

Research Article

Water Quality at the Brikama Water Treatment Plant, Gambia

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Abstract

Aim: A staggering 43% of the over 2 million population of The Gambia depends on contaminated water sources for domestic purposes, including pipe-borne water supplied by the National Water and Electricity Corporation (NAWEC), the nation's sole provider of pipe-borne water. The main objective of this study was to assess the physico-chemical and bacteriological quality parameters of the water sourced from the Brikama Public Water Treatment plant, specifically post-aeration and chlorination, as well as during its provisional storage at the plant prior to distribution to consumers. **Method:** Physico-chemical and bacteriological data were acquired from the management authorities of the plant through a meticulous review of their operational water quality monitoring records of 2022. A key informant guide regarding the plant's operations was used to elicit information from the management via interviews with the on-site personnel. **Results:** The averages of the Electrical Conductivity (EC=30 μ S/cm), Residual Chlorine (RCI₂= 0.3 mg/l), and Total Dissolved Solids (TDS= 20 mg/l) of the water fell within the limits established by the WHO guidelines. Conversely, the averages of the Temperature (30 °C), Total Coliform (TC=2 cfu/100 ml), and Hydrogen Potential (pH=6.1) of the water were deemed unacceptable according to the same guidelines. **Conclusions and Recommendations:** This paper investigates critical water quality issues and infrastructural and operational deficiencies at the Brikama public water treatment plant in The Gambia. While some parameters meet WHO guidelines, others like Temperature, Total Coliform, and pH remain subpar, increasing contamination risks. Recommendations include further water treatment at the household level, infrastructural improvements, and the implementation of a comprehensive Water Quality Data Information System. Enhanced public education and system maintenance are pivotal to improving water safety standards and protecting community health.

Keywords

Water Treatment Plant, Water Quality, Gambia

1. Introduction

The geogenic quality of the water in the Shallow Sand Aquifer throughout The Gambia is generally regarded as commendable, with the exception of its low pH values, which fluctuate between 5.0 and 6.7, alongside elevated iron concentrations in certain locales [1]. Total dissolved solids

range from 10.3 mg/l to 383 mg/l, and calcium levels vary from 3.1 mg/l to 69 mg/l, all of which fall within the acceptable concentrations stipulated by the World Health Organization (WHO) guidelines for municipal water quality [1, 2].

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Nevertheless, a staggering 43% of the over 2 million population of The Gambia depends on contaminated water sources for domestic purposes, including pipe-borne water supplied by the National Water and Electricity Corporation (NAWEC), the nation's sole provider of pipe-borne water [3, 4]. The Brikama Water Treatment Plant, situated in the West Coast Region where the majority of the population is concentrated and abstraction rates are the highest in the country, stands as one of the most advanced municipal water treatment facility in The Gambia.

The raw water from the fields entering the treatment facility through pipelines undergoes treatment via aeration, chlorination, and temporary storage prior to distribution [5]. The plant is supplied by 17 boreholes at various locations, delivering raw water at a rate ranging from 4 to 107 cubic meters per hour [6]. Upon entry, the raw water is subjected to aeration in designated chambers. Water cascades over shells from the roof and is collected at the floor of chambers via pipelines for storage in reservoirs. The aerated water is subsequently chlorinated using gaseous chlorine from 50 kg cylinders, maintained at a storage cylinder pressure of approximately 1.5 kg/cm². Following this process, the water is temporarily stored in ground-level reservoirs before being elevated into two overhead distribution tanks with a capacity of 1500 m³ each, intended for use by the target population in Brikama and surrounding areas for domestic, industrial, and municipal purposes [5, 6].

Burst pipes, low pressures, and unsanitary conditions prevalent in and around African cities exert significant detrimental effects on the quality of water supplied to consumers [7, 8]. Similar to other water utilities across Africa, the rapidly growing population, which escalates water demand, coupled with aging infrastructure and insufficient investment in water service provision, has culminated in subpar service performance by national utility companies, including NAWEC, thereby compromising supply quality [5, 6, 8].

A comprehensive approach to mitigating health threats through municipal water systems must be predicated on robust scientific water quality data and services operating effectively. This study aims to assess the water supply system in accordance with WHO 2011 water safety plans, with the explicit objective of assessing principal water quality parameters at the treatment plant site subsequent to processing and prior to distribution to consumers and also obtain information on the operations and the infrastructure of the plant.

2. Methods and Materials

2.1. Study Design

A descriptive cross-sectional study design was employed to evaluate the water quality supplied from the treatment facility to consumers in Brikama. Secondary data analysis was conducted on the Physico-chemical and bacteriological quality of the water from data acquired through a comprehensive review

of their operational water quality monitoring records and operational logs. The current operational protocols and conditions were ascertained from the onsite personnel including the site engineer, and operations manager of the plant through a key informant interview.

The assessment tools utilized were formulated in accordance with the guidelines established by the WHO 2011, Water Safety Plan Standards, the prevailing drinking water quality standards of The Gambia Standards Bureau, and supplementary research. These tools underwent modification and validation through peer reviews and empirical testing.

The collected data of year 2022 was meticulously organized and subjected to statistical analysis to determine averages, as well as minimum and maximum values, alongside correlations, utilizing the Excel 2016 Data Analysis Toolpak.

2.2. Study Setting

Geographically situated at 13°16' 3" North and 16°38' 46" West, Brikama lies on a flat plain characterized by a relatively high-water table, positioned less than 20 kilometers from the Atlantic Ocean.

Brikama is the most populous settlement within the Brikama Local Government Area which has a land area of approximately 1,800 square kilometers and housing a population of just under one million inhabitants. While the national population density has increase from 174 in 2013 to 227 individuals in 2024 per square kilometer, Brikama boasts a significantly higher density of 652 individuals per square kilometer in 2024 [4].

The economic landscape of Brikama is diverse, encompassing activities such as trade, horticulture, livestock husbandry, refining, automotive repair and maintenance services, as well as medical and health services. The surrounding areas of the town have been extensively mined, with numerous old quarries inadequately managed, resulting in environmental degradation. Many of these sites have been repurposed into open landfills, as highlighted in the findings of Camara et al. (2021) [9].

3. Results

3.1. Key Infrastructural and Operational Information

The plant commenced operations in 2009. The predominant structural challenges to date encompass ruptured pipes and malfunctions within various components of the plant system, including the closure of certain wells, the inoperability of the onsite laboratory, and the complete dysfunction of the lime dosing system, all of which pose a substantial risk of contamination to the water supply system. Operationally, the plant grapples with considerable difficulties in detecting ruptured pipes, relying predominantly on unreliable consumer

complaints. These complaints also encompass organoleptic quality issues such as odor, color, and taste. Consumers are insufficiently informed about water quality through reports; however, water quality data is disseminated to key stakeholders, including the Public Utility Regulatory Authority of the country. The sole method of chemical disinfection employed is chlorine. Supplies of chlorine are occasionally jeopardized, particularly in instances where the plant confronts threats to chlorine availability due to border issues, such as travel restrictions imposed during the COVID-19 pandemic. Factors such as power outages and substandard procedures significantly undermine water quality.

3.2. Bacteriological and Physico-Chemical Quality of Treated Water of the Plant

The post-chlorination quality of water, prior to its distribution, encompassed six quality parameters that were meticulously assessed during this study. Among these parameters, one was bacteriological, while the remaining were classified as either physical or chemical. Table 1 presents the monitoring data collected by the plant for the operational year 2022. The means of the parameters of interest were juxtaposed with the WHO drinking water standards established in 2011. Notably, the means for pH, Total Coliform load, and Temperature failed to comply with WHO standards, whereas the other parameters remained within acceptable limits set by the organization.

Table 1. Plant monitoring water quality data 2022.

Parameter	Statistics			WHO limits	
	Minimum	Mean	Maximum	Lower	Upper
pH (Hydrogen potential: range 0-14)	5.6	6.1	6.5	6.5	8.5
Temperature ($^{\circ}$ Celsius)	27	30	33	25 at tap	
Electrical Conductivity (μ S/cm)	30	91	180	400	
Total Dissolved Solids (mg/l)	20	60	120	1000	
Total coliform (cfu/100 ml)	2	1.1	6	0	
Residual Chlorine (mg/l)	0.18	0.3	1.3	0.2 5	

Table 2 delineates the correlation among the six quality parameters presented in numeric form in Table 1. A value of 1 illustrates a perfect positive correlation, with values closer to 1 indicating a stronger association. A robust and affirmative correlation was observed among the majority of the parameters, with Total Dissolved Solids (TDS) and Electrical Conductivity (EC) exhibiting the most substantial correlations, while Total Coliform (TC) and pH demonstrated the weakest associations.

4. Discussions

Although the plant infrastructure is relatively recent, having been in operation for less than three decades, the facility has already begun to encounter a range of operational and structural challenges both within the plant itself and throughout its catchment area and distribution network.

Among the most pressing issues are the ruptured pipes. When a pipe bursts within a public water supply system, it poses a significant risk of contamination if the water becomes exposed to external elements such as soil, debris, or microbiological agents. The likelihood of contamination escalates if the ruptured pipe is situated near potential sources of pollutants, such as industrial establishments or agricultural zones, as evidenced in Brikama, illustrated in Tables 1 and 2. The contamination of pipe-borne water is particularly pronounced in Brikama, where the system pressure frequently fluctuates. When pipe pressure is elevated, the risk of external contaminants infiltrating the water supply is diminished; conversely, when pipe pressure is low, the vulnerability to contamination from external materials increases significantly. Similar structural deficiencies have been documented in various studies concerning developing neighborhoods [6, 8].

Table 2. Correlation matrix of water quality data.

	pH	Temperature	Electrical Conductivity	Total Dissolved Solids	Total Coliform	Residual Chlorine
pH	1					
Temperature	0.9933993	1				
Electrical Conductivity	0.9753888	0.994242697	1			
Total Dissolved Solids	0.9736842	0.993399268	0.999971096	1		
Total Coliform	0.6880833	0.766777076	0.831144548	0.8353483	1	
Residual Chlorine	0.8572809	0.910679469	0.949702191	0.9520557	0.963471	1

Furthermore, the plant lacks the capability to detect ruptured pipes within the distribution network, thereby impeding its ability to respond effectively to such incidents. Instead, it relies on consumer complaints, which are often uncertain and unreliable. The rupture and leakage of pipes can be attributed to normal wear and tear over time, corrosion, heavy traffic, and other anthropogenic activities in proximity to the pipes.

The study highlights a communication barrier between the public water supply system and its consumers. The BWTP lacks adequate arrangements to inform consumers about any issues pertaining to the quality of the water being supplied, in stark contrast to the best practices observed in high-income countries such as the United States. Customers served by a public water system can readily contact their local water supplier to inquire about contaminants present in their drinking water and are encouraged to request a copy of their Consumer Confidence Report [6]. This report enumerates the levels of detected contaminants in the water, including those monitored by the U. S. Environmental Protection Agency, and indicates whether the system adheres to state and EPA drinking water standards [6]. Access to water quality data significantly influences the healthy and appropriate utilization of water resources. Moreover, in Brikama, there exists only one public water supply plant catering to all needs. For optimal health outcomes, the selection of disinfectants is of paramount importance. For instance, in certain regions of the U. S., chlorination can be substituted with alternative disinfection methods, which facilitate better health and medical decisions regarding additives in water.

Additional factors that jeopardize the water quality from the plant include power outages, intermittent shortages of consumable supplies, and substandard operational procedures. Consequently, it is evident that consumers expressed dissatisfaction with the water they receive from the plant, particularly concerning its organoleptic characteristics. Water that is discolored, odorous, or foul-smelling may harbor potentially harmful pathogens and heavy metals. It is widely acknowledged that sediments or suspended solids must be present

before hydraulic events can transport them to consumers, leading to dissatisfaction [7]. Waters exhibiting elevated temperatures and bacterial counts exceeding the WHO health-based guidelines are likely to adversely affect the color, odor, and taste of the water.

Alarming, the average and individual chlorine residual levels are lower than those deemed acceptable for low- and middle-income countries by the WHO [2]. According to the WHO 2011 guidelines, insufficient chlorine residuals in pipe-borne waters are ineffective in safeguarding against contamination, potentially resulting in morbidity and, in the most severe cases, mortality upon ingestion across all demographics, particularly among the most vulnerable populations, such as children [2]. The Demographic and Health Survey of 2019 indicates that water-related diseases remain among the leading causes of mortality within the Gambian populace. The presence of Total Coliform has been confirmed, with results indicating a robust positive correlation between residual chlorine and Coliform levels, which is contrary to established norms. This observation suggests a systemic failure to thwart the infiltration of undesirable substances into the treated water, as exemplified by compromised piping infrastructure. Furthermore, the pH consistently registers below the World Health Organization's stipulated requirements. Although pH typically has no direct repercussions for consumers, it remains one of the most critical operational parameters in water quality management. Vigilant oversight of pH control is imperative at all stages of water treatment to ensure effective clarification and disinfection. This suboptimal pH level implies potential geogenic influences, whereby adequate aeration and chlorination could have rectified the pH fluctuations; however, it appears that the facility is predominantly preoccupied with fulfilling water demand. Temperature emerged as the third parameter of concern in this analysis. Elevated water temperatures facilitate the proliferation of microorganisms and may exacerbate issues related to taste, odor, color, and corrosion [2, 10, 11].

4.1. Conclusions

This study established that pipe-borne water in and around Brikama is at risk of contamination through various processes and infrastructural deficiencies from the wells to the consumers. The distribution network of pipes traverses potential pollutant pathways, and a ruptured or leaking pipe could readily result in water inundating the surrounding area, thereby introducing contaminants into the system. Furthermore, there exists a significant communication gap between service providers and consumers regarding the dissemination of water quality data, which is as crucial as the provision of water itself. There exists a substantial risk of various contaminants compromising drinking water quality from the Brikama Water Treatment Plant (BWTP), in accordance with WHO standards for such waters.

In conclusion, the complexities surrounding water contamination in Brikama underscore the urgent need for a comprehensive strategy that integrates proactive management, consumer education, and stakeholder collaboration. By collectively addressing these challenges, it is possible to create a more resilient water supply system that prioritizes the health and well-being of all community members.

4.2. Recommendations

First and foremost, water supply companies must conduct the necessary feasibility studies prior to the excavation of wells intended for public water supply. Designated well sites must conform to the minimum standards for such facilities. Regular site monitoring and supervision protocols should be instituted, accompanied by an effective coordination mechanism; all of which collectively serve to mitigate the pollution of water sources.

NAWEC must institutionalize a Water Quality Data Information System (WQDIS) platform that empowers them to disseminate pertinent information to consumers and relevant authorities. The WQDIS will furnish consumers with critical insights into their water quality for various reasons, proving indispensable for informed decision-making processes among concerned authorities. It is imperative for consumers to be duly informed by the water supply authority regarding matters of water quality. In the event of a contamination incident, consumers may be advised to boil their water prior to use or to resort to bottled water until the situation is rectified. Regulatory authorities can collaborate closely with public water service providers in this regard.

Furthermore, additional treatment of public pipe-borne water at both household and community levels prior to its consumption is prudent and essential. Treatment methods as straightforward as allowing water to stand for a minimum of one hour can facilitate the settling of particulates to the bottom of the container. Engaging in rolling boiling for a few minutes can effectively sterilize the water. Maintaining the water at a chilling temperature can inactivate harmful organisms, while exposing it to ample sunlight disrupts the genetic

material of bacteria.

Since this study did not ascertain the supplementary treatment services already available at the household level, it advocates for further investigations to address critical questions concerning pipe-borne drinking water issues in Brikama, The Gambia, and beyond. Additionally, the collection of water samples at the household level would constitute an intriguing exploration into the variations in drinking water quality.

Ultimately, mitigating and addressing issues such as ruptured pipes and water contamination events within the Brikama public water supply system necessitates a coordinated effort among the water supply authority, local and central governments, researchers, and consumers. Moreover, in order to enhance the integrity of water quality and safeguard public health, it is imperative to implement rigorous monitoring and maintenance protocols throughout the water supply chain. Regular inspections of the distribution infrastructure, alongside swift repairs of any identified faults, are essential in minimizing the risk of contamination.

Application of an appropriate concentration of disinfectant constitutes a pivotal element for most treatment systems to attain the requisite level of microbial risk mitigation. By considering the degree of microbial inactivation necessary for the more resilient microbial pathogens through the application of the product of disinfectant concentration and contact time at a specific pH and temperature, one can ensure that other, more susceptible microbes are also effectively managed. The storage of water subsequent to disinfection and prior to its distribution to consumers can enhance disinfection efficacy by prolonging disinfectant contact times. This factor can be particularly significant for more resistant microorganisms, such as *Giardia* and certain viruses.

Public awareness campaigns should also be initiated to educate consumers about the importance of water quality and the potential hazards associated with contaminated water sources. By fostering a sense of community responsibility and encouraging proactive engagement, both consumers and service providers can work collaboratively to uphold the highest standards of water safety.

Furthermore, the establishment of robust feedback mechanisms between stakeholders will facilitate the timely exchange of information regarding water quality concerns and contaminant outbreaks. This collaborative approach will not only empower consumers but also enable service providers to respond more effectively to emerging challenges.

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Author Contributions

Samba Camara: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing – original draft

Data Availability Statement

Correspondence should be made to Samba Camara.

Conflicts of Interest

The authors declare no conflicts of interest

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