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Physicochemical, Microbial, and Heavy Metal Assessment of Sachet Water: Evaluating Potential Health Impacts in Mainland Lagos State, Nigeria

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Abstract

Globally and locally, there is a significant shortage of potable water for domestic and other uses. Water quality refers to the assessment of its physical, chemical, and microbial properties. Ensuring the potability and suitability of water is critical for reducing human mortality, preventing the destruction of aquatic ecosystems, and ensuring the safe production of goods that require high-quality water. Water is considered of good quality if its physico-chemical, heavy metal, and microbial concentrations remain within permissible limits set by international and national regulatory standards. Thirty (30) commercially packaged sachet water samples from popular brands were randomly but evenly selected from three (3) Local Government Areas: Amuwo-Odofin, Ojo, and Lagos Mainland, within the Lagos Mainland area of Lagos State, Nigeria. These water samples were annotated and analyzed in the laboratory for their physico-chemical, heavy metal, and microbial parameters using standard scientific methods. The results indicated that all the analyzed water samples met the threshold limits for physico-chemical, heavy metal, and microbial parameters as established by international and national regulatory standards.The commercially packaged sachet water samples analyzed from the three (3) Local Government Areas in the Lagos Mainland area of Nigeria were found to be potable, free from waterborne infectious microbes, heavy metal contamination, and physical impurities.

Keywords: *Microbial, Physico-Chemical, Potability, Potable, Regulatory Bodies, Toxicity.*

Introduction

This study is motivated by one of the seventeen (17) Sustainable Development Goals (SDGs) established by the United Nations. Specifically, the sixth (6th) goal focuses on ensuring the availability and sustainable management of clean water and sanitation for all [2, 3, 16]. While approximately 70% of the earth's surface is covered by water, a significant portion of the global population faces limited access to safe drinking water [7]. This disparity highlights the urgency of addressing issues related to water quality and accessibility.

Clean freshwater is indispensable for the survival and flourishing of humanity. It serves a wide range of purposes, from domestic use such as drinking, cooking, and sanitation to industrial processes critical for development [2, 4]. Beyond these practical applications, the availability of potable water plays a pivotal role in maintaining public health. Ensuring access to high-quality drinking water helps preserve public health by reducing the prevalence of waterborne illnesses and mitigating risks associated with carcinogenic diseases, such as colon and bladder cancer [12, 13]. Therefore, access to safe and potable water is a fundamental requirement for the well-being and prosperity of any population.

Water is considered of premium quality when it is clear, tasteless, odorless, and free from contaminants, including fecal materials. This encompasses its physical, chemical,

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radiological, and biological characteristics, which collectively determine its suitability for consumption and other uses [1, 11]. Addressing the challenges of providing clean water and ensuring a sanitized environment is essential for achieving sustainable development and improving global health outcomes.

Materials and Methods

Study Area, Design, and Population

Lagos State is one of the thirty-six (36) states in Nigeria, the most populous nation in Africa. Nigeria is located in the western region of the African continent, and Lagos State is situated in its southwestern part. It is firmly positioned within the South-West geopolitical zone of the country, making it a crucial economic and administrative hub [9, 10]. Lagos State is often referred to as the "Centre of Excellence" due to its economic significance and rapid urbanization.

Geographically, Lagos State lies on Latitude 6°27′ North and Longitude 3°23′ East. It was formerly the Federal Capital Territory (FCT) of Nigeria before the capital was moved to Abuja in 1991. Despite this transition, Lagos remains Nigeria's commercial nerve center and one of the most rapidly growing megacities in the world [18]. It shares boundaries with Ogun State to the north, Ondo State to the east, the Republic of Benin to the west, and the Atlantic Ocean to the south, which significantly influences its climate, economy, and environmental conditions.

The climate of Lagos State is tropical, characterized by high humidity and significant seasonal variations in temperature and rainfall. The state experiences an average relative humidity of approximately 79%, with an average monthly temperature range of 23°C to 32°C. The tropical monsoon climate results in two major seasons: the rainy season, which typically spans from April to October, and the dry season, which lasts from November to March. The abundant rainfall supports diverse ecological systems but also contributes to frequent flooding, which is exacerbated by poor drainage and waste management systems.

Administratively, Lagos State is structured into two primary regions: the Lagos Mainland and Lagos Island. It is further subdivided into five administrative divisions, which include Ikeja, Badagry, Ikorodu, Lagos Island, and Epe. These divisions are further broken down into twenty (20) Local Government Areas (LGAs) and thirty-seven (37) Local Council Development Areas (LCDAs), each governed by a chairman or chairwoman. Among these, Alimosho Local Government Area is the largest in terms of both population and landmass. The state's administrative divisions play a crucial role in governance, urban planning, and service delivery.

Lagos State's coastal geography presents both opportunities and challenges. Being a coastal state, it is regularly subjected to the forces of nature, such as strong winds, ocean currents, and wave activities. It experiences a mean wind speed of approximately 1.19 m/s [18], which influences its maritime and commercial activities. However, its proximity to the Atlantic Ocean makes it vulnerable to coastal erosion, sea level rise, and flooding, especially in low-lying areas like Victoria Island, Lekki, and Ajah.

Despite its economic and infrastructural advancements, Lagos State faces several pressing urban challenges. The state struggles with inadequate sanitation and waste management systems, leading to environmental pollution and health hazards. Poor housing conditions, overcrowding, and inadequate ventilation remain significant concerns, particularly in informal settlements and densely populated areas. Additionally, access to clean and potable water remains a major challenge, affecting both residential and industrial areas. The rapid urbanization of Lagos has placed immense pressure on existing infrastructure, making the provision of basic services increasingly difficult.

In summary, Lagos State is a dynamic and rapidly evolving region, serving as a crucial economic, cultural, and administrative center in Nigeria. Its strategic location, tropical climate, and unique coastal characteristics shape its development and environmental challenges. While the state continues to experience rapid growth and urbanization, addressing critical issues such as waste management, housing, potable water supply, and climate resilience remains vital for sustainable development.

Sample Size and Sampling Technique

To ensure a representative and unbiased selection, I randomly chose a total of thirty (30) sachet water samples from three (3) Local Government Areas (LGAs) within Lagos Mainland. Specifically, ten (10) samples were collected from each of the following LGAs: Ojo, Amuwo-Odofin, and Lagos Mainland Local Government Areas. This sampling was conducted in March 2023, a period chosen to minimize seasonal variations in water quality that might occur due to changes in rainfall patterns or temperature fluctuations.

The sachet water samples were sourced from various points of sale, including local markets, eateries, and motor parks, to ensure a diverse range of sources commonly patronized by residents of these areas. To enhance the reliability of the study, I prioritized purchasing sachet water brands that were the most popular within each Local Government Area. This approach was crucial in ensuring that the selected samples were truly representative of the predominant sachet water consumed by the residents in the respective LGAs.

Each sample was carefully labeled using an annotation system to facilitate proper identification and tracking. The samples collected from Ojo were designated as OJ-01 to OJ-10, those from Amuwo-Odofin were labeled AO-01 to AO-10, and those from Lagos Mainland were coded as LM-01 to LM-10 (Table 1). Immediately after collection, all sachet water samples were placed in a cooling chest to maintain a stable room temperature of approximately 25°C. This step was essential in preventing any potential chemical or microbial alterations that could compromise the accuracy of subsequent laboratory analyses.

Following the collection process, the samples were promptly transported to the laboratory for detailed physicochemical and microbiological analyses. Throughout this process, strict quality assurance and control measures were observed to ensure the reliability and validity of the results. The laboratory adhered to standardized protocols for water quality assessment, ensuring that all procedures were carried out under controlled conditions to minimize contamination or external influences that could affect the findings.

Table 1. Annotated Representative Water Samples Taken and Analyzed from the Three Local Governments

S/No	Water Sachet Brand	Address of Water Sachet Brand	Local Council Development (LCD)	Local Government Area (LGA)	Annotation of Samples
1.	Branca Water	24 Road Singer Compound, Festac Town, Lagos	Amuwo – Odofin	Amuwo – Odofin	AO – 01 to AO – 10
2.	Orisun Water	21, Olokobi Street, Shibiri Ekunpa, Oto-Awori, Lagos	Oto-Awori	Ojo	OJ – 01 to OJ – 10
3.	More Life Water	56, Sholanke Street, Akoko, Lagos	Yaba	Lagos Mainland	LM – 01 to LM – 10

Analysis

All representative samples underwent comprehensive physicochemical and microbial analysis, following the established guidelines outlined by the American Public Health Association [5]. The physicochemical parameters assessed included pH, turbidity, total solids (TS), total dissolved solids (TDS), electrical conductivity (EC), salinity, dissolved oxygen (DO), biological oxygen demand (BOD), alkalinity, acidity, total hardness, and the presence of calcium, magnesium, and trace metals.

Additionally, microbial parameters were evaluated to determine the total coliform, faecal coliform, and total heterotrophic bacteria plate counts (HPC/THB). All analyses were conducted in a certified, standard laboratory to ensure accuracy, reliability, and compliance with industry standards.

Results

Physicochemical Results of the Analyzed Water Samples

The suitability, potability, and acceptability of water for drinking, recreational, domestic, and industrial purposes are influenced by its physicochemical properties [8]. The physicochemical parameters of water samples from three Local Government Areas (LGAs) under study—Amuwo-Odofin (AO), Ojo (OJ), and Lagos Mainland (LM)—are presented in Tables 2-4.

Physicochemical Parameters

The pH values at room temperature (25°C) ranged from 6.83–7.35 (AO), 6.87–7.74 (OJ), and 6.88–7.50 (LM). Water temperature varied from 25.8–27.3°C (AO), 25.4–28.6°C (OJ), and 26.1–27.3°C (LM). Electrical Conductivity (EC) values, measured in microsiemens per centimeter (µS/cm), ranged from 43.3–48.1 µS/cm (AO), 23.3–31.6 µS/cm (OJ), and 131.6–134.8 µS/cm (LM).

Turbidity was consistently <1 NTU across all locations. Salinity levels were 0.02 ppt (AO), 0.01 ppt (OJ), and 0.07 ppt (LM). Total Dissolved Solids (TDS) concentrations varied from 30.7–34.1 mg/L (AO), 16.5–22.6 mg/L (OJ), and 93.5–96.2 mg/L (LM), while alkalinity levels ranged from 40.0–80.0 mg/L (AO), 26.0–60.0 mg/L (OJ), and 1.0–50.0 mg/L (LM).

Acidity was recorded between 1.00–5.00 mg/L (AO), 2.00–6.00 mg/L (OJ), and 1.00–7.00 mg/L (LM). Total Suspended Solids (TSS) ranged from <1.00–8.00 mg/L (AO), <1.00–5.00 mg/L (OJ), and <1.00–3.00 mg/L (LM). Total Solids (TS) concentrations varied between 28.1–41.0 mg/L (AO), 15.0–23.4 mg/L (OJ), and 90.1–102.0 mg/L (LM).

Total Hardness values were 18.0–36.0 mg/L (AO), 19.0–38.0 mg/L (OJ), and 1.0–26.0 mg/L (LM), while Dissolved Oxygen (DO) levels ranged from 4.95–6.85 mg/L (AO), 4.88–6.87 mg/L (OJ), and 5.01–5.71 mg/L (LM). Biological Oxygen Demand (BOD) levels were 0.02–4.23 mg/L (AO), 0.04–3.10 mg/L (OJ), and 0.08–1.74 mg/L (LM).

Mineral Composition

The Calcium (Ca) concentrations were 3.61–7.21 mg $CaCO_3$/L (AO), 3.81–7.62 mg $CaCO_3$/L (OJ), and 2.00–5.21 mg $CaCO_3$/L (LM). Magnesium (Mg) levels varied from 1.94–3.48 mg $CaCO_3$/L (AO), 1.84–3.68 mg $CaCO_3$/L (OJ), and 0.97–2.52 mg $CaCO_3$/L (LM).

These results highlight variations in water quality across the studied LGAs, providing insight into its suitability for various uses.

Table 2a. Physico-Chemical Parameters of the Annotated Representative Water Samples Taken and Analyzed from Amuwo-Odofin (AO) Local Government

S. No	PHYSICO-CHEMICAL PARAMETERS	ANNOTATED WATER SAMPLES				
		AO- 01	AO- 02	AO- 03	AO- 04	AO- 05
1	pH @ 25^0C	7.04	6.86	6.74	6.85	6.98

2	Temperature (^{0}C)	26.5	26.8	26.5	27.3	25.8
3	Conductivity (µs/cm)	47.10	45.90	48.0	46.40	43.30
4	Turbidity (NTU)	<1	<1	<1	<1	<1
5	Salinity (ppt)	0.02	0.02	0.02	0.02	0.02
6	TDS (mg/L)	33.5	32.6	34.10	32.90	30.7
7	Alkalinity (mg/L)	48.0	80.0	75.0	60.0	65.0
8	Total Hardness (mg $CaCO_3$/L)	20.0	20.0	35.0	18.0	27.0
9	TSS (mg/L)	1.0	5.0	1.0	<1	<1
10	Total Solid (mg/L)	32.8	35.0	33.5	34.0	28.1
11	Acidity (mg/L)	1.00	2.00	1.00	2.00	3.0
12	DO (mg/L)	5.58	5.01	5.14	6.85	4.95
13	BOD (mg/L)	1.08	1.26	1.28	0.82	4.23
14	Calcium (mg $CaCO_3$/L)	4.01	4.01	7.01	3.61	5.41
15	Magnesium (mg $CaCO_3$/L)	1.94	1.94	3.39	1.74	2.61

Table 2b. Physico-Chemical Parameters of the Annotated Representative Water Samples Taken and Analyzed from Amuwo-Odofin (AO) Local Government

SN	**PHYSICO-CHEMICAL PARAMETERS**	**ANNOTATED WATER SAMPLES**				
		AO- 06	**AO- 07**	**AO- 08**	**AO- 09**	**AO- 10**
1	pH @ 25^{0}C	6.85	6.99	7.35	6.89	6.83
2	Temperature (^{0}C)	26.2	26.3	27.0	27.3	25.8
3	Conductivity (µs/cm)	45.30	47.70	45.90	46.7	48.10
4	Turbidity (NTU)	<1	<1	<1	<1	<1
5	Salinity (ppt)	0.02	0.02	0.02	0.02	0.02
6	TDS (mg/L)	32.10	33.9	32.6	33.0	34.0
7	Alkalinity (mg/L)	40.0	49.0	50.0	53.0	50.0
8	Total Hardness (mg $CaCO_3$/L)	24.0	25.0	36.0	20.0	28.0
9	TSS (mg/L)	1.0	<1	1.0	1.0	8.0
10	Total Solid (mg/L)	34.1	32.5	36.0	37.0	41.0
11	Acidity (mg/L)	1.00	4.0	4.0	5.00	5.0
12	DO (mg/L)	5.20	5.24	4.96	5.07	4.96
13	BOD (mg/L)	1.39	2.02	0.70	1.80	0.02
14	Calcium (mg $CaCO_3$/L)	4.81	5.01	7.21	4.01	5.61
15	Magnesium (mg $CaCO_3$/L)	2.32	2.42	3.48	1.94	2.71

Table 3a. Physico-Chemical Parameters of the Annotated Representative Water Samples Taken and Analyzed from Ojo (OJ) Local Government

S. No	PHYSICO-CHEMICAL PARAMETERS	ANNOTATED WATER SAMPLES				
		OJ – 01	**OJ – 02**	**OJ – 03**	**OJ – 04**	**OJ – 05**
1	pH @ 25^0C	7.62	7.74	6.88	6.96	6.87
2	Temperature (^{0}C)	26.4	26.5	26.8	25.9	26.3
3	Conductivity (µs/cm)	23.9	23.30	28.20	24.20	31.60
4	Turbidity (NTU)	<1	<1	<1	<1	<1
5	Salinity (ppt)	0.01	0.01	0.01	0.01	0.01
6	TDS (mg/L)	17.0	16.50	19.90	17.20	22.60
7	Alkalinity (mg/L)	60.0	48.0	36.0	50.0	40.0
8	Total Hardness (mg $CaCO_3$/L)	19.0	26.0	32.0	30.0	26.0
9	TSS (mg/L)	1.0	<1	1.0	5.0	2.0
10	Total Solid (mg/L)	15.0	15.0	23.4	20.0	21.5
11	Acidity (mg/L)	5.0	5.0	6.0	3.0	2.0
12	DO (mg/L)	5.45	5.15	5.06	6.87	4.97
13	BOD (mg/L)	0.76	0.04	0.26	1.28	1.40
14	Calcium (mg $CaCO_3$/L)	3.81	5.21	6.41	6.01	5.21
15	Magnesium (mg $CaCO_3$/L)	1.84	2.52	3.09	2.90	2.52

Table 3b. Physico-Chemical Parameters of the Annotated Representative Water Samples Taken and Analyzed from Ojo (OJ) Local Government

S. No	PHYSICO-CHEMICAL PARAMETERS	ANNOTATED WATER SAMPLES				
		OJ – 06	OJ – 07	OJ – 08	OJ – 09	OJ – 10
1	pH @ 25^0C	7.29	7.50	6.88	7.11	7.22
2	Temperature (^{0}C)	28.6	26.8	25.5	25.4	26.8
3	Conductivity (µs/cm)	25.10	27.70	24.40	28.5	30.20
4	Turbidity (NTU)	<1	<1	<1	<1	<1
5	Salinity (ppt)	0.01	0.01	0.01	0.01	0.01
6	TDS (mg/L)	17.90	19.90	17.3	17.5	18.2
7	Alkalinity (mg/L)	26.0	27.0	30.0	35.0	55.0
8	Total Hardness (mg $CaCO_3$/L)	20.0	21.0	38.0	25.0	20.0
9	TSS (mg/L)	1.0	3.0	<1	<1	<1
10	Total Solid (mg/L)	19.30	18.2	19.0	20.0	16.30
11	Acidity (mg/L)	5.0	3.0	2.0	2.0	3.0
12	DO (mg/L)	4.88	5.08	5.16	5.40	5.73
13	BOD (mg/L)	3.10	1.05	1.20	1.90	1.20
14	Calcium (mg $CaCO_3$/L)	4.01	4.21	7.62	5.01	4.01

15	Magnesium (mg $CaCO_3$/L)	1.94	2.03	3.68	2.42	1.94

Table 4a. Physico-Chemical Parameters of the Annotated Representative Water Samples Taken and Analyzed from Lagos Mainland (LM) Local Government

S. No	**PHYSICO-CHEMICAL PARAMETERS**	**ANNOTATED WATER SAMPLES**				
		LM – 01	LM – 02	LM – 03	LM – 04	LM – 05
1	pH @ 25^0C	7.10	7.11	7.08	7.13	6.96
2	Temperature (^{0}C)	27.1	27.3	27.0	26.9	26.4
3	Conductivity (µs/cm)	132.70	131.60	131.60	133.30	132.10
4	Turbidity (NTU)	<1	<1	<1	<1	<1
5	Salinity (ppt)	0.07	0.07	0.07	0.07	0.07
6	TDS (mg/L)	94.2	93.5	93.5	94.0	93.8
7	Alkalinity (mg/L)	30.0	1.0	7.0	5.0	7.0
8	Total Hardness (mg $CaCO_3$/L)	25.0	24.0	25.0	21.0	26.0
9	TSS (mg/L)	2.0	3.0	<1	<1	3.0
10	Total Solid (mg/L)	99.0	102.0	90.10	97.8	95.0
11	Acidity (mg/L)	3.0	1.0	7.0	5.0	7.0
12	DO (mg/L)	5.43	5.05	5.7	5.01	5.47
13	BOD (mg/L)	0.20	0.88	0.14	1.74	1.32
14	Calcium (mg $CaCO_3$/L)	5.01	4.81	5.01	4.21	5.21
15	Magnesium (mg $CaCO_3$/L)	2.42	2.32	2.42	2.03	2.52

Table 4b. Physico-Chemical Parameters of the Annotated Representative Water Samples Taken and Analyzed from Lagos Mainland (LM) Local Government

S. No	**PHYSICO-CHEMICAL PARAMETERS**	**ANNOTATED WATER SAMPLES**				
		LM – 06	**LM – 07**	**LM – 08**	**LM – 09**	**LM – 10**
1	pH @ 25^0C	7.37	7.09	7.15	7.22	7.10
2	Temperature (^{0}C)	26.5	26.1	26.5	27.0	26.8
3	Conductivity (µs/cm)	134.80	134.20	133.80	131.60	133.90
4	Turbidity (NTU)	<1	<1	<1	<1	<1
5	Salinity (ppt)	0.07	0.07	0.07	0.07	0.07
6	TDS (mg/L)	95.80	96.2	94.50	93.5	95.0
7	Alkalinity (mg/L)	45.0	40.0	50.0	38.0	30.0
8	Total Hardness (mg $CaCO_3$/L)	25.0	10.0	15.0	20.0	26.0
9	TSS (mg/L)	<1	<1	3.0	<1	3.0

10	Total Solid (mg/L)	96.0	97.0	100.0	95.1	94.2
11	Acidity (mg/L)	1.0	3.0	3.0	5.0	5.0
12	DO (mg/L)	5.68	5.34	5.71	5.44	5.33
13	BOD (mg/L)	1.30	1.30	0.16	0.08	1.72
14	Calcium (mg $CaCO_3$/L)	5.01	2.0	3.01	4.01	5.21
15	Magnesium (mg $CaCO_3$/L)	2.42	0.97	1.45	1.94	2.52

Heavy Metals in Analyzed Water Samples

The analyzed packaged sachet water samples from three Local Government Areas (LGAs) — Amuwo-Odofin (AO), Ojo (OJ), and Lagos Mainland (LM) — contained Iron (Fe), Lead (Pb), Zinc (Zn), and Chromium (Cr), with concentrations summarized in Tables 5–7.

- Iron (Fe) (mg/L): Ranged from 0.02–0.07 (AO), 0.02–0.05 (OJ), and 0.01–0.07 (LM) (Tables 5–7).
- Lead (Pb) (mg/L): Levels were <0.001 (AO), <0.001–0.0032 (OJ), and <0.001–0.0027 (LM) (Tables 5–7).
- Zinc (Zn) (mg/L): Ranged from 0.60–0.531 (AO), 0.031–0.153 (OJ), and 0.020–0.041 (LM) (Tables 5–7).
- Chromium (Cr) (mg/L): Detected at <0.001–0.006 (AO), <0.001 (OJ), and <0.001–0.065 (LM) (Tables 5–7).

Table 5. Heavy Metals Concentrations Present in the Annotated Representative Water Samples Taken and Analyzed from Amuwo-Odofin (AO) Local Government

S. No	**Heavy Metals (mg/L)**	**ANNOTATED WATER SAMPLES**				
		AO- 01	**AO- 02**	**AO – 03**	**AO- 04**	**AO - 05**
1	Iron	0.07	0.02	0.02	0.02	0.03
2	Lead	<0.001	<0.001	<0.001	<0.001	<0.001
3	Zinc	0.140	0.070	0.100	0.086	0.531
4	Chromium	<0.001	0.0060	0.0051	<0.001	<0.001
	Heavy Metals (mg/L)	**AO- 06**	**AO- 07**	**AO- 08**	**AO- 09**	**AO - 10**
1	Iron	0.05	0.03	0.03	0.05	0.04
2	Lead	<0.001	<0.001	<0.001	<0.001	<0.001
3	Zinc	0.60	0.078	0.041	0.181	0.110
4	Chromium	<0.001	<0.001	<0.001	<0.001	<0.001

Table 6. Heavy Metals Concentrations Present in the Annotated Representative Water Samples Taken and Analyzed from Ojo (OJ) Local Government

S. No	**Heavy Metals (mg/L)**	**ANNOTATED WATER SAMPLES**				
		OJ – 01	**OJ – 02**	**OJ – 03**	**OJ-04**	**OJ – 05**
1	Iron	0.03	0.02	0.02	0.02	0.02
2	Lead	<0.001	<0.001	0.0015	<0.001	<0.001
3	Zinc	0.031	0.060	0.122	0.094	0.050
4	Chromium	<0.001	<0.001	<0.001	<0.001	<0.001

	Heavy Metals (mg/L)	OJ –06	OJ – 07	OJ – 08	OJ– 09	OJ – 10
1	Iron	0.02	0.05	0.02	0.04	0.04
2	Lead	0.0032	<0.001	<0.001	0.0022	<0.001
3	Zinc	0.153	0.040	0.060	0.044	0.056
4	Chromium	<0.001	<0.001	<0.001	<0.001	<0.001

Microbial Analysis of Analyzed Water Samples

Microbial analyses assessed Total Coliform, Total Heterotrophic Bacterial (THB) counts, and Faecal Coliform (Tables 8–10).

- Total Coliforms (CFU/mL): Not detected (ND) in all samples (Tables 8–10).
- Total Heterotrophic Bacterial (THB) Counts (CFU/mL):
  - AO: $1.0 \times 10^0 – 6.0 \times 10^1$ (Table 8).
  - OJ: $2.0 \times 10^0 – 3.4 \times 10^1$ (Table 9).
  - LM: $7.0 \times 10^0 – 5.6 \times 10^1$ (Table 10).

Table 7. Heavy Metals Concentrations Present in the Annotated Representative Water Samples Taken and Analyzed from Lagos Mainland (LM) Local Government

S. No	Heavy Metals (mg/L)	ANNOTATED WATER SAMPLES				
		LM–01	LM –02	LM –03	LM-04	LM – 05
1	Iron	0.01	0.02	0.04	0.02	0.07
2	Lead	0.0018	0.0012	0.0017	0.0022	0.0021
3	Zinc	0.033	0.0028	0.030	0.040	0.020
4	Chromium	<0.001	<0.001	0.0065	0.004	<0.001
	Heavy Metals (mg/L)	**LM–06**	**LM –07**	**LM –08**	**LM-09**	**LM – 10**
1	Iron	0.03	0.04	0.03	0.03	0.04
2	Lead	<0.001	<0.001	<0.001	0.0027	0.0021
3	Zinc	0.03	0.041	0.026	0.040	0.036
4	Chromium	<0.001	0.0064	<0.001	<0.001	<0.001

These results highlight the variations in heavy metal concentrations and microbial presence across the studied LGAs.

Table 8. Microbial Properties of the Annotated Representative Water Samples Taken and Analyzed from Amuwo-Odofin (AO) Local Government

S. No	Microbial Properties (CFU/ml)	ANNOTATED WATER SAMPLES				
		AO – 01	AO – 02	AO – 03	AO – 04	AO – 05
1	Total Coliform	ND	ND	ND	ND	ND
2	THB	4.0×10^1	2.3×10^1	1.7×10^1	8.0×10^0	2.1×10^1
3	Faecal Coliform	ND	ND	ND	ND	ND

	Microbial Properties (CFU/ml)	AO- 06	AO- 07	AO- 08	AO- 09	AO- 10
1	Total Coliform	ND	ND	ND	ND	ND
2	THB	6.0×10^1	1.5×10^1	2.5×10^1	1.0×10^0	4.2×10^1
3	Faecal Coliform	ND	ND	ND	ND	ND

Discussion

Interpretation of Water Sample Analysis Results

The laboratory results were compared to standards set by FEPA, NAFDAC, WHO, NIS, and NSDW. Any parameter exceeding the specified limit indicates compromised water quality, while values below the limit or marked as NS (Not Stated) or NG (No Guideline) indicate potable water.

Table 9. Microbial Properties of the Annotated Representative Water Samples Taken and Analyzed from Ojo (OJ) Local Government

S. No	Microbial Properties (CFU/ml)	ANNOTATED WATER SAMPLES				
		OJ– 01	OJ– 02	OJ– 03	OJ– 04	OJ– 05
1	Total Coliform	ND	ND	ND	ND	ND
2	THB	3.4×10^1	3.1×10^1	2.8×10^1	3.3×10^1	2.0×10^0
3	Faecal Coliform	ND	ND	ND	ND	ND
	Microbial Properties (CFU/ml)	**OJ – 06**	**OJ – 07**	**OJ – 08**	**OJ – 09**	**OJ – 10**
1	Total Coliform	ND	ND	ND	ND	ND
2	THB	2.4×10^1	3.0×10^1	2.1×10^1	1.8×10^1	2.8×10^1
3	Faecal Coliform	ND	ND	ND	ND	ND

Physico-Chemical Analysis

- **Color & Turbidity**: All samples were colorless and had turbidity below 1 NTU, meeting regulatory standards.
- **pH Levels**: Ranged from 6.83 to 7.74 across the three LGAs, within the permissible 6.5–8.5 range, confirming potability.
- **Temperature**: Values between 25.4°C and 28.6°C were within the WHO limit of 40°C or ambient temperature.
- **Dissolved Oxygen (DO)**: Ranged from 4.88–6.87 mg/L; within WHO's 6 mg/L limit, indicating good quality.
- **Biological Oxygen Demand (BOD)**: Ranged from 0.02–4.23 mg/L, well below the 6–50 mg/L limit, confirming safe quality.
- **Electrical Conductivity (EC)**: Ranged from 23.3–134.8 µs/cm, far below the 1000 µs/cm threshold.
- **Salinity**: All samples had values (0.01–0.07 ppt) significantly below the 200 ppt WHO limit.
- **Alkalinity & Acidity**: Alkalinity (1.0–80.0 mg/L) was well within WHO's 120–600 mg/L limit. Acidity levels were negligible.

- **Total Dissolved Solids (TDS)**: Ranged from 16.5–96.2 mg/L, well below limits set by FEPA (2000 mg/L), WHO (600 mg/L), and NAFDAC (500 mg/L).
- **Total Suspended Solids (TSS) & Total Solids (TS)**: TSS values (1.00–8.00 mg/L) were well below regulatory limits. TS values showed no stated regulatory threshold but were within expected potable ranges.
- **Hardness**: Total hardness (1.00–38.00 mg/L) categorized the water as soft. Calcium (2.00–7.62 mg/L) and Magnesium (0.97–3.68 mg/L) levels were within acceptable limits.

The analyzed packaged water samples from Amuwo-Odofin, Ojo, and Lagos Mainland LGAs met the potability standards of regulatory bodies, confirming their safety for consumption.

Table 10. Microbial Properties of the Annotated Representative Water Samples Taken and Analyzed from Lagos Mainland (LM) Local Government

S. No	Microbial Properties (CFU/ml)	ANNOTATED WATER SAMPLES				
		LM–01	**LM– 02**	**LM – 03**	**LM– 04**	**LM – 05**
1	Total Coliform	ND	ND	ND	ND	ND
2	THB	5.6×10^1	9.0×10^0	1.4×10^1	1.5×10^1	2.0×10^1
3	Faecal Coliform	ND	ND	ND	ND	ND
	Microbial Properties (CFU/ml)	**LM – 06**	**LM – 07**	**LM – 08**	**LM – 09**	**LM – 10**
1	Total Coliform	ND	ND	ND	ND	ND
2	THB	ND	7.0×10^0	1.3×10^1	ND	1.2×10^1
3	Faecal Coliform	ND	ND	ND	ND	ND

Interpretation of Heavy Metal and Microbial Analysis of Packaged Sachet Water

Heavy Metal Assessment

The analysis of sachet water samples from Amuwo-Odofin, Ojo, and Lagos Mainland Local Government Areas showed the following heavy metal concentrations (mg/L):

- **Iron (Fe):** 0.01–0.07 mg/L (all well below the 0.3 mg/L limit set by WHO, 2011).
- **Lead (Pb):** <0.001–0.0032 mg/L (within regulatory limits of 0.01–<1 mg/L set by FEPA, NAFDAC, WHO, NIS, and NSDW).
- **Zinc (Zn):** 0.020–0.60 mg/L (within the general limit of <1–3 mg/L; NIS has no specified limit).
- **Chromium (Cr):** <0.001–0.065 mg/L (well within regulatory limits of 0.05 mg/L; NIS has no specified limit).

The findings confirm that the sachet water samples are free from heavy metal toxicity, making them safe for commercial and domestic use, in line with previous studies [8, 14].

Microbial Assessment

Microbial analysis of the water samples showed:

- **Total Heterotrophic Bacteria Plate Counts (HPC/THB) and Faecal Coliforms:** Not detected in any samples.
- **HPC/THB Range:**

1. Amuwo-Odofin: $1.0 \times 10^0 – 6.0 \times 10^1$ CFU/mL
2. Ojo: $2.0 \times 10^0 – 3.4 \times 10^1$ CFU/mL
3. Lagos Mainland: $7.0 \times 10^0 – 5.6 \times 10^1$ CFU/mL

All values fall within WHO and NSDW limits (≤100 CFU/mL, [6, 17]).

The results confirm the microbial safety of the sachet water, indicating that production

processes—water sourcing, treatment, and packaging—meet quality standards [6, 15].

Summary and Conclusion

This study assessed 30 representative samples of commercially packaged sachet water from three Local Government Areas in Lagos Mainland—Amuwo-Odofin, Ojo, and Lagos Mainland—to determine their suitability for drinking. The samples were analyzed for physico-chemical, heavy metal, and microbial properties.

The **physico-chemical analysis** (including pH, temperature, BOD, DO, turbidity, color, TSS, TS, TDS, EC, salinity, acidity, alkalinity, total hardness, calcium, and magnesium) confirmed that all values were within acceptable limits set by regulatory bodies.

The **heavy metal analysis** (Iron, Zinc, Chromium, and Lead) revealed concentrations within permissible limits, posing no risk of toxicity.

The **microbial analysis** (Total Coliform, Faecal Coliform, and Total Heterotrophic Bacteria Plate Counts) showed that all samples met the required safety standards, with no harmful microbial contamination detected.

Based on these findings, the commercially packaged sachet water produced in the studied areas is deemed safe for drinking and domestic use, free from heavy metal toxicity and microbial contamination.

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