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# Assessment of Water Treatment Quality at the Brikama Water Treatment Plant, Gambia

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**Abstract:** ***Aim**: This study assessed the physico-chemical and bacteriological quality parameters of treated water from the Brikama Public Water Treatment plant, specifically post-aeration, chlorination, and during its temporal storage at the plant prior to distribution to consumers. **Method**: Physico-chemical and bacteriological data were acquired from a review of the plant operational water quality monitoring records from January to December of 2022. A key informant interviews was used to elicit information on plant operations from the management. **Results**: The mean Electrical Conductivity (EC=30 µS/cm), Residual Chlorine ($RCl_2$= 0.3 mg/l), and Total Dissolved Solids (TDS= 20 mg/l) of the quality of the water was within the limits based on WHO standards. However, the mean Temperature (30 °C), Total Coliform count (TC=2 cfu/100 ml), and Hydrogen Potential (pH=6.1) of the water quality were not in line with the same standards. **Conclusions and Recommendations**: This study assessed critical water quality treatment infrastructural and operational deficiencies at the Brikama public water treatment plant in The Gambia. While some parameters meet WHO standards, other important parameters such as Temperature, Total Coliform count, and pH remain subpar, thus the increased risk of water-borne or related diseases from use of such water. It is therefore recommended that further water treatment alternatives at the plant level or at the household level should be implemented. In addition, water treatment and distribution infrastructural system maintenance or improvements, and the implementation of a comprehensive Water Quality Data Information System including public education must be enhanced to improving water safety standards and protecting community health.*

**Keywords:** Water Treatment, Residual chlorine, Coliform, 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) standard guidelines for municipal water quality [1],[2].

Nevertheless, a staggering 43% of the over two million of The Gambian population depends on potentially contaminated water sources for domestic purposes, including pipe-borne water supplied by the National Water and Electricity Company (NAWEC), the nation's sole provider of pipe-borne water [3],[4]. The Brikama Water Treatment Plant, situated in the West Coast Region serves a sizable and an ever-increasing population within and around Brikama and abstraction rates are also the highest in the country due to the demand for water. The Treatment plant commissioned by NAWEC as one of the most advanced municipal water treatment facility in The Gambia.

The raw water from the boreholes in the fields are supplied to the treatment facility through pipelines are treated by 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]. The raw water is subjected to aeration in designated chambers. The water cascades over shells from the roof of the aeration chambers and is collected at the floor through 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/cm$^2$. 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 m$^3$ 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],[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 quality treatment system in accordance with WHO 2011 water safety plans, specifically assessing the major water quality parameters at the treatment plant prior to distribution to consumers and the operational and infrastructure deficits of the plant for appropriate standard water quality treatment. This study is significant as it highlights key vulnerabilities in water treatment infrastructure that affect public health outcomes in The Gambia.

## 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 review of 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 drinking water quality standards of The Gambia Standards Bureau, and our supplementary research. These tools underwent modification and validation to contextualized the tools.

### 2.2 Study setting

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 per square kilometer in 2024, Brikama LGA's population density of 652 individuals per square kilometer is significantly higher than the national density in 2024 [4]. 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, and less than 20 kilometers from the Atlantic Ocean.

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].

### 2.3 Data analysis

The data was analyzed Excel 2016 Data Analysis Toolpak and statistical analysis to determine mean, minimum and maximum values, alongside and correlations based on the WHO standard guidelines. Six quality parameters (pH, Temperature, Electrical Conductivity, Total Dissolved Solids, Coliform Count, and Residual Chlorine) were assessed. Among these parameters, coliform count was considered as bacteriological, while the remaining were categorized physico-chemical.

## 3. Results

### 3.1 Key infrastructural and operational information

From the key informant interviews, it was revealed that the plant commenced operations in 2009, since then there has not been any major maintenance on the facility. The predominant structural challenges reported by key informants included: 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, thus relying predominantly on consumer complaints for corrective measures. 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 the use of 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.

The two 1500 $m^3$ temporal storage tanks capacity at the treatment plant is insufficient to meet the water treatment using chlorine time interval before it is discharged to larger community water storage tanks for distribution to end users based on the population demands. According to the key informants, the plant was originally designed to serve a population of 300,000 inhabitants, current demands on the plant is far more than that. These coupled with low pressure in some areas, damaged pipe networks and inadequate capacity to repair damaged pipe networks further compounds the risk of inadequate treatment and poor water quality.

### 3.2 Bacteriological and Physico-chemical quality of treated water of the plant

Table 3.1 presents the mean, minimum and maximum values of the treated water quality monitoring data for 2022. There is significant variation in reported mean values for the parameters of interest to that of the WHO drinking water standards established in 2011, notably, the mean for; pH, Total Coliform load, and Temperature

**Table 3.1:** 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 (*º Celsius)* | 27 | 30 | 33 | 25 at tap | |
| Electrical Conductivity *(µS/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 3.2 delineates the correlation among the six quality parameters presented in numeric form in Table 3.1. A robust and affirmative correlation was observed for Total Dissolved Solids (TDS) and Electrical Conductivity (EC) exhibiting the most substantial correlations, while Total Coliform (TC) and pH demonstrated the weakest associations.

**Table 3.2:** 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 |

1 = a perfect positive correlation, with values closer to 1 indicating a stronger association

## 4. Discussions

This investigation seeks to analyze the effectiveness of the water treatment system, concentrating on the infrastructural inadequacies and operational limitations, as well as critical water quality indicators such as pH, temperature, electrical conductivity, total dissolved solids, coliform count, and residual chlorine. The results illuminated considerable deficiencies in water treatment capacity and marked discrepancies from the stipulated World Health Organization (WHO) drinking water quality standards concerning total coliform (TC), temperature and pH.

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. The single most reported operational challenge reported by key informants is the issue of burst pipes in the supply system. This poses significant risk of contamination if the water becomes exposed to external elements such as soil, debris, or microbiological agents. The likelihood of contamination further increases if the affected pipes are within or close to potential sources contamination from pollutants. The potential causes of contamination of pipe-borne water in Brikama may be associated with water supply system when the pressure frequently fluctuates between periods of water discharge from the water well and post-treatment insufficient effects of chlorine on the water. When pipe pressure is elevated, the risk of external contaminants infiltrating the water supply is diminished. Similar structural deficiencies have been documented in studies other developing countries [6], [8].

Furthermore, the plant lacks the capability to detect ruptured pipes within the distribution network, thereby impeding its ability to respond effectively to such incidents. 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.

Additional factors that affects operational capacity of the treatment plant and thus affecting the water quality include: power outages, intermittent shortages of consumable supplies, and substandard operational procedures. Consequently, consumer complaints through 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 not be present before treated water is supplied to consumers, if not, this could lead 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.

Alarmingly, the study revealed that the mean and minimum chlorine residual levels are lower than acceptable standards 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 Gambia 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 which can also provide optimal media for the growth of micro-organisms. 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 than meeting the quality.

Elevated water temperatures facilitate the proliferation of microorganisms and may exacerbate issues related to taste, odor, color, and corrosion [2].

### 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 and capacity for water treatment and there is risk of various contaminants compromising drinking water quality from the Brikama Water Treatment Plant (BWTP), in accordance with WHO standards for such waters. This risk is associated with coliform counts, the pH and the Temperature of treated water from the plant.

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 water quality for the health and well-being of all community members.

### 4.2 Recommendations

NAWEC must conduct environmental studies prior to the excavation of wells intended for public water supply and this sites must conform to the minimum standards for such facilities. Regular site monitoring and supervision protocols should be instituted, enhanced by an effective coordination mechanism; all of which collectively serve to mitigate the pollution of water sources.

There is an urgent need for maintenance of the plant infrastructure and operationalizing the onsite lab for effective monitoring and supervision of the water quality. In addition, there is need to augment the tank capacity of the treatment plant to enhance the amount and effectiveness chlorine reflected in the total residual chlorine.

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. In the event of a contamination, consumers may be advised alternative water treatment options prior to use or use of bottled water until the situation is rectified.

Further studies are recommended to determine the type, and sources of the coliforms present in the treated water from the plant. This will further inform the bases for the treatment that should be instituted 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 from the plant to the end user.

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, can ensure that other, more susceptible microbes are also effectively managed.

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. This will ensure a sense of community responsibility and encouraging proactive engagement. 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.

**Data Availability:**
Correspondence should be made to Samba Camara at scamara@utg.edu.gm

**Conflict of Interest:**
The authors declare that there is no conflict of interest regarding the publication of this article

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