgabal (mountain) hand pumped deep well showed low values of 1.2/ml MPN Coliforms, log_{10} 0. 698 TBC and traces of fungi. The low values observed may be due to the fact that the well is uncontaminated artisan underground well. Contamination may be caused by humans. Confirmation of the contamination could be verified by the analysis of fecal Coliforms (Fc) and fecal streptococci (Fs). If Fs/ Fc more than 4 the source of contamination is human, if 0.7 is of animal origin as reported by author [10] cited by author [9].

Hay Elganayin (gardens) and Yau yau village, Kashalango shallow wells are close to khor Nyala. High Coliforms values 7/ml MPN are reported for Hay Elganayin and 2.5/ml MPN for Yau yau village shallow well. While Elganayin shallow is hand pumped, Yau yau water is drawn by rope and bucket. Hay Elganayin showed TBC log_{10} 0.845 with Nil value for Yau yau. No fungi were detected in both. The drinking water of these wells

could be improved by treatment at the outlet with pipe distribution to the consumers. The probable cause of the contamination by high Coliforms may be due to contamination of Khor Nyala. The source of its contamination needs to be investigated.

Table 7: Microbiological Analysis of Raw Wells Water in SD (Nyala and Kashalango village)

Source of sample	TBC log_{10}/ml	Coliforms MPN/ml	Fungi /ml
Hay Elgabal (H.P, DW)	log_{10} 0.698	1.2	traces
Hay Elganayin (M.P, SW)	log_{10} 0.845	7	Nil
Yau yau area (SW, RB)	Nil	2.5	Nil

Table 8: Microbiological Analysis of Hafirs (Nyala), and Khors Water in SD

Source of sample	TBC log_{10}/ml	Coliforms MPN/ml	Fungi /ml
Manawashi Hafirs	log_{10} 2.278	25.5	+++
Goz Badeen	log_{10} 1.875	14.7	+++
Nyala Khor	log_{10} 1.0	10	Nil

The microbiological analyses of drinking water from Manawashi Hafir, Goz Badeen Rahad and Nyala Khor are presented in table 8.

The highest value of Coliforms of ND and SD is reported in Manawashi Hafir 25.5/ml MPN, log10 2.278 TBC and presence of fungi. Author [9] studying microbiology of Hafir drinking water in Kordufan State reported that the highest Coliforms load was detected in open hafirs with range 0- 920/100ml. He noticed seasonal variations of microbiological contamination, highest in autumn and lowest in summer. Protected hafirs showed the lowest number of Coliforms. Khor Badeen Rahad had a high value of Coliforms 14.7/ml MPN, TBC log_{10} 1.875/m and presence of fungi.

The physico- chemical characteristics of drinking water of Khor Nyala had been studied by authors [16]. The microbiological analysis showed 10/ml MPN Coliforms, log_{10} 1.0TBC and Nil value for fungi. The water is very clear gravel filtered. It is difficult to detect the source of the contamination of Khor Nyala. Author [15]

stated that under such conditions improved hygiene and education had to accompany water improvement efforts.

Microbiological analysis of Nyala town treated water are presented in table 9. The Coliforms value reported 5/ml MPN, TBC log10 1.204/ml and Nil value of fungi. Tap water in Nyala Government Rest House showed 3/ml Coliforms, log10 1.342 TBC and Nil value for fungi.

Table 9: Microbiological Analysis of Treated Tap Water in Nyala

Source of sample	TBC $\log_{10}$/ml	Coliforms MPN/ml	Fungi /ml
Nyala Water Station	$\log_{10}$ 1.204	5	Nil
Nyala Governmental Rest House	$\log_{10}$ 1.342	3	Nil

The methods of treatment and disinfection of Nyala Drinking Water Station needs improvement.

4. Conclusion

1. It is concluded that in the spite of the fact that high values of Coliforms in drinking water in SD no serious outbreak of water- borne diseases had not been reported. However the source of Coliforms contamination of Khor Nyala had to be investigated.

2. The deep artisan ground water well of Hay Elgabal had to be improved, treated then piped before distribution to the different parts of the area.

3. The present system of treatment and disinfection of SD and ND drinking water stations should be improved.

4. The open drinking water wells in ND should be improved, and the present system of drawing water changed to pumping system. Also treatment and disinfection at the outlet should be carried out.

5. More attention is needed for Golo protected dam Maleet open dam to decrease the present level of Coliform bacteria.

6. Hafirs and Rahads should be protected to reduce the present loads of Coliforms.

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