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EVALUATION OF THE PORTABILITY OF SACHET WATER USING WEIGHTED ARITHMETIC WATER QUALITY INDEX AND WATER POLLUTION INDEX IN ASABA METROPOLIS, SOUTHERN NIGERIA

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ABSTRACT

This study explored the potability of sachet water in Asaba, Southern Nigeria, using the Weighted Arithmetic Water Quality Index (WQIA) and Water Pollution Index (WPI). Using established parameters, the pH, turbidity, electrical conductivity, total dissolved solids (TDS), sulphate, phosphate, chloride, zinc, lead, and iron of 100 sachet water samples obtained from different retail locations in Asaba were analyzed. The results of the investigation were compared to the WHO and SON drinking water guidelines. The WQIA was used to categorize overall quality of sachet water, while the WPI provided details on the pollution status of each sample. The results showed that turbidity was between (0.00 - 0.62 NTU), pH (6.50 -7.60), electrical conductivity (24.60 -77.20 µS/cm), total dissolved solids (12.10 - 65.30 mg/L), sulphate (0.18 - 2.65 mg/L), phosphate (0.01 - 0.04 mg/L), chloride (3.10 - 39.30 mg/L), zinc (0.00 - 0.05 mg/L), lead (0.000 - 0.007 mg/L) and iron (0.02 - 0.09 mg/L. These results were all within the acceptable range for drinking water. The WQI value of 5.61 classified the sachet water as excellent, whilst the WPI value of 0.26 showed a very low pollution load. According to these results, the Asaba Metropolis' sachet water is of excellent quality and safe for ingestion by humans. In order to uphold these high standards and guarantee ongoing public health protection, the article highlights the efficacy of present production techniques and regulatory processes while advising ongoing monitoring and quality verification.

Keywords: Evaluation, Potability, Water Pollution Index, Water Quality Index, Sachet Water

INTRODUCTION

Human nutrition usually requires water, either directly as drinking water or indirectly as a component of food. Water continues to be the primary source of illness and infant mortality in both industrialized and developing countries, despite its everyday applications. It is essential to existence as well. Water quality is dependent on how it is used because it may present harmful health and environmental risks to the general public (Mukate *et al.,* 2019; Hossain and Patra, 2020; Chukwurah *et al.,* 2023; Ochuko *et al.,* 2024). The sixth Sustainable Development Goal (SDG) is access to clean water (Oludairo and Aiyedun, 2015). Sadly, many nations still struggle to provide their citizens with access to safe drinking water, particularly developing nations like Nigeria (WHO/UNICEF, 2010; Naziru *et al.,* 2023). Majority of people still lack access to safe drinking water, despite the fact that governments in developing countries devote a small portion of their national budget to treating avoidable waterborne infections (Cobbina *et al.,* 2013; Olukanni *et al.,* 2014; Oloruntoba *et al.,* 2016; *Olannye et al.,* 2017; Oloruntoba and Olannye, 2019; Ochuko *et al.,* 2024).

Nigeria has been manufacturing sachet water since the 1990s, and because of scientific and technological developments, the industry is currently one of the fastest-growing in the nation (Airaodion *et al.,* 2019). More locally made sachet water, known as "clean water" in Nigeria, is being produced, sold, and consumed in Nigerian towns and rural areas as well as in many other parts of the continent (Muhammad and Dansabo, 2018). Public health in Nigeria is at risk due to the ongoing rise in the sale and careless consumption of packaged drinking water (Oyedeji *et al.,* 2010). Although packaged water was uncommon twenty years ago, many people now depend on it (Rahman *et al.,* 2017). In the majority of underdeveloped countries, where public drinking water is limited and unavailable, groundwater from boreholes is packaged into plastic materials (sachet water) for human consumption as an alternative source of sustainable drinking water. People buy and consume professionally produced, processed, and sealed water in polythene sachets or bags. The lower costs and cleaner drinking water provided by this profitable enterprise mostly benefit Nigeria's lowest socioeconomic levels (Dada, 2011). As a less costly alternative to bottled water, sachet drinking water was brought to Nigerian markets. Before water is considered suitable for human consumption, it must fulfill a variety of physical, chemical, and microbiological standards. The purpose of these rules is to ensure that the water is suitable for human consumption. Potable water is defined as water that is devoid of contaminants such as harmful chemicals and microorganisms. Public health is at risk from chemical contaminants in drinking water, which can have detrimental impacts on health right away (Yousefi *et al.,* 2017).

The importance of a drinking water supply for the socioeconomic well-being of the populace cannot be overstated. The health of a town is often impacted by the source and flow of its water supply. Water that is meant for human consumption must be clean, safe, and tasty. In reality, the quality of the water sources should not exceed the top limits specified in the standards for water quality (Obi *et al.,* 2004). Drinking untreated or insufficiently treated water has resulted in numerous disease outbreaks and poisonings over the world (Fong *et al.,* 2007; Ochuko *et al.,* 2024). Several sachet water quality evaluations have found violations of international quality standards (Ibrahim *et al.,* 2015; Meride and Ayenew, 2016; and Airaodion *et al.,* 2019). According to the Institute of Public Analysts of Nigeria (IPAN), half of the sachet water sold on the streets of Lagos is unsafe for human consumption (Osibanjo *et al.,* 2000).

Due to their inability to access high-quality drinking water, residents of Asaba City have mostly become reliant on bottled sachet water, which they perceive to be safe and clean. Their consumption has increased dramatically as a result. The growing demand for this drinking water product is primarily due to the region's geology and the absence of reliable, clean municipal water. However, before packaging the water for retail sale, some manufacturers of packaged or sachet water neglect to sufficiently evaluate the water's cleanliness (Emenike *et al.,* 2017). The taste and appearance of packaged water are unfortunately valued more by most consumers than the inherent, potentially dangerous loads of contaminants, which include physical (turbidity, suspended solids), chemical (organic, bisphenol A, phthalate esters, and polycyclic aromatic hydrocarbons), and microbiological (total coliform, Escherichia coli) contaminants (Mgbakor *et al.,* 2012).

Drinking water must be free of physical, chemical, and microbiological contaminants in proportions that are not hazardous to human health in order to meet WHO drinking water quality guidelines. However, it has been demonstrated that sachet-packed water contains components such as calcium, chromium, iron, and aluminum (Emenike *et al.,* 2018). Similarly, it has been shown that groundwater contains higher than permitted levels of manganese, nickel, lead, and cadmium (Ayedun *et al.,* 2015). Furthermore, in certain regions of Nigeria, groundwater has been found to have higher than permitted levels of fluoride (Emenike *et al.,* 2018) and light polycyclic aromatic hydrocarbons (Adekunle *et al.,* 2017).

To address these problems and assess the overall safety of sachet water, instruments like the Weighted Arithmetic Water Quality Index (WQI_A) and the Water Pollution Index (WPI) have been developed. These indices offer a thorough approach to evaluating water quality by combining multiple data points on water quality into a single composite index. The WQI_A is particularly helpful since it rates each signal based on its importance for water quality and human health. By integrating physical, chemical, and microbiological elements, it generates a single score that reflects the overall quality of the water (Bharti and Katyal, 2011; Akoteyon *et al.,* 2011; and Ochuko *et al.,* 2023). Good water quality is indicated by a high WQI_A score, whereas contamination or other problems with water quality are indicated by a low score (Opafola *et al.,* 2020). WQI seeks to convert complex water quality data into information that the general public can understand and utilize to determine whether water is fit for drinking and for the long-term maintenance of public health.

In a similar manner, the WPI assesses the degree of contamination from several pollutants to determine the level of pollution in the water. It is a helpful tool for identifying potentially contaminated water sources and evaluating the water quality in different locations. The WPI can categorize water as having low, moderate, or severe pollution levels, guiding the required safety and health measures, claim Hossain and Patra (2020). These indicators are helpful tools for controlling the quality of water, particularly in environments where monitoring and management are inconsistent. By using the WQI_A and WPI to guide their decisions on water treatment, storage, and distribution practices, stakeholders can ensure that sachet water meets all safety standards and is safe for human consumption.

Studies conducted in Nigeria have revealed varying degrees of water contamination in sachet water, especially in urban areas where demand is high but regulatory control may be inadequate (Opafola *et al.,* 2020; Uche *et al.,* 2022; Okeola *et al.,* 2023). For instance, Akinsola and Oyewumi (2021) assessed the quality of sachet water brands in Ondo State and discovered that most of them did not meet acceptable standards. In a similar vein, research on the quality of packaged water in Northern Nigeria by Okeola *et al.* (2023) and Ezeugwunne *et al.* (2009) focused on the effects of prolonged storage on water safety. No comparable study has been conducted in Asaba, Delta State, despite numerous tests in other parts of Nigeria showing that the sachet water does not fulfill the basic WHO quality requirements. Thus, the goal of this study is to evaluate the drinking water quality of sachets in Asaba Metropolis using the WQI_A and WPI indices. These indicators are used to identify areas with high levels of contamination, determine whether the water is fit for human consumption, and recommend modifications to water management practices. This study will also contribute to the growing body of knowledge on water quality management in urban Nigeria and help policy initiatives to ensure that consumers have access to clean drinking water.

MATERIALS AND METHODS

Area of Study

Asaba is the Capital of Delta State, Nigeria. A rapidly rising city located along the western bank of the Niger River, in Oshimilli South Local Government Area. Between latitude 6^0 11'53.7"N and longitude 6^0 43'54.7"E, Asaba is tucked away (Figure 1). It is situated roughly 160 kilometers north of the point where the Niger River empties into the Atlantic Ocean, 60 degrees north of the equator, and the same distance east of the meridian. The size of the greater Asaba is roughly 300 square kilometers. Throughout the rainy season, Asaba receives 2,700 mm of fertile rainfall on average, while throughout the dry season, it maintains an average tropical temperature of 32. The native tongue of Asaba and the nearby communities is Ibo. Asaba's population has increased since it became the capital of Delta State, and its generally non-indigenous, cosmopolitan populace is still there today. Because of its advantageous location, it serves as a center for social and economic activity, drawing both locals and tourists. As of the 2006 census, Asaba has 149,603 residents, with a rapidly expanding metropolitan population of more than half a million. The recently founded Dennis Osadebay University is located there.

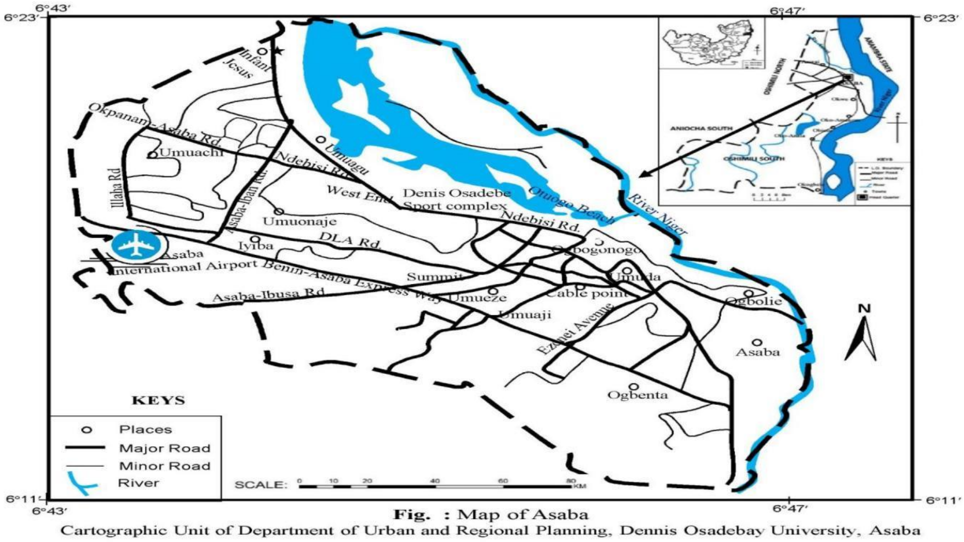

Figure 1: Map of Asaba showing the Study Area

Sample Collection
To ensure adequate representative sampling for meaningful results, a preliminary survey was conducted prior to selecting the sachet water for analysis. Inquiries led to the discovery of well-known brand names that are mostly utilized in the study area. A total of one hundred (100) samples consisting of ten (10) brands that have been approved by the National Agency for Food and Drug Administration and Control (NAFDAC) were chosen at random from water vendors in markets, restaurants/food serving areas (Bukhas), and motor parks over the course of five working days in October and November 2024. The producers in the research region packaged the samples. The evaluation did not reveal the identities of these sachets water in order to protect the customers and participating companies. After being brought to the lab and placed in a refrigerated box, the samples were processed immediately for physico-chemical analysis.

Water Quality Analyses
The Standard Methods for the Examination of Water and Wastewater (APHA, 2005) methods were followed in order to perform the water analysis. Turbidity, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Sulfate (mg/L), Phosphate (mg/L), Chloride, Zinc, Lead, and Iron were among the eleven (11) chosen physico-chemical parameters that were analyzed in the water samples.

Data Analysis
Microsoft Excel and the Statistical Package for Social Sciences (SPSS 20.0) were used to input and analyze the data. In this investigation, descriptive statistics was employed. Descriptive statistics (mean, standard deviation, maximum and minimum values) were used to summarize the levels of turbidity, pH, electrical conductivity, total dissolved solids, dissolved oxygen, sulfate, phosphate, chloride, zinc, lead, and iron for sachet water samples collected from different retail locations throughout Asaba.

Determination of Water Quality Index
The Weighted Arithmetic Mean Method (Figure 2) was used in this study to calculate the Water Quality Index (WQI), which used the most frequently measured water quality variables to classify water quality based on the degree of purity (Bangalore and Latha, 2008; Chauhan *et al.,* 2010; Balan *et al.,* 2012; Chowdhury *et al.,* 2012 and Shweta *et al.,* 2013). Horton (1965) introduced the weighted arithmetic water quality index (WQI_A), which was later improved by Brown *et al.,* (1972).

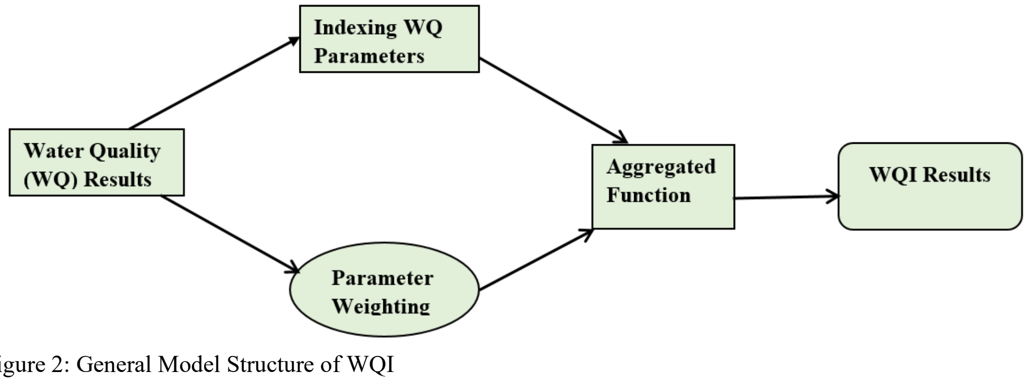

Figure 2: General Model Structure of WQI

The following formulas in equations 1 – 3 were utilized to calculate WQI:

$$WQI_A = \frac{\sum Q_i W_i}{\sum W_i} \quad (1)$$

The quality rating scale (Q_i) for each parameter is calculated by using the expression:

$$Q_i = 100\left(\frac{V_i - V_0}{S_i - V_0}\right) \quad (2)$$

Where,

V_i = Estimated Concentration of the relevant i th parameter in the water under analysis.
V_0 = The optimal ith parameter value in pure water. $V_0 = 0$ (except pH = 7.0; and DO = 14.6 mg/l).
S_i = Recommended Standard value for the i th parameter.
The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$W_i = \frac{K}{S_i}, \quad K = \frac{1}{\sum\left(\frac{1}{S_i}\right)} \tag{3}$$

Where K = proportionality constant and can also be calculated by using the above simultaneous equation.
The rating of water quality according to this WQI is given in Table 1.

Table 1: Classification of Water Quality based on Weighted Arithmetic Water Quality Index Method

WQI Value	Water Quality Status	Grade
0 -25	Excellent	A
26 – 50	Good	B
51 – 75	Poor	C
76 – 100	Very Poor	D
> 100	Unsuitable for drinking purpose	E

Source: Brown *et al.,* (1972), Chatterji and Razuidding (2002), Shweta *et al.,* (2013)

Assessment of Water Contamination (Water Pollution Index [WPI])
WPI is computed using the function in equation 4 and 5:

$$WPI = \frac{1}{n}\sum_{i=1}^{n} PL \tag{4}$$

$$PL = 1 + \left(\frac{I_C - S_d}{S_d}\right) \tag{5}$$

Where S_d is the standard or maximum allowable limit for the several variables taken into consideration, I_c is the measured concentration of the ith parameter, WPI is the Water Pollution Index, n is the number of parameters, and PL stands for Pollution Load. The rating of water quality according to WPI is given in Table 2.

Table 2: Classification of Water Pollution Index (WPI)

Value	Indication
< 0.5	Excellent Water
0.5 – 0.75	Good Water
0.75 – 1	Moderately Polluted Water
>1	Highly Polluted Water

Source: Hossain and Patra, 2020

RESULTS AND DISCUSSION

Result

Tables 3, 4, and 5 display the findings of the study's physico-chemical parameters, water quality index, and water pollution index for the sachet water. The turbidity (0.00 - 0.62 NTU), pH (6.50 -7.60), electrical conductivity (24.60 - 77.20 µS/cm), total dissolved solids (12.10 - 65.30 mg/l), sulphate (0.18 - 2.65 mg/l), phosphate (0.01 - 0.04 mg/L), and chloride (3.10 - 39.30 mg/L) levels of the packaged sachet water were within the World Health Organization (WHO 2011) and the Standard Organization of Nigeria (SON, 2007) limits. The mean dissolved oxygen concentration of the packed sachet water (5.60 mg/l) was within the Standard Organization of Nigeria's (SON, 2007) drinking water limit and slightly above the World Health Organization's (WHO) 2011 drinking water guidelines. Nonetheless, it was found that the concentration ranges for zinc (0.00 - 0.05 mg/l), lead (0.000 - 0.007 mg/L), and iron (0.02 - 0.09 mg/L) were all within the World Health Organization's (WHO, 2011) and Standard Organization of Nigeria's (SON, 2007) permissible limits for drinking water.
The computed results showed that the water quality index (WQI) was 5.61 and the water pollution index (WPI) was 0.26. The sachet water is in the excellent range of the water quality index (WQI) and water pollution index (WPI) classes, as shown in Tables 1 and 2.

Table 3: Summary of the Physico-Chemical Parameters of Sachet Water in Asaba, Metropolis, Southern Nigeria and the Standard Limits Recommended by Standard Organization of Nigeria (SON, 2007) and World Health Organization (WHO, 2011)

Parameter	Test Result (Min - Max)	Mean ± SD	SON, 2007	WHO, 2011
Turbidity(NTU)	0.00 - 0.62	0.44 ± 0.28	5	3
pH	6.50 -7.60	7.02 ± 0.39	6.5 - 8.5	6.5 - 8.5
EC(mS/cm)	24.60 -77.20	46.01 ± 21.40	1000	1000
TDS (mg/L)	12.10 - 65.30	35.13 ± 20.28	500	500
DO (mg/L)	3.54 - 7.15	5.60 ± 1.21	7.5	5.0
Sulphate (mg/L)	0.18 - 2.65	1.13 ± 0.78	100	100
Phosphate (mg/L)	0.01 - 0.04	0.02 ± 0.01	5	10
Chloride (mg/L)	3.10 - 39.30	15.73 ± 11.47	250	250
Zinc(mg/L)	0.00 - 0.05	0.02 ± 0.02	3.0	1.5
Lead (mg/L)	0.000 - 0.007	0.00 ± 0.00	0.01	0.01
Iron (mg/L)	0.02 - 0.09	0.06 ± 0.02	0.3	0.1

Table 4: Calculation of Water Quality Index (WQI) of Sachet Water in Asaba, Metropolis, Southern Nigeria

Parameter	Mean Test Result	WHO Limits (S_i)	K	Weightage (W_i)	Quality Rating (Q_i)	[(W_i) (Q_i)]
Turbidity(NTU)	0.44	3	0.0090	0.003	14.67	0.04401
pH	7.02	6.5 - 8.5	0.0090	0.0011	1.33	0.001463
EC(mS/cm)	46.01	1000	0.0090	0.000009	4.60	0.0000414
TDS (mg/L)	35.13	500	0.0090	0.000018	7.01	0.00012618
DO (mg/L)	5.60	5.0	0.0090	0.0018	93.75	0.16875
Sulphate (mg/L)	1.13	100	0.0090	0.00009	1.13	0.0001017
Phosphate (mg/L)	0.02	10	0.0090	0.0009	0.2	0.00018
Chloride (mg/L)	15.73	250	0.0090	0.000036	6.29	0.00022644
Zinc(mg/L)	0.02	1.5	0.0090	0.006	1.33	0.00798
Lead (mg/L)	0.00	0.01	0.0090	0.9	0.00	0.00
Iron (mg/L)	0.06	0.1	0.0090	0.09	60	5.4
				$\sum W_i$=1.002953		$\sum[(W_i)(Q_i)]$=5.62287872

Table 5: Calculation of Water Pollution Index (WPI) of Sachet Water in Asaba, Metropolis, Southern Nigeria

Parameter	I_c	S_d	I_c-S_d	(I_c-S_d)/S_d	PL=1+(I_c-S_d)/S_d)	WPI
Turbidity(NTU)	0.44	3	-2.56	-0.85	0.15	0.26
pH	7.02	6.5 - 8.5	-1.48	-0.17	0.83	
EC(mS/cm)	46.01	1000	-953.99	-0.95	0.05	
TDS (mg/L)	35.13	500	-464.87	-0.93	0.07	
DO (mg/L)	5.60	5.0	0.6	0.12	1.12	
Sulphate (mg/L)	1.13	100	-98.87	-0.99	0.01	
Phosphate (mg/L)	0.02	10	-9.98	-1.00	0.00	
Chloride (mg/L)	15.73	250	-234.27	-0.94	0.06	
Zinc(mg/L)	0.02	1.5	-1.48	-0.99	0.01	
Lead (mg/L)	0.00	0.01	-0.01	-1	0.00	
Iron (mg/L)	0.06	0.1	-0.04	-0.4	0.6	
					2.9	

Discussion

The study's findings demonstrated that the physicochemical parameters of the sachet water sampled in Asaba Metropolis, Southern Nigeria, fell within the acceptable ranges set by the Standard Organization of Nigeria (SON, 2007) and the World Health Organization (WHO, 2011), two important regulatory bodies. Although the Water Pollution Index (WPI) value of 0.26 indicates a low pollution load (Table 2), the Water Quality Index (WQI) score of 5.61 classifies the water as excellent (Table 1), meaning that consumers don't face any immediate health risks from the analyzed sachet water. It was determined that the physicochemical parameters of pH, turbidity, total dissolved solids, electrical conductivity, and dissolved oxygen (DO) were all within acceptable limits. According to WHO guidelines, drinking water should have a pH of 6.5 to 8.5 to guarantee water palatability and prevent corrosion or scaling (Table 3). The observed turbidity levels were below the 5 NTU limit, indicating proper filtration practices during water treatment. These findings corroborated those of Opafola *et al.,* (2020), who discovered that the turbidity levels of packaged water samples tested in southwest Nigeria were acceptable. The amounts of possible pollutants, including lead, iron, and zinc, were either undetectable or well below the allowable criteria in terms of heavy metal composition. This is important since, even at modest exposure levels, heavy metals can cause long-term health problems (Okeola *et al.,* 2023). Effective source water protection and quality assurance throughout manufacturing are demonstrated by keeping heavy metal concentrations below crucial thresholds. The excellent WQI score indicates that the cumulative effect of the tested parameters aligns closely with ideal water standards. As pointed out by Ravikumar *et al*., (2013), WQI values less than 25 typically denote water that is of excellent quality, requiring no significant treatment before consumption. The very low WPI value (0.26) further reinforces the interpretation that the sampled sachet water brands exhibit minimal pollution. WPI values less than 1.0 indicate low levels of contaminant load relative to safe drinking water standards (Kaurish and Younis, 2018).

Furthermore, the results from Asaba Metropolis point to a higher level of production and regulatory compliance when contrasted with earlier research on sachet water quality in Nigeria, such as that conducted by Akinsola and Oyewumi (2021), who discovered that multiple sachet water brands in Ondo State exceeded microbial and chemical contamination limits. This could be the result of improved manufacturing hygiene, efficient regulatory monitoring, and increased public knowledge of water safety. Given the outstanding quality that was recorded, it is essential that current manufacturing standards be upheld and even increased. Any breakdown in production procedures or distribution chain hygiene could ultimately lead to microbial growth or chemical contamination, as shown in the work of Omalu et al. (2010), where post-production contamination significantly contributed to the reduction of packaged water quality.

Overall, the study's results confirm that Asaba Metropolis' sachet water is currently safe to drink and emphasize how crucial ongoing monitoring is to maintaining water quality and safeguarding human health.

CONCLUSION

All tested physicochemical parameters, such as pH, turbidity, total dissolved solids, conductivity, dissolved oxygen, sulphate, phosphate, chloride, and heavy metal concentrations, were found to be within the acceptable limits established by national and international drinking water standards (e.g., WHO and SON guidelines) after an evaluation of sachet water in Asaba Metropolis. The water receives an exceptional rating from the Weighted Arithmetic Water Quality Index (WQI_A) due to its small deviation from the ideal quality requirements. The extraordinary mobility and safety of the sachet water samples for human consumption are further supported by the Water Pollution Index (WPI) score, which shows an extraordinarily low pollution load. These remarkable findings imply that the sachet water brands under investigation are efficiently handled through the use of appropriate treatment procedures and secure packaging techniques. As a result, sachet water in this research region can be regarded as healthy, safe, and suitable for drinking without posing any acute health risks. Therefore, our study suggests that manufacturers of sachet water should keep up their rigorous adherence to the present manufacturing hygiene requirements, water treatment procedures, and quality assurance programs, all of which have helped to achieve the exceptional water quality that has been noted. Although classical physicochemical criteria are within limits, future research should also look at new pollutants (such as microplastics, medicines, and endocrine-disrupting chemicals).

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