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Research Article

ASSESSMENT OF DRINKING WATER QUALITY IN THE PUBLIC NETWORK OF GADAREF STATE, SUDAN

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ABSTRACT

Background: Access to safe drinking water remains a critical public health challenge in Sudan. This study assessed the bacteriological and physicochemical quality of water within the public distribution network of Gadaref Locality, Gadaref State, Sudan. **Methods**: An analytical cross-sectional study was conducted from January to November 2020. A total of 28 water samples were collected from the main storage tank, three sub-tanks, and household points across three distribution lines (Northern, Southern, Circular). Analyses were performed for Escherichia coli (E. coli), total coliforms, residual chlorine, and turbidity using standard field and laboratory methods (Pooltester, graduated turbidity tube, and membrane filtration). Supplementary data were gathered via interviews with water authority officials and field observations. **Results**: All samples from the main and sub-tanks were free of E. coli and total coliforms. Residual chlorine levels at these points were acceptable (0.3–0.4 mg/L). However, turbidity exceeded the WHO guideline value (5 NTU) in the main tank (7.5 NTU) and one sub-tank (6 NTU). At the household level, 41.7% (10/24) of sampled homes showed bacteriological contamination with E. coli (range: 1–18 CFU/100 ml), strongly associated with low or absent residual chlorine (0.0–0.2 mg/L). A statistically significant relationship was found between residual chlorine levels and E. coli contamination at household points (χ^2 = 11.93, df = 2, p = 0.003). Turbidity in household samples varied (2–7 NTU). Interviews confirmed a severe water scarcity issue, with the network covering only ~35% of the population, and revealed a breakdown in routine water quality monitoring. **Conclusion**: While water quality at the source was generally bacteriologically safe, significant secondary contamination occurs during distribution and storage at the household level, exacerbated by low residual chlorine. The study highlights a critical need for strengthened chlorination practices, infrastructure maintenance to reduce turbidity, expansion of the network coverage, rehabilitation of monitoring systems, and community health education on safe water handling.

KEYWORDS: Drinking Water Quality; *E. coli*; Residual Chlorine; Turbidity; Water Safety; Sudan; Gadaref.

1. INTRODUCTION

Safe and readily available drinking water is a fundamental human right and a cornerstone of public health.[1] Globally, waterborne diseases linked to contaminated water and poor sanitation remain a leading cause of morbidity and mortality, particularly among children in developing countries.[2] The World Health Organization (WHO) estimates that improving water, sanitation, and hygiene could prevent approximately 829,000 diarrheal deaths annually.[2] Sudan faces acute water security challenges driven by climatic variability, population growth, economic constraints, and under-investment in infrastructure.[3] States like Gadaref, situated in an arid to semi-arid zone, experience chronic water scarcity, forcing reliance on mixed sources including surface water (dams, seasonal rivers) and groundwater, which are vulnerable to contamination.[4]

Monitoring the quality of piped water is essential for preventing disease outbreaks. Key indicators include

microbiological safety (e.g., absence of fecal indicators like *E. coli*), adequate disinfectant residual (e.g., chlorine), and acceptable physicochemical parameters like turbidity, which can shield pathogens and hinder disinfection.[1, 5] Recent studies in similar Sudanese contexts, such as in Khartoum and North Darfur, have identified system vulnerabilities, including intermittent supply, low disinfectant residuals, and contamination in storage containers, leading to a high prevalence of waterborne illnesses.[6,7]

This study was conducted to assess the quality of drinking water within the public distribution network of Gadaref Locality. The objectives were to: 1) evaluate the bacteriological quality; 2) measure residual chlorine levels; 3) assess turbidity; and 4) identify associated risk factors from source to point of consumption, thereby providing evidence for targeted interventions.

2. METHODOLOGY

2.1. Study Area and Design

The study was conducted in Gadaref Locality, Gadaref State (coordinates: ~12.17° N, 36.34° E). The locality has an estimated population of 618,881. The climate is tropical savannah. The public water network, fed by a combination of Nile water, groundwater, and dam sources, serves approximately 35% of the population, with the remainder relying on about 82 wells.[8] The network distributes water via three main lines: Northern, Southern, and Circular. An analytical cross-sectional study design was employed over the period January to November 2020.

2.2. Sample Collection and Size

The sample size was determined using WHO guidelines for drinking water quality surveillance, suggesting one sample per 10,000 populations plus 10 additional samples, resulting in 28 samples.[5]0 Sampling points were purposively selected to represent the system:

- **Source Points (n=4):** Main storage tank ("Army Tank") and three sub-tanks (Al Gamhorea, Al Saraf Dam, Al Sharef Alagib).
- **Household Points (n=24):** Eight homes from each of the three distribution lines (Northern, Southern, Circular).

2.3. Laboratory and Field Analysis

- **Bacteriological Analysis:** 100 ml water samples were aseptically collected in sterile bottles, stored on ice, and transported to the Gadaref State Ministry of Health Laboratory. Analysis for *E. coli* and total coliforms was performed using the membrane filtration method with Wagtech Potatest incubation and counting.
- **Residual Chlorine:** Measured on-site at the time of collection using a digital Pooltester.
- **Turbidity:** Measured on-site using a calibrated graduated turbidity tube (a traditional but locally practical method). Results are reported in Nephelometric Turbidity Units (NTU).
- **Quality Control:** Sterile techniques were used during sampling. Equipment was calibrated according to manufacturer guidelines.

2.4. Qualitative Data Collection

Structured interviews were conducted with the director of the Gadaref State Water Authority to understand operational challenges, treatment practices, and monitoring capacity. Field observations were made in neighborhoods to document water storage practices and general environmental sanitation.

2.5. Data Analysis

Data were analyzed descriptively using frequencies and percentages. Results were compared against the WHO guideline values for drinking water quality (2017) and the Sudanese standards.[1,9]

2.6. Ethical Considerations

Verbal informed consent was obtained from heads of households for sample collection. Permission for the study was granted by the University of Alzaeim Alazhari and the Gadaref State Water Authority.

3. RESULTS

3.1. Water Quality at Source Tanks

As shown in Table 1, all samples from the main tank and sub-tanks showed **zero** *E. coli* and total coliforms. Residual chlorine levels were within the recommended range of 0.2-0.5 mg/L.[5] However, turbidity exceeded the WHO guideline value of 5 NTU in the main tank (7.5 NTU) and the Al Saraf Dam sub-tank (6 NTU).

Table 1: Water Quality Parameters at Source Tanks.

Sample Source	*E. coli* (CFU/100ml)	Total Coliform (CFU/100ml)	Residual Chlorine (mg/L)	Turbidity (NTU)
Army Tank (Main)	0	0	0.3	7.5
Al Gamhorea Tank	0	0	0.3	5
Al Saraf Dam Tank	0	0	0.4	6
Al Sharef Alagib Tank	0	0	0.4	4

3.2. Water Quality at Household Points

Significant deterioration in water quality was observed at the point of consumption (Tables 2 & 3).

- **Bacteriological Contamination:** Overall, 41.7% (10/24) of household samples were contaminated with *E. coli*. Contamination was most prevalent in the Southern Line (62.5%, 5/8 samples), followed by the Circular Line (37.5%, 3/8) and the Northern Line (25%, 2/8). One sample from the Southern Line showed a high count of 18 CFU/100ml.
- **Residual Chlorine:** Chlorine residual was depleted (0.0 mg/L) in 41.7% (10/24) of household samples. No sample from a contaminated household had a residual chlorine level ≥ 0.2 mg/L.
- **Turbidity:** Values at households ranged from 2 to 7 NTU, with several exceeding the 5 NTU guideline.

Table 2: Summary of *E. coli* Contamination by Distribution Line.

Distribution Line	No. of Samples	No. (%) Contaminated (*E. coli* > 0)	Range of *E. coli* (CFU/100ml)
Northern	8	2 (25%)	1-2
Southern	8	5 (62.5%)	3-18
Circular	8	3 (37.5%)	4-10
Total	**24**	**10 (41.7%)**	**1-18**

"A Chi-square test revealed a statistically significant association between residual chlorine levels and E. coli contamination at household points (X^2 =11.93, df = 2, p = 0.003)."

Table 3: Association between Residual Chlorine and *E. coli* Presence at Households.

Residual Chlorine (mg/L)	No. of Household Samples	No. (%) with *E. coli* Contamination	
0.0	10	8 (80%)	**p = 0.003**
0.1	6	2 (33.3%)	
0.2	8	0 (0%)	

3.3. Interview and Observational Findings

- **Water Scarcity & Coverage:** The Water Authority confirmed a severe shortage, with the existing network covering only about 35% of the municipal population. A new network expansion project was reportedly underway.
- **Breakdown in Monitoring:** Routine water quality analysis by the authority had ceased due to the complete destruction of the central laboratory during the 2019 revolution, although chlorination of the network was reportedly ongoing.
- **Storage and Sanitation:** Field observations revealed unsafe water handling practices, including the use of uncovered storage containers. Environmental sanitation was poor, with solid waste accumulations in streets and drainage channels (*khirans*).

DISCUSSION

This study reveals a critical disconnect between water quality at the source and at the point of consumption in Gadaref Locality. The absence of fecal indicators in all source tanks indicates that central treatment, particularly chlorination, was initially effective—a finding consistent with well-managed water supply points in similar settings.[10] However, the high prevalence of E. coli contamination in household samples (41.7%) signifies a severe public health risk, as the presence of this bacterium is a definitive indicator of recent fecal contamination and the potential presence of enteric pathogens.[1]

The strong inverse correlation between residual chlorine and bacterial contamination is a key finding. In all cases where E. coli was detected, residual chlorine was below the recommended minimum of 0.2 mg/L, and it was absent (0.0 mg/L) in 80% of contaminated samples. This relationship was found to be statistically significant (χ^2 = 11.93, df = 2, p = 0.003). This demonstrates a systemic failure to maintain an adequate disinfectant residual throughout the distribution network. Factors likely contributing to this include: long and aging pipeline networks allowing chlorine decay; intermittent supply leading to stagnation and biofilm formation; and possible ingress of contaminated water through leaks, especially during low-pressure periods.[11,12] This aligns with studies from other parts of Sudan and Sub-Saharan Africa identifying low residual chlorine as a primary risk factor for in-system contamination.[6,7] Elevated turbidity in the main tank and one sub-tank (>5 NTU) is another concern. High turbidity can protect microorganisms from disinfection, interfere with chlorine efficacy, and stimulate bacterial regrowth in pipelines.[1,5] This suggests a need to optimize coagulation, sedimentation, and filtration processes at the treatment stage. The qualitative findings contextualize the laboratory results. The extensive water scarcity and limited network coverage force reliance on alternative, often unsafe sources, increasing disease risk.[3] The destruction of

monitoring capacity is a severe setback for water safety planning, leaving the system blind to quality fluctuations. Finally, observed poor household storage practices are a well-documented cause of secondary contamination, negating the safety of water delivered through an otherwise functional system.[13]

Study Limitations: The use of a graduated tube for turbidity measurement, while practical, is less precise than nephelometric instruments. The study period (2020) may have been influenced by the unique socio-political disruptions in Sudan, potentially affecting system performance. A broader chemical analysis (e.g., for nitrates, heavy metals) was beyond the study's scope but is recommended for future work**.**

5. CONCLUSION AND RECOMMENDATIONS

This study concludes that the drinking water from the public network in Gadaref Locality is microbiologically safe at the point of treatment but becomes contaminated by the time it reaches consumers. The principal causes are the loss of disinfectant residual within the distribution system and unsafe household water storage practices. Compounding these technical issues are systemic challenges of water scarcity, inadequate infrastructure coverage, and a collapsed quality monitoring framework.

To address this, a multi-pronged intervention strategy is urgently needed

1. **Technical Reinforcement:** Optimize chlorination dosing to ensure a consistent residual chlorine level of ≥ 0.2 mg/L at all extremities of the network. Improve treatment processes to reduce turbidity at source to below 1 NTU for effective disinfection.
2. **Infrastructure Investment:** Accelerate the expansion of the piped network to increase coverage. Implement a systematic program for leak detection and pipeline maintenance.
3. **Institutional Capacity Building:** Rehabilitate the water quality laboratory and re-establish a routine, risk-based water safety monitoring and surveillance program as per WHO guidelines.
4. **Community Engagement:** Launch targeted health education campaigns focusing on the importance of using and maintaining clean, covered storage containers and safe water handling practices.

REFERENCES

1. World Health Organization. Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: WHO, 2022.
2. WHO/UNICEF Joint Monitoring Programme (JMP). Progress on household drinking water, sanitation and hygiene 2000-2022: special focus on gender. New York: UNICEF, 2023.
3. United Nations Environment Programme. Sudan: post-conflict environmental assessment. Nairobi: UNEP, 2020.
4. Sulieman HM, Ahmed AGM. Water scarcity and adaptive management in the dry savannah of Eastern Sudan: a review. Environ Challenges, 2023.
5. World Health Organization. Guidelines for drinking-water quality: surveillance and control of community supplies. Volume 3. 2nd ed. Geneva: WHO, 1997.
6. Mohamed H, Ali A, Hussein R. Assessment of drinking water quality in Khartoum State, Sudan. Sudan J Public Health, 2021; 16(2): 45-55.
7. Gizaw Z, Adane M, Azanaw J. Household drinking water quality and its associated factors in flood-prone settings of Northwest Ethiopia. J Water Health, 2022; 20(5): 851-62.
8. Gadaref State Water Authority. Annual operational report 2019. Gadaref, Sudan: The Authority, 2020. (Unpublished)
9. Sudanese Standards and Metrology Organization. Drinking water standards - specification (SSMO 2012). Khartoum, Sudan: SSMO, 2012.
10. Wright J, Gundry S, Conroy R. Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. Trop Med Int Health, 2004; 9(1): 106-17.
11. Kumpel E, Nelson KL. Intermittent water supply: prevalence, practice, and microbial water quality. Environ Sci Technol, 2016; 50(2): 542-53.
12. Bishoge OK, Mbelwa Y, Mvile BN. Challenges facing the implementation of water safety plans in sub-Saharan Africa: a systematic review. J Water Health, 2020; 18(6): 937-51.
13. Shaheed A, Orgill J, Ratana C, Montgomery MA, Jeuland MA, Brown J. Water quality and waterborne disease in the Niger River Inland Delta, Mali: a study of local knowledge and response. Health Place, 2014; 30: 182-90.