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Bacteriological and physicochemical quality of sachet water sold in the city of N'djamena, Chad

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Abstract

Water is a precious and essential natural resource for multiple uses. Given its vital functions in human life, the bacteriological and physicochemical quality of drinking water should comply with international water requirements for public health purposes. Like many African cities, a form of water in plastic bags emerged a few years ago in N'Djamena, to meet the needs of the population. This sachet water, which mainly comes from the formal sector and is consumed daily by the population of N'Djamena, raises concerns about its quality. The present cross-sectional and prospective study aimed to determine the bacteriological and physico-chemical parameters of plastic bag water sold in the town of N'Djamena. Using a non-probability convenience sampling, sachet water samples (n=50) were collected from different brands (n=10) within the city of N'Djamena for a period of three months (March to May 2023). The physicochemical analyses of water (pH, conductivity, turbidity, $NH4^{+}$, Fe^{2+}, $SO4^{2-}$ and $NO3^{-}$ levels, Na^{+} and K^{+} levels, and TH, Ca^{2+}, Mg^{2+}, Cl^{-} and $HCO3^{-}$ levels) were carried out using pH meter, conductivity meter, turbidimeter, spectrophotometry, flame photometry, and volumetry, respectively. On the other hand, the bacteriological parameters (Escherichia coli count, total coliform count, fecal enterococci count, and total viable count) were undertaken using the filter membrane technique.

Based on the bacteriological parameters, all sachet water samples (100%) violated WHO guidelines and standards for drinking water quality in terms of total coliform and total viable contamination levels. Additionally, 3 out of 50 of water samples (6%) did not comply with WHO and Chad standards based on physicochemical characteristics.

This poor quality of sachet water results from poor production, storage, and transport conditions of this water. Therefore, the consumption of sachet water exposes the populations of N'Djamena to health risks.

Keywords: Sachet water, bacteriological parameters, physicochemical characteristics, pollution, WHO standards, N'Djamena.

Introduction

Water is the most basic human need that is required to sustain life, which is offered naturally to Man (Nguepidjo et al., 2020). The human body requires water daily to function properly and to avoid dehydration (Messanvi et *al.*, 2022). Unfortunately, the rapid rate of population

growth, urbanization, agricultural and industrial revolution particularly in developing countries such as Chad cause water shortages thereby compromising access to sufficient and safe drinking water (Mohamed, 2014, Matchawe et *al.*, 2022).

The consumption of unsafe water represents the highest rate of health risks including waterborne diseases worldwide with Africa being the most vulnerable (WHO, 2012). The UNICEF/WHO 2022 Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene indicates that 2.2 billion people (27% of the world's population) do not have access to safe water (UNICEF/WHO, 2023). Given the ongoing population growth of the Chadian capital city in the last decade (UN, 2023), a category of water packaged in plastic bags has experienced exponential growth to cover the increased demand of the population for water supply (Hissein, 2020). Owing to its refreshing nature, low cost, and availability, sachet waters not only meet the needs of the consumers but also constitute a source of income for the producers and sellers (Dieng et *al.*, 2021). However, drinking water which constitutes a crucial factor in the prevention of water-borne diseases deserves keen attention (Ouahchia et *al.*, 2015).

Safe drinking water should not present any health risk to the consumers irrespective of the different stages of life (WHO, 2017; UN, 2022). Therefore, water safety constitutes the most important public health concern (Benajiba et *al.*, 2013; Nguefack et *al.*, 2018). Unfortunately, the companies in charge of producing sachet water are more preoccupied with water quantity than water quality (Alassane, 2015) forgetting that consumption of impure water exposes populations to water-related diseases (Akiyo, 2017). Sachet water is part of the informal sector of activities escaping the control of national regulatory bodies in charge of water safety. Additionally, its daily consumption by the population of N'Djamena must trigger concerns about its quality and safety. Moreover, the absence of clear management of residual plastic bags after water consumption poses the problem of environmental pollution (Akiyo, 2017). Therefore, this study aimed to evaluate the bacteriological and physicochemical characteristics of sachet water sold in N'Djamena.

Methods

2.1. **Study site**

The city of N'Djamena is located at 12°06'59" north latitude and 15°04'20" east longitude. It is located on the western edge of the country at the confluence of the Chari River with the

Logone River; limited to the north by the region of Hadjer-Lamis, to the East by the Chari-Baguirmi region, to the South by Logone and the West by the Republic of Cameroon. It developed on an alluvial plain of gentle slopes (Figure 1).

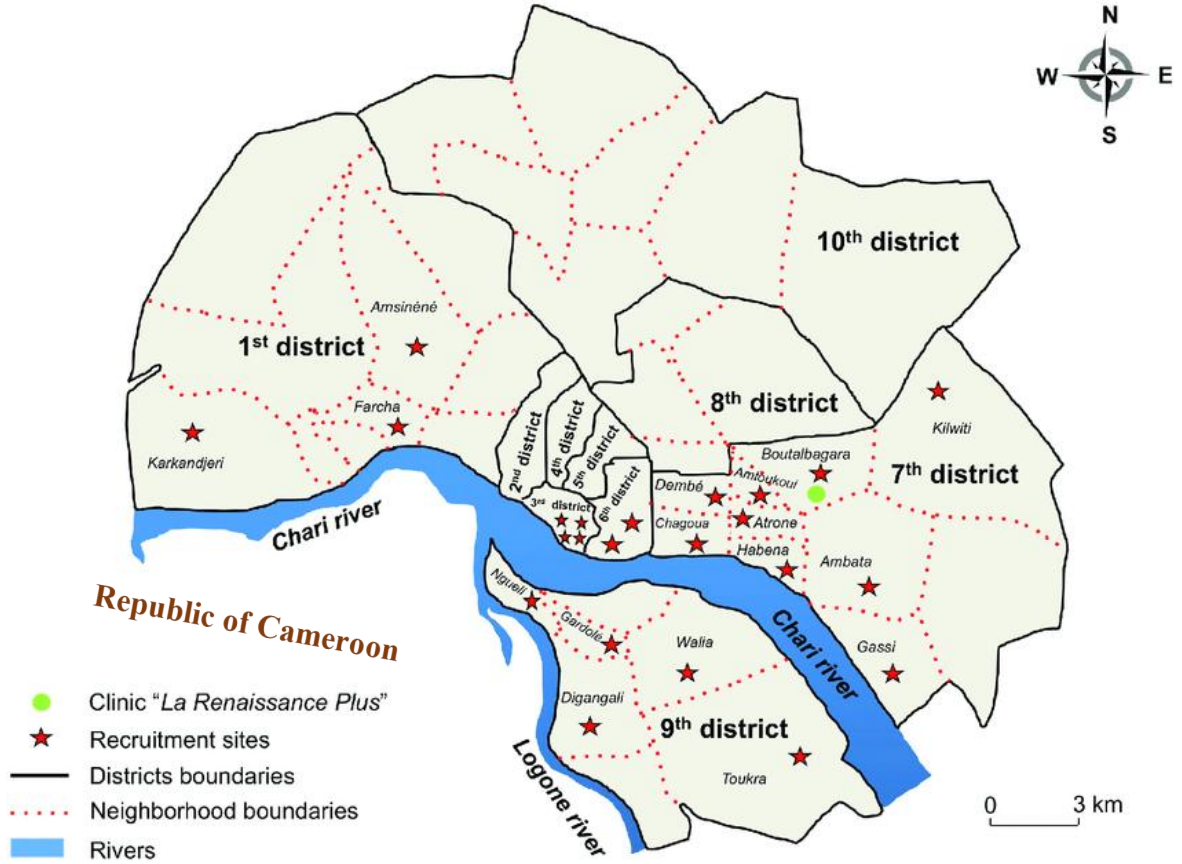

Figure 1: Map of the City of N'djamena

2.2. Collection of samples

A prospective cross-sectional study design was used to evaluate the bacteriological and physico-chemical parameters of sachet water sold within the city of N'Djamena. Using a non-probability convenience sampling, sachet water samples (n=50) were purchased in Koundoul, Nguéli, Central, and Dembé markets within the city of N'Djamena from different brands (n =10) for a period of three months (March to May 2023). The samples were carefully labeled (comprising the number, name of the brand, and date of collection), then placed in an icebox and brought to the laboratory immediately for analyses (ISO 5667-3, 2004; ISO 5667-1, 2007).

2.2.1. Determination of bacteriological quality of sachet

The bacterial load of 100 mL of each water sample was carried out on Chromocult Agar (for total coliforms-TC, Escherichia coli-EC); Slanetz and Bartley Agar (for fecal enterococci)-FE;

Plate count agar (mesophilic aerobic flora-MAF) using filter membrane technique. Previously, each culture medium was prepared and poured into a Petri dish (Ø =55 mm). After the Petri dishes were allowed to cool at room temperature, the filter membrane was then placed on the surface of each culture medium. After incubation at 37°C for 24 to 48 hours (ISO 9308-2:1990b), the colonies were identified and counted using a colony counter.

2.2.2. Measurement of physicochemical parameters of sachet water

The following physicochemical parameters (pH, conductivity, turbidity, $NH4^{+}$, Fe^{2+}, $SO4^{2-}$ and $NO3^{-}$ levels, Na^{+} and K^{+} levels, and TH, Ca^{2+}, Mg^{2+}, Cl- and HCO3- levels) were determined using pH meter, conductivity meter, turbidimeter, spectrophotometry, flame photometry, and volumetry, respectively.

Results

Interestingly, none of the water samples recorded the presence of *E.coli* and fecal Enterococcus irrespective of the water brand (Table 1). However, except for the brands Alh and Nad (for MAF), all the water samples sold in plastic bags in the town of N'Djamena failed to comply with the WHO standards for drinking water (<1/100 mL and <500/100 Ml), in terms of TCC and MAF respectively.

Table 1: Bacteriological quality of sachet water sold in the city of N'Djamena

Brand	**Microbial load of water (CFU/100 mL)**			
	EC	**TCC**	**FE**	**MAF**
Zai	0	52	0	1088
Sal	0	108	0	736
Alh	0	35	0	480
Man	0	72	0	1600
Alm	0	112	0	576
Nad	0	126	0	305
Mad	0	82	0	800
Ada	0	98	0	1400
Gal	0	48	0	816
Ala	0	54	0	522
WHO (2010) Standard values	0	<1	0	<500

The physicochemical analyses included fourteen variables (pH, conductivity, turbidity, hardness, calcium, magnesium, sodium, potassium, ammonium, iron, bicarbonate, chloride, sulfate, and nitrate). All the water samples irrespective of their origin (brand) complied with the WHO and Chad standards based on pH levels (Table 2). Additionally, except for the brand Gal, sachet water samples sold in N'Djamena complied well with the World Health Organization standards in terms of electrical conductivity. The (World Health Organization) establishes that the turbidity of drinking water should not exceed 5 NTU, and not be below 1 NTU. Unfortunately, the turbidity of sachet waters fell below the permissible levels except for water produced by two brands, Ada and Alm. There were no significant statistical variations among the different water brands based on their physical parameters ($p<0.05$).

Table 2: Physical characteristics of the sachet water samples sold within the town of N'Djamena

Brand	**pH**	**Conductivity (µS/cm)**	**Turbidity (NTU)**	**Hardness (mg/L)**
Zai	6.75	229	0.39	6.1
Sal	6.61	192.7	0.29	5.8
Alh	6.53	389	0,75	19
Man	6.83	123.9	0.30	10.5
Alm	6.46	245	1.07	11.0
Nad	6.59	328	0.,26	8.4
Mad	7.75	133.4	0.75	13.7
Ada	6.17	145.2	1.25	16.0
Gal	6.38	1103	0.96	12.5
Ala	7.3	209	0.33	11.6
WHO (2017)	**6.5-8.5**	**≤ 400**	**5.0**	**200**

Statistically, the sachet waters did not significantly differ in terms of their mineral contents ($P<0.05$). Irrespective of the water brand, the mineral contents (calcium, magnesium, sodium and potassium, bicarbonate, chlorides, sulfates, and nitrates) of sachet water sold in N'Djamena were lower than the standard values (Table 3). These results sufficiently demonstrate that the sachet waters sold in Chad are not qualified to be designated mineral waters. However, the ammonium and iron levels of sachet water produced respectively by brand Gal and brands: Sal, Alh, Man, Nad, and Ada were beyond the permissible levels laid down by the World Health Organization and Chadian standard for drinking water quality.

Table 3: Macro-elements (mg/mL) of sachet water samples sold within the city of N'Djamena

Brand	Ca	Mg	Na+	K+	NH_4+	Fe	HCO^-_3	Cl-	SO_4^{-2}	NO^-_3
Zai	3.5	2.6	1.7	1.2	0.13	0.19	0.4	0.6	53	2.2
Sal	3.3	2.5	1.3	1.0	0.14	1.16	0.5	0.4	2	6.6
Alh	12	7.0	1.5	0.5	1.0	0.9	0.7	0.5	14	5.4
Man	8.6	1.9	7.3	1.1	0.2	0.75	0.8	0.15	23	3.9
Alm	6.3	4.7	2.0	0.7	0.16	0.3	0.6	0.3	1	6.8
Nad	4.7	3.7	1.7	1.6	0.1	1.07	0.7	1.2	7	3.6
Mad	9.0	4.7	6.8	1.2	0.14	0.26	0.3	0.4	39	7.7
Ada	5.2	10.8	1.2	1.4	0.17	0.77	0.5	0.8	61	4.8
Gal	7.1	5.4	2.8	1.2	1.9	0.29	0.2	3.2	1	5.3
Ala	5.8	5.8	3.3	1.8	0.14	0.14	0.9	0.5	5	4.9
Std values	**100**	**50**	**200**	**12**	**1.5**	**0.3**	**200**	**250**	**250**	**50**

Discussion

The present study revealed that sachet water sold within the city of N'Djamena failed to comply with the international requirements for drinking water in terms of total coliform and total viable counts. Although total coliforms can derive from sources other than fecal matter, the high total coliform contamination levels of the studied water samples may be considered an indication of pollution. Equally, a high total viable count may indicate poor quality of drinking water affecting its taste or odor. The total coliform bacteria in drinking water may have emerged from the environment, human or animal wastes. Their high presence in the sachet waters sold in Chad may unveil the deficiency of the treatment system put in place by the various water brands. This might also be attributed to contamination during the packaging process or other production stages of sachet waters. The high total heterotrophic bacteria counts recorded in sachet waters might suggest that potentially dangerous microorganisms could have contaminated them, thereby rendering them unfit for human consumption. A good number of previous studies equally reported high total coliforms and total viable counts in sachet waters (Ble et al., 2015; Mosi et al., 2018; Addo et al., 2019; Traoré et al., 2023). However, our results differed from those of Nguepidjo et al. (2020) who showed that 92.6% of water samples were highly contaminated from the microbiological point of view. The bacteriological quality of sachet waters in this study calls for a proper understanding of the production environment and processes of these waters. Natural mineral waters are exclusively underground water sources and should often be microbiologically safe (Soumana, 2019).

The hydrogen ion concentration (pH) of water plays a vital role during chemical reactions and biological activities that occur in water. In the present study, the pH values of sachet waters fell within the standard range (6.5-8.5). Our results support findings from previous studies that reported similar observations concerning the pH range of sachet waters (Kamelé et al., 2022; Addo et al., 2019; Dieng, 2021; Traoré et al., 2023; Ibrahim et al., 2022; Soumana, 2019). However, pH values lower than 6.5 recorded by some water brands in this study appear too acidic for human consumption and can cause health problems such as acidosis, and some synergistic effects on heavy metal toxicity (Adesakin et al., 2020).

Electrical conductivity (EC) directly reflects the amount of total dissolved solids in water, thus a high EC in drinking water is associated with bad taste. Except for water from the Gal brand, the electrical conductivity values of sachet waters sold in N'Djamena are well below the recent maximum value recommended by WHO (WHO, 2017). The general Low conductivity of the studied water samples indicates their low mineralization (Kamelé et al., 2022). Similarly, previous studies conducted by Kamelé et al (2022), Addo et al (2019), and Kouakou et al (2022) reported EC values lower than the standard value. However, other authors (Ibrahim et al., 2022; Traoré et al., 2023) reported slightly higher EC values compared to our findings. These differences may be attributed to the producing environment, period, and procedures of these waters.

Turbidity is the relative clarity of drinking water. In this present study, 80 % of water brands produced sachet waters with turbidity levels below the permissible values. This result indicates that sachet waters produced and sold in N'Djamena might derive from groundwater sources. Naturally, underground waters undergo filtration. Additionally, the water brands in this study might have implemented additional artificial treatments such as filtration and reverse osmosis (Traoré et al., 2023). Our results agree with the findings of Soumana (2019), Kamelé et al (2022), and Traoré et al (2023) who recently reported relatively lower turbidity levels of sachet waters compared to the WHO guidelines. Nevertheless, the turbidity levels of sachet waters studied by Ibrahim et al (2022) in Wukari (Nigeria) were relatively higher than our findings.

Hardness is primarily a function of the geology of the area and determines the presence of dissolved salts of calcium and magnesium. Although the harness levels of sachet waters in this study were lower than those of the WHO recommendation, they still enter into the category of hard waters because of their relative calcium and magnesium contents in comparison to other minerals. Our results are close to those of Dieng (2021), Traore, and

colleagues (Traoré et al., 2023) but differ from those of Addo and teammates (Addo et al., 2019).

The amount of chloride in all sachet water samples sold in N'Djamena was lower than the standard values of WHO for drinking water. Although, chloride is generally not considered a health risk, however, its relatively low concentrations in the studied water samples may affect their taste. Previous studies reported slightly higher concentrations of chloride in sachet waters (Addo et al., 2019; Ibrahim et al., 2022; Traoré et al., 2023).

Not only did all the sachet waters sold within the city of N'Djamena comply with the WHO guidelines concerning nitrate levels, but none of the water brands registered nitrate concentrations above 10 mg/L. Drinking water with levels of nitrate above 10 mg/L can lead to immediate health problems for infants less than six months old and people with certain health problems. Once more, our results are close to those of Ibrahim et al (2022) and Addo et al (2019) but differ from those of Traoré et al., 2023.

Even though the presence of ammonia in drinking water does not have a direct impact on health, it remains an indicator of possible bacterial contamination or pollution from sewage or animal waste. Long-term exposure to drinking water containing more than 1 mg/l (ppm) ammonia may be damaging to internal organ systems (Kamelé et al., 2022). In the present, sachet water produced by the brand Gal falls under this category. Therefore, consumers in N'Djamena are exposed to the toxic health effects of such water. The ammonium concentrations of plastic waters studied by Kamelé et al. (2022) were very close to our results; however, very lower levels of ammonia were reported by Traoré et al (2023) in sachet waters consumed within the capital city of Burkina Faso.

People who are not used to drinking water with high sulfate can get diarrhea and dehydration from drinking the water. Infants are often more sensitive to sulfate than adults. At present, all the sachet waters irrespective of the water brand comply with the international requirements for drinking water based on sulphate levels. The low sulfate concentrations of the water samples in the current study may be attributed to the type of soils surrounding the production environment of these waters and the absence of anthropogenic activities around the production sites. Our findings are close to those of Kamelé and colleagues Kamelé et al., 2022) (but differ from those of Addo and teammates and Traoré and collaborators (Addo et al., 2019; Traoré et al., 2023).

Bicarbonate is a natural component of all mineral waters that play a vital role in buffering acids and ensures that the mineral water tastes pleasantly clean and refreshing. The bicarbonate levels of our water samples respected the WHO compliance for drinking water; however, their very low HCO-3 concentrations portray their weak buffering capacity if exposed to environmental contaminants.

Conclusion

Natural mineral water is exclusively underground water sources and should often be microbiologically safe. Despite the absence of E.coli and fecal Enterococcus, all the water samples sold in plastic bags in the town of N'Djamena failed to comply with the WHO standards for drinking water based on total coliform and total viable counts. Based on physical characteristics (pH, EC, turbidity, and hardness), 10 and 20% of water samples did not comply with the WHO recommendations for drinking water based on EC and turbidity. Based on the macro-element contents, only 10% of sachet water samples did not comply with the standard values. The small sample size and the lack of information on the production environment and processes limit the validity of the conclusion of the present study.

The bacteriological quality of sachet waters in this study calls for a proper understanding of the production environment and processes of these waters. The Chadian Government and other stakeholders should impose intensified training activities on good hygiene and manufacturing practices for the water brands operating in the country. Continual surveillance and monitoring of the quality of sachet water should be put in place to ensure total compliance with water safety standards. Therefore, regular testing and inspection must be undertaken to identify potential gaps for orientating prompt corrective actions. In perspective, comprehensive studies including KAP studies, and physicochemical and microbiological assessments of sachet waters produced at the country level should be envisaged.

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