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Full Length Research Paper

Physico-chemical and bacteriological characterisation of drinking water in cheap restaurants in Ivory Coast: Case of the municipality of Dimbokro

Wolfgang Toussaint Yapo[1]*, Rodrigue Kotchi Orou[3], Thierry Oscar Seki[1], Eric Charles Ahiman Ake[1], Georges Tchape Gbagbo[1], Veronique Mambo[4] and N'cho Christophe Amin[1,2]

[1]Water and Food Laboratory, National Institute of Public Hygiene, BPV 14 Abidjan, Ivory Coast.
[2]Laboratory of Water Sciences and Techniques and Environmental Engineering, UFR of Earth Sciences and Mining Resources (UFR-STRM), Félix Houphouët Boigny University of Cocody, 22 BP 582 Abidjan 22, Ivory Coast.
[3]Department of Analytical Chemistry - Bromatology, General Chemistry, Mineral Chemistry, UFR of Pharmaceutical and Biological Sciences, Félix Houphouët-Boigny University, Abidjan, Ivory Coast.
[4]Laboratory of Environmental Sciences (LSE), UFR-SGE, University of Abobo-Adjamé, 02 B.P. 801 Abidjan 02, Ivory Coast.

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Street food plays a particularly important role in urban centers, where rapid urbanization and economic difficulties have led to an increase in restaurants. However, hygiene in these establishments is often problematic. This study aims to evaluate the quality of drinking water provided in the inexpensive restaurants of the city of Dimbokro. To achieve this, water samples were collected, resulting in a total of thirty samples. The classical physicochemical parameters were determined using spectrophotometric and electrochemical methods, while bacteriological analyses were conducted using the membrane filtration technique. The results revealed that the analyzed waters were weakly mineralized and all contained numerous germs, including *Enterococcus faecalis*, total coliforms (TC), thermotolerant coliforms (TTC), *Escherichia coli*, *Pseudomonas* species, and anaerobic sulfite-reducing germs.

Key words: Water quality, physico-chemical, bacteriological, hygiene.

INTRODUCTION

Water is essential to life, serving multiple purposes including drinking, personal hygiene, and domestic activities (Seki et al., 2024). Therefore, water intended for drinking must be safe to preserve the health of consumers (WHO, 2017). In line with this, the WHO (2009), through the International Drinking Water Supply and Sanitation Decade, recommended good water quality for all by 2015. Water is a natural resource essential to human survival, representing a critical global issue for the socio-economic development of a country (UN, 2018).

*Corresponding author. E-mail: twolfgang2y@gmail.com.

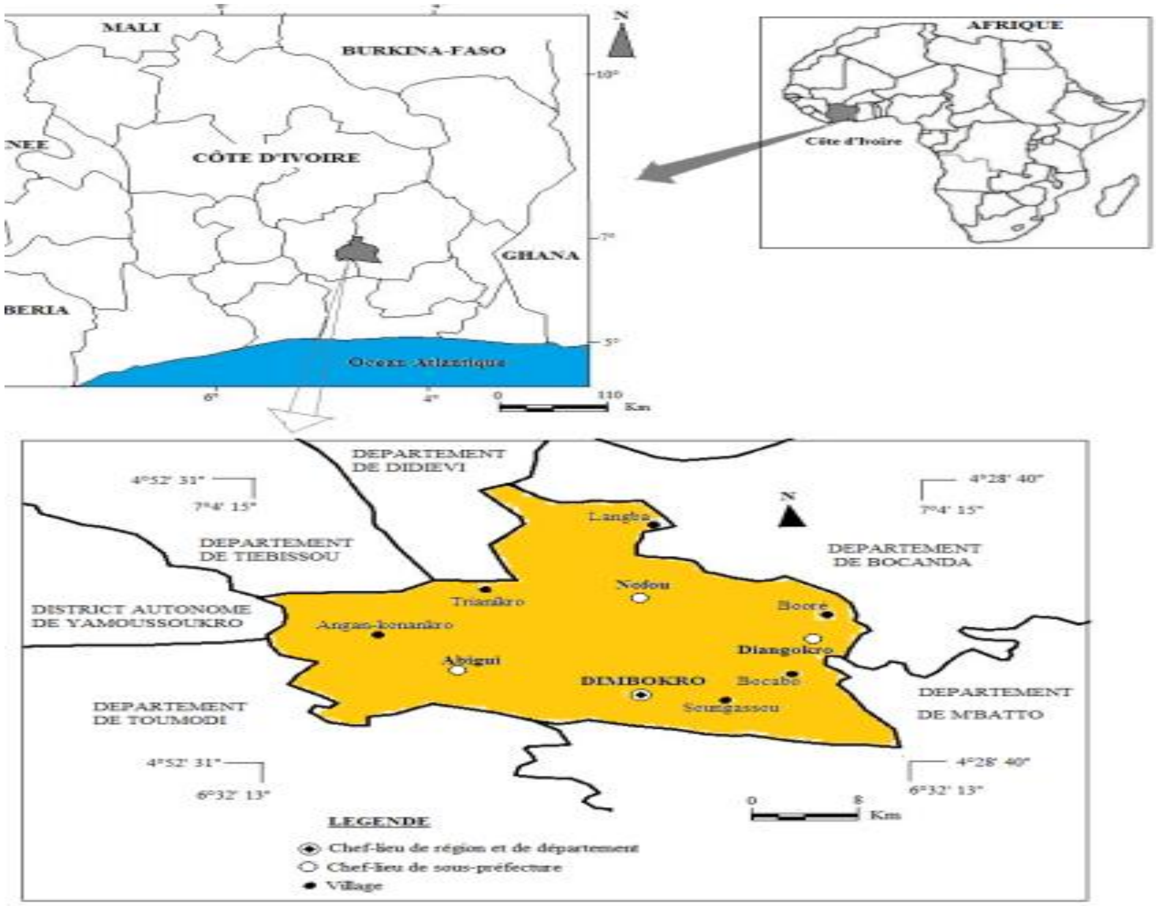

Figure 1. Geographical location of Dimbokro department.

Across all continents, access to water is more difficult in developing countries, where water resources are threatened both in volume and quality (Floresse, 2021).

Additionally, gargotes represent a significant portion of daily urban food consumption for low- and middle-income populations, who make up the vast majority of urban dwellers, particularly in developing countries (FAO, 2007).

However, in these countries, the lack of knowledge among sellers at these food establishments exacerbates risks. Poor hygiene, unsanitary conditions at sales locations, and proximity to household waste deposits are all concerns for state services and civil society organizations responsible for protecting public health (FAO, 2007). Indeed, non-potable water consumed at these establishments can carry numerous diseases of chemical or microbiological origin (Sognon et al., 2022), exposing consumers to significant health risks. Therefore, the objective of this study is to determine the physicochemical and bacteriological quality of the water consumed at these gargotes to highlight the potential health risks to which populations are exposed.

MATERIALS AND METHODS

Study area

The town of Dimbokro, whose gargotes were the subject of this study, is the capital of the N'Zi region. It is located between longitudes 4°42'W and latitudes 6°39'N, covering an area of 141 km². The population is estimated at 102,192 inhabitants (GCPH, 2014). The department of Dimbokro is characterized by two types of vegetation: forest and savannah. It has an equatorial climate with two rainy seasons and two dry seasons, specifically classified as Baoulean-Attian (Figure 1).

Equipment

The main measuring equipment consisted of a photometer (WAGTECH 7100Se, UK), a pH meter (HACH HQ11d, France), a conductivity meter (HACH HQ14d, France), and a turbidimeter (TURB 430 IR, France) for the physicochemical parameters, along with a membrane filtration device for the bacteriological parameters.

Sampling

Water sampling was done in the gargotes, where 30 water samples

Table 1. Environmental hygiene of gargotes.

Status parameter	Presence		Absence	
	n=30	%	n=30	%
wastewater	11	36.7	19	63.3
Wild deposits	2	6.7	22	93.3
Stench	17	56.7	13	43.3
Harmful vectors	18	60	12	40

were sampled. Samples were taken in 1000 ml polyethylene bottles for physico-chemical parameters and in 500 ml sterile bottles for microbiological parameters.

Samples collection, transport, and storage

The samples were stored in a cooler, protected from light, at a temperature between 4 and 8°C, and transported to the laboratory with the cold chain maintained using ice packs.

Physico-chemical analyses

The physicochemical parameters were determined by the following methods:

1) Turbidity is determined by HACH nephelometry (AOAC, 1990).
2) Mineral salts and color were determined by colorimetry using a Palintest 7100 SE photometer with pre-programmed filters and calibration curves.
3) Titrimetry was used for the determination of organic matter (FSA, 1997).
4) pH is measured with a digital laboratory pH meter of the HACH type equipped with a combined electrode (FSA, 1997).
5) Conductivity is measured using an AOAC type conductivity meter (AOAC, 1990). Operational wavelengths range from 410 to 640 nm.

Microbiological analyses

The microorganisms were identified and counted by filtering homogeneous aliquots of 100 and 50 ml through a membrane with a pore diameter of 0.45 µm (Kanohin et al., 2017). The membrane was then placed on selective culture media and incubated for 24 h at 37°C in a thermostatic oven. Microbiological analyses identified and enumerated *Enterococcus faecalis*, total coliforms (TC), thermotolerant coliforms (TTC), *Escherichia coli*, *Pseudomonas* species and anaerobic sulfite-reducers.

RESULTS

Hygiene of the immediate environment of the gargotes

Regarding the hygiene of the gargotes, the presence of wastewater in 36.7% of the sites, wild deposits (6.7%), foul smell (56.7%), as well as harmful vectors (60%) was observed (Table 1).

Physicochemical analyses

The results of the physicochemical analyses of the water of the gargotes are entered in Table 2. Physicochemically, the water of the gargotes has an average conductivity of 100.14 51.91 µS/cm. This shows that these waters are weakly mineralized.

Bacteriological analyses

The results of bacteriological analyses revealed the presence of fecal contamination bacteria in all 30 samples. The maximum microbial loads were 2.6×10^3 CFU/100 ml for total coliforms, 1.6×10^3 CFU/100 ml for thermotolerant coliforms, 1.4×10^3 CFU/100 ml for *E. coli*, and 8×10^1 CFU/100 ml for *E. faecalis* (Table 3).

Non-conformities of parameter contents

The majority of the water used in the gargotes is non-potable and therefore presents a risk to users. The parameters causing the non-compliance are bacteriological (Table 4).

DISCUSSION

This study conducted in makeshift restaurants in certain areas of Dimbokro provided information on the environmental vulnerability of these establishments and their impact on consumer health. The results of environmental hygiene surveys revealed that these restaurants are affected by the presence of household waste and wastewater. These findings are consistent with those of Sainou et al. (2019), who identified unsanitary conditions and the absence of sewage drainage systems as environmental risks.

A thorough analysis of the chemical parameters studied allows for an evaluation of the hygienic quality of the water consumed. The pH, which indicates the acidity or alkalinity of water (Merhabi et al., 2019; Korfali and Jurdi, 2011), ranged from 6.9 to 8 in this study. These values align with the accepted standard of 6.5 to 8.5 (WHO,

Table 2. Physicochemical properties of gargle water (n=30).

Parameter	Min	Med	Moy	Max	WHO (2004)/Ivory Coast standard standards
pH	6.9	7.4	7.39	8	6.5-8.5
Turbidity	0.5	1.1	1.40	4	≤ 5 UNT
Conductivity	69	90.5	100.14	342	100-1000 µS/cm
Temperature (T°)	16.2	21	20.74	24.5	25°C
NO_3^-	0.14	1.52	2.14	16.4	≤ 50 mg/l
NO_2^-	0	0.01	0.01	0.09	≤ 0.1 mg/l
NH_4+	0.01	0.045	0.13	0.75	≤ 1.5 mg/l
Cl^-	2.1	4.45	8.09	40	≤ 200 mg/l
DHT	5	50	57.66	195	≤ 500 mg/l
TAC	5	27.5	38.83	310	-
iron	0.01	0.2	0.16	0.45	≤ 0.3 mg/l
Al	0.006	0.03	0.052	0.17	≤1.5 mg/l
F-	0.04	0.49	0.51	0.89	≤ 1.5 mg/l

Table 3. Bacteriological parameters of water from gargotes (n=30).

Parameter	Min	Med	Moy	Max	WHO standards (2004) (CFU/ml)
CT	10	1000	1042.2	2600	0
Cth	0	42.5	237.37	1600	0
E. coli	0	35	204.17	1400	0
E. faecalis	0	0	6.83	80	0
ASR	0	0	0	0	0

Table 4. Non-conformities of the water parameters of the gargotes.

Parameter	WHO Standards (2004) (CFU/100 ml)	No. of unconfirmed	Proportion of no compliance (%)
Thermotolerant coliform	0	30	100
Total coliforms	0	30	100
E. coli	0	30	100
E. faecalis	0	30	100

2008), although they differ from those reported by Gohaida et al. (2016) for drinking water in Cotonou. According to Blinda (2007), pH values between 5 and 9 support normal flora and fauna development.

Conductivity reflects the degree of water mineralization and provides information on salinity (Rodier and Legube, 2009; Ould Cheikh et al., 2011). The average conductivity of the water in the gargotes was 100 µS/cm, indicating weak mineralization. This is lower than the values reported by Tampo et al. (2014) in Togo, which ranged from 550 to 4460 µS/cm, but close to the values obtained by Adejuwon and Mbuk (2011) for drinking water in Lagos, Nigeria, with a range of 22 to 315 µS/cm.

Turbidity describes the transparency or clarity of water and is a key parameter perceived by consumers (WHO, 2017). The average turbidity in this study was 4 NTU, which is below the maximum acceptable value of 5 NTU set by WHO (2008). Although these values are within recommended limits, they are on the higher side and similar to findings by Gbohaida et al. (2016) in Benin and Babadjidé (2011). According to Pritchard et al. (2007), high turbidity may indicate the presence of microorganisms.

Average water temperatures in the gargotes were above 20°C, which promotes microorganism growth (Rodier et al., 1996). The maximum recorded temperatures were around 24.5°C, which, according to Beldjilali and Arabe (2018), significantly increases bacterial activity.

Average chlorine values were as high as 40 mg/L, similar to the values reported by Coulibaly (2005) but significantly higher than the Beninese standards. These values are also comparable to those in studies by Lagnika et al. (2014).

However, according to Gbagbo et al. (2020), chlorine's reaction with organic matter can lead to the formation of carcinogenic chlorinated derivatives, such as trihalomethanes. To mitigate the risk of waterborne diseases and ensure water safety, Tampo et al. (2014) recommend adapting chlorination methods to the composition of the water.

The results of the bacteriological analysis revealed the presence of pathogenic bacteria (anaerobic sporulated sulfite-reducing bacteria) and fecal contamination bacteria (total coliforms, thermotolerant coliforms, *E. coli*, and *E. faecalis*) in the water from the gargotes. All water samples from the restaurants were found to be non-compliant with safety standards. For *E. faecalis*, the maximum concentration was 80 CFU/ml. The presence of these fecal germs indicates past fecal contamination, suggesting a probable risk that these germs could originate from an unsanitary environment, as noted by Seki et al. (2024). This result is consistent with the findings of Dovonou et al. (2017) and Mondesir et al. (2018).

Thermotolerant coliforms in this study reached a maximum value of 1600 CFU/ml. These coliforms, of animal or human origin, indicate recent fecal contamination (Balloy et al., 2019). They are considered pathogenic due to the increased risk of gastrointestinal disease (EPA, 2012). *E. coli* also provides information about recent fecal contamination, implying a likely risk of pathogens in these waters. In this study, *E. coli* concentrations reached up to 1400 CFU/ml, exceeding WHO (2014) recommendations. According to WHO (2014), water intended for human consumption must be free of bacteria indicating fecal pollution. Sources of pollution in drinking water have also been identified by Ahoussi et al. (2012a, b).

The high bacterial load observed in this study is attributed to the inadequate sanitation system and environmental conditions in these neighborhoods (Ouattara et al., 2016). These results align with those of Yapo et al. (2010), Gbabgo et al. (2020), and Merhabi et al. (2019). The presence of these bacteriological contaminants in drinking water poses a risk of waterborne infections such as gastroenteritis, particularly for vulnerable groups like children under five. According to WHO (2014), water for human consumption must be free of pollution-indicating bacteria. The high bacterial load and presence of numerous bacteria in the drinking water in this study are consistent with findings from previous research (Yapo et al., 2010; Gbabgo et al., 2020; Merhabi et al., 2019). The fecal origin of pollution in water resources was also highlighted by Ahoussi et al. (2012a, b) in surface waters of localities. The city of Dimbokro lacks an adequate sanitation system, and surface water used by the population is contaminated by various forms of waste, including garbage and stagnant wastewater. Therefore, the water from these restaurants is not drinkable according to WHO standards (2008). To safeguard consumer health, it is crucial to enhance hygiene measures in these makeshift restaurants.

Conclusion

This is one of the first studies on water consumption in Ivorian gargotes. It highlights the quality of water in Dimbokro and its impact on public health. The results of the bacteriological analyses indicate that almost all water samples are non-compliant, containing fecal contamination germs. This suggests a significant risk to consumers in these makeshift restaurants, which typically have poor hygiene standards. To better protect public health, it is essential to improve hygiene practices in these catering establishments.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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