Direct Research Journal of Public Health and Environmental Technology

Direct RESEARCH JOURNALS

Vol. 10(3), Pp. 68-74, October 2025
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Research Article
ISSN: 2734-2182
https://journals.directresearchpublisher.org/index.php/drjphet; https://www.ajol.info/index.php/drjphet

Comparative Analysis of Microbial Load and Physicochemical Parameters in Sachet and Bottle Water Sold Around Madala Zuba Axis Nigeria

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ABSTRACT

Access to safe drinking water remains a major public health challenge in Nigeria, particularly in semi-urban areas like Madalla-Zuba where packaged sachet and bottled water are the primary sources of drinking water. This study conducted a comparative analysis of microbial load and physicochemical parameters of sachet (pure) and bottled water sold around the Madala–Zuba axis. Twenty-five samples (15 sachet and 10 bottled water brands) were randomly collected and analyzed using standard microbiological and physicochemical methods. Results revealed that 12 out of 15 sachet water brands met World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ) guidelines for physicochemical properties, although several samples showed acidic pH values below recommended limits. The microbiological analysis found no Coliforms and Escherichia Coli in the sachet water samples, making them microbiologically safe. In contrast, two bottled water brands (Dzuba and Yneb) recorded microbial contamination, with isolates including Enterobacter aerogenes, Shigella spp., Staphylococcus aureus, and Pseudomonas aeruginosa. These findings highlight inconsistencies in packaged water quality, and challenge the assumption that bottled water is always safer than sachet water in this study showing better microbial safety compared to some bottled water brands. The study underscores the need for continuous monitoring, strict regulatory enforcement, and improved production practices to safeguard public health and ensure consumer confidence in packaged drinking water.

Keywords: *Sachet water, Bottled water, physicochemical parameters and microbiological contents*



Article information
Received 30 August 2025
Accepted 7 October2025
Published 17 October 2025
DOI: https://doi.org/10.26765/DRJPHET20327300
Citation: Shehu, D. E. (2025). Comparative Analysis of Microbial Load and Physicochemical Parameters in Sachet and Bottle Water Sold Around Madala Zuba Axis Nigeria. Direct Research Journal of Public Health and Environmental. Vol. 10(3), Pp. 68-74. This article is published under the terms of the Creative Commons Attribution License 4.0.

INTRODUCTION

Water is an essential resource for human survival and development. . Research has shown that two third of human body weight is made up water. The human brain contains eighty five percent (85%) of water, Muscles contain approximately 75% water and Bones, thirty three percent (33%) (Legros et al., 2020). It is difficult to survive long without water. Access to safe and clean drinking water is a fundamental human right, essential for human health, dignity, and well-being (WHO, 2019). However, many urban dwellers in Nigeria, particularly around Madala-Zuba axis, rely on packaged water (sachet and bottle) as their primary source of drinking water (Adeyemi

et al., 2017). Sachet and bottled water refer to commercially treated water packaged in sealed containers for human consumption.The difference between the two types of water is the material used to package them. There is a common perception that bottled water is of higher quality than sachet water, though this assumption is not always supported by evidence. (Nwankwo & Ogbonna, 2015, Okoro et al., 2017). However, the quality of these products is often uncertain, and there are concerns about the potential health risks associated with consuming contaminated or poorly regulated packaged water (CDC, 2020). Contaminated water sources have contributed significantly to epidemic outbreaks in urban and rural communities and this is more evident where there is no proper supply of potable water. (Mustapha and Adamu 1991). Water consumers are frequently unaware of the potential health risks associated with exposure to water borne contaminants which have often led to diseases like diarrhoea, cholera, dysentery, typhoid fever, legionnaire's disease and parasitic diseases. The continuous increase in the sale and indiscriminate consumption of packaged drinking water in Nigeria is of public health significance, as the prevalence of water related diseases in developing countries like Nigeria is determined by the quality of their drinking water

Nigeria experiences recurrent outbreaks and endemic transmission, with a high cases of deaths and economic burden due to water borne diseases like cholera (WHO, 2020) Cholera is reported to have an estimated 1.4 million cases and 100,000 deaths annually (WHO, 2019). In 2020, cholera outbreak in Nigeria's Borno State was affected over 10,000 people, with a case fatality rate of 2.5% (NCDC, 2020). Similarly, in 2018, a cholera outbreak in Zamfara State affected over 1,500 people, with a case fatality rate of 1.3% (WHO, 2018). According to a report by Nigerian Centre for Disease Control (2024) 30 states reported a total of 882 suspected cases of cholera including 16 deaths resulting in a case of fatality ratio (CFR) of 1.9%. Although consumption of well water has decrease due to awareness of water borne diseases associated with well water, consumption of packaged water has however increased.

Shortfalls in the distribution of treated pipe borne water leads to the resort to alternative sources of drinking water. The quality of packaged water (pure and bottle) is a critical public health concern, particularly in semi urban areas like Madala-Zuba axis. The increasing demand for packaged water has led to a proliferation of brands and vendors, raising concerns about the safety and quality of these products.

In Nigeria, the National Agency for Food and Drug Administration and Control (NAFDAC) has reported cases of contaminated packaged water, highlighting the need for regular monitoring and evaluation. Moreover, the World Health Organization (WHO, 2019) recommends that drinking water should meet certain quality standards to prevent waterborne diseases. Despite the importance of packaged water quality, there is a dearth of research on the microbial load and mineral nutrient content of pure water and bottle water sold in Madala-Zuba axis. This study aims to bridge this knowledge gap by providing a comprehensive analysis of the quality of packaged water in the area. Reports indicated that there is isolation of some pathogenic organisms like *Salmonella*, *Shigella* and *Escherichia coli* from drinking water. Most reported cases in Typhoid fever were not unconnected with drinking of sachet packaged water

Organisms which are well characterized and mostly present can include strains of *Salmonella*, *Shigella*, *Leptospirai*, Enteropathogenic *Escherichiacoli*, *Francisella*, *Vibrio*, *Mycobacteria*, Human enteric viruses, Cysts of *Entamoeba histolytica*, *Giardia lamblia*, or other pathogenic protozoans and larvae of various pathogenic worms. (Anochie et al., 2018). Earlier investigations conducted in Bauchi, Kan|, Owerri, Lagos and Zaria on the safety of drinking water have shown that bottled water has good microbiological quality while the quality of some sachet water was noted to be doubtful. This observation was based on studies carried out on water samples to ascertain the presence of heterotrophic bacteria, indicators of faecal contamination (total coliforms, faecal coliforms and *enterococci*). Mustapha and Adamu (1991). Lack of information on pathogenic or parasitic organisms associated with drinking water creates some uncertainties in our understanding of the overall quality of drinking water in our markets. Some sachet waters have been reported to contain bacteria such as *Bacillus sp., Pseudomonas sp., Klebsiella sp., Streptococcus sp.,* and *oocysts of Cryptosporidia sp*. Apart from environmental contaminants, improper storage and handling by vendors also poses a serious threat to the health of the ignorant consumers Augustine et al (2019). Pure water is known to be colorless, odorless and tasteless with high boiling and melting points as well as high heat of vaporization. Pure water can be slightly ionized reversibly to yield hydrogen and hydroxyl ions. Therefore, water is not just a solvent in which the chemical reactions of the living cell occur (Alhassan et al., 2008). It is often considered in direct participation in those reactions. Quality of drinking water is evaluated based on its chemical components. This is done by assessing the pH, hardness, total alkalinity, dissolved oxygen, carbon dioxide, heavy metals and organic constituents. Consumption of sachet water in Nigeria is on the increase irrespective of whether they have NAFDAC Certification or not. However, despite the strong effort by NAFDAC in the regulation and quality assessment of sachet water and other foods and drugs in Nigeria, most manufacturers have not complied with the agency's regulation. There are a growing number of reported public illnesses such as typhoid, diarrhea and other water borne diseases arising from consumption of sachet water. Sachet water serves as a major source of potable drinking water in Ibadan and it environ as well as most cities in Nigeria.

Several studies have been carried out on water quality of varying degrees and coverage. Some were carried out on the chemical quality of the water, some on the microbiological quality, some on the physical quality and some on the physiochemical quality of the water. For instance Alhassan et al. (2008), in their study of sachet water packaged within Kano metropolis, analyzed the physicochemical characteristics (color, taste, odour, alkalinity, total hardness, pH, chloride, using standard methods. All samples were tasteless, colorless and odourless. The pH, alkalinity and total hardness were within WHO permissible limit. Airaodion et al. (2022) examined the microbiological quality of sachet drinking water and bottled water sold on the streets of Kumasi, Ghana and concluded that bottle water in the Ghanaian market is of good microbiological quality.

Overall, this study is justified by the need to ensure the safety and quality of packaged water products, promote public health, and inform policy and regulatory decisions.

The primary Objectives of this study are:

1 To determine the microbial load (Total Coliform, E. coli, and Total Bacterial Count) of pure water and bottle water samples
2 Analyze the physicochemical parameters of pure water and bottle water samples
3 To compare the microbial load, identify pure water and bottle water samples that exceed acceptable limits for microbial load or physicochemical parameters and
4 To provide recommendations for improving the water quality of pure water and bottle water.

Questions such as what is the microbial load count of pure and bottle water samples?

What are the levels and types of mineral nutrients present in pure water and bottle water sample?

How do the microbial load counts and physicochemical parameter level of pure water compare to those of bottle water?

Which of the pure water and bottle water samples exceed the acceptable limits for microbial load or mineral nutrient content?

MATERIALS AND METHODS

Ten different brands of bottled water and fifteen sachet water brands commonly sold in madallah and zuba axis were randomly purchased from various sales outlets like open markets, supermarkets and street after inspecting for tears or leaks that could introduce contamination on the bottle so as to prevent bacterial contamination of the samples. A total of 25 samples (15 pure water and 10 bottle water). Microbial load (Total Coliform, E. coli, and Total Bacterial Count) and physicochemical parameters were determined using standard microbiological and physicochemical methods.

RESULTS

The results from (Table 1) show that the pH values of bottled water samples were acidic (~5.0–7.3). Several fall below the 6.5 minimum guideline. Temperature was around 27–29 °C. Turbidity was Low (≈0.3–1.0 NTU) and within WHO/NSDWQ limits. Conductivity and total dissolve solid (TDS) was low, and well below guideline maxima. Alkalinity and Hardness had acceptable levels within safe ranges. Chloride: Concentrations was below 250 mg/L guideline, safe for taste and health. All samples were clear and odorless, marked as unobjectionable (UO) per WHO standards. The results in (Table 2) revealed that most bottled brands reported MPN < 1.1 (ND) and negligible viable counts. However two bottled brands show small but positive MPNs: Dzuba (MPN ≈ 3; total viable count ≈ 0.1 × 10^1 CFU/mL) and Yneb (MPN ≈ 2; total viable count ≈ 0.2 × 10^1 CFU/mL); both have faecal coliforms listed (not ND). From (Table 3) the pH of most sachet samples show acidic pH values (~5.0–7.2). Majority of these fall below the WHO and NSDWQ guideline range (6.5–8.5). This indicates acidity, which can cause corrosion and affect taste. Temperature: Recorded between ~26.7–29 °C, reflecting normal ambient storage in tropical climates. WHO/NSDWQ do not set a strict health limit, but high temperature can influence microbial regrowth. Turbidity was very low (≈0.2–0.7 NTU), which is well within the WHO/NSDWQ limit of 5 NTU. This suggests effective filtration. Conductivity and TDS values reported were well below the guideline maxima, meaning the sachet waters were low in dissolved solids and salts. Alkalinity and Hardness were moderate values across sachet brands, all within safe limits. Chloride levels were below the 250 mg/L guideline, indicating absence of saline contamination. Colour and Odour were all marked as unobjectionable (UO) with low colour units, meaning the water is clear and acceptable to consumers.

From (Table 4) all listed sachet brands in the table show MPN (thermos tolerant/faecal coliform) values reported as < 1.1 (MPN/100 mL) and “ND” (not detected) for faecal coliform. Total viable counts are reported as zero or negligible. For the samples tested, sachet waters had no detectable faecal coliforms by the MPN method used and very low heterotrophic/viable counts. According to WHO and Nigerian drinking-water standards, thermotolerant coliforms/E. coli should be no detectable in any 100 mL sample; the sachet results therefore appear to meet that microbiological criterion.

Table 5 listed probable organisms recovered from the positive bottled samples (and possibly from other samples): Enterobacter aerogenes, Shigella (from a colorless rod isolate), Staphylococcus aureus (cocci,

Table 1: Physico-Chemical Parameters tested for Bottled Water.

Water Samples	pH	Temp.(°C)	Turbidity (NTU)	Odour	Colour (Pt.Co)	Conductivity(µs/cm)	Total Dissolved S0lids (mg/l)	Alkalinity(mg/l)	Hardness(mg/l)	Chloride ion (mg/l)	Salinity	Resistivity
C wa	5.0	26.8	0.22	UO	1	12.66	74.8	34	36	26.27	0.3	0.08
Aqua	5.0	27.0	0.31	UO	1	164.3	98.5	36	34	30.53	0.4	-1
CMv	6.0	27.3	0.60	UO	1	32.0	180.8	42	36	20.53	0.3	0.03
Zub	7.3	27.0	1.99	UO	2	54.4	327	176	20.8	25.56	0.5	-1
Wan	5.0	28.5	0.15	UO	2	17.25	103.3	38	34	24.85	0.3	0.06
Wak	5.0	29.3	0.26	UO	1	26.10	161.8	34	34	21.3	0.3	0.04
Jes	5.0	27.0	0.27	UO	1	34.0	200.3	30	38	17.75	0.3	0.3
Jtle	5.0	27.0	0.26	UO	2	2.56	154.3	38	42	21.3	0.4	-1
I rain	5.0	27.1	0.19	UO	2	13.67	81.3	40	40	21.3	0.3	0.07
Nebo	5.7	27.7	0.27	UO	2	12.7	81.2	30	30	21.4	0.2	0.07
WHO Guide	6.5-8.5	5	Ambient	UO	15	1250	1500			250		
NSDWQ	6.5-8.5	5	Ambient	UO	15	1000	1500			250		

Keys: NTU=Nephelometri turbidity unit, -ve=Negative, WHO Guide=World Health Organization guidelines, NSDWQ=Nigeria standards for drinking water quality, °C=Dedree Celcius, -=Not tested, UO=Unobjectionable,

Table 2: Microbial Analysis of bottle Water.

Bottled Water brands	In 10 bottles of 10ml broth/10ml of water	MPN/100ml sample	Total viable count CFU/ml	Faecal coliform	Confidence Limits (9)	
					Low	High
Ewan	0	<1.1	0	ND	-	3.3
Dzuba	3	3.6	0.1×10^1	ND	0.91	9.7
C mv	0	<1.1	0	ND	-	3.3
Gjes	0	<1.1	0	ND	-	3.3
Baqua	0	<1.1	0	ND	-	3.3
Fwak	0	<1.1	0	ND	-	3.3
Irai	0	<1.1	0	ND	-	3.3
Cwan	0	<1.1	0	ND	-	3.3
Hnes	0	<1.1	0	ND	-	3.3
Yneb	2	2.2	0.2×10^1	ND	0.37	8.1
way	0	<1.1	0	ND	-	3.3

Table 3: Physico-Chemical Parameters Tested for Sachet Water.

Water Samples	pH	Temp.(°C)	Turbidity (NTU)	Odour	Colour (Pt.Co)	Conductivity(µs/cm)	Total Dissolved S0lids (mg/l)	Alkalinity(mg/l)	Hardness(mg/l)	Chloride ion (mg/l)	Salinity	Resistivity
Jaw	5.0	27.1	0.46	UO	1	35.8	21.5	20	18	49.7	0.3	0.03
Za	7.0	27.0	0.37	UO	1	91.9	55.5	54	178	39.76	0.3	0.01
Carb	5.0	26.9	0.22	UO	1	16.93	101.5	14	32	55.38	0.3	0.06
Lash	6.0	27.0	0.36	UO	2	43.4	26.0	30	38	42.6	0.3	0.02
Bles	7.0	27.0	0.59	UO	1	104.7	62.6	46	70	72.42	0.4	-1
Isa	5.0	27.0	0.20	UO	2	25.8	15.51	12	70	72.42	0.3	0.04
Mo	6.8	27.0	0.77	UO	2	74.9	44.6	24	46	28.4	0.3	0.01
Im	7.2	26.9	0.31	UO	1	111.0	66.5	46	110	28.4	0.4	-1
Deg	5.0	27.0	0.45	UO	2	26.8	16.06	20	40	49.7	0.3	0.04
VP	7.0	26.9	0.31	UO	1	65.4	39.2	42	70	39.76	0.3	0.02
New	6.4	26.7	0.28	UO	1	57.6	35.1	24	66	41.18	0.3	0.02
Sun	5.0	26.9	0.35	UO	1	85.1	50.9	20	98	65.32	0.3	0.01
Yo	7.2	26.9	0.72	UO	2	108.4	65.0	56	124	42.6	0.4	-1
SH	7.2	27.0	0.61	UO	2	104.0	62.4	58	40	39.76	0.4	-1
RP	6.6	26.9	0.44	UO	1	64.9	39.0	38	76	39.76	0.3	0.02
WHO Guide	6.5-8.5	5	Ambient	UO	15	1250	1500			250		
NSDWQ	6.5-8.5	5	Ambient	UO	15	1000	1500			250		

Key: NTU=Nephelometri turbidity unit, -ve=Negative, WHO Guide=World Health Organization guidelines, NSDWQ=Nigeria standards for drinking water quality, °C=Dedree Celcius, -=Not tested, UO=Unobjectionable

Table 4: Microbial Analysis of Sachet Water

Satchet brands	Water	In 10 bottles of 10ml broth/10ml of water	MPN/100ml sample	Total viable count CFU/ml	Faecal coliform	Confidence Limits (95%)	
						Low	High
N bles		0	<1.1	0	ND	-	3.3
Ajaw		0	<1.1	0	ND	-	3.3
O isa		0	<1.1	0	ND	-	3.3
Za		0	<1.1	0	ND	-	3.3
Rdeg		0	<1.1	0	ND	-	3.3
Svp		0	<1.1	0	ND	-	3.3
Mo		0	<1.1	0	ND	-	3.3
Im		0	<1.1	0	ND	-	3.3
Ish		0	<1.1	0	ND	-	3.3
Vp		0	<1.1	0	ND	-	3.3
SH		0	<1.1	0	ND	-	3.3
YO		0	<1.1	0	ND	-	3.3
car		0	<1.1	0	ND	-	3.3
nw		0	<1.1	0	ND	-	3.3
sun		0	<1.1	0	ND	-	3.3

Table 5: Biochemical Characteristics of Isolates

Samples	Pigmentation	Cell shape	Gram reaction	Citrate	MRTest	Indole Test	Oxidase	Catalase	Voges Proskauer	Coagulase	Probable Organism
Dzuba	Pink	Rods	-ve	+ve	+ve	-ve	-ve	+ve	+ve	-ve	*E. aerogenes*
Dzuba	Colorless	Rods	-ve	-ve	+ve	-ve	-ve	+ve	-ve	-ve	*Shigella Sp.*
Dzuba	Yellow	Cocci	+ve	+ve	+ ve	-ve	-ve	+ ve	+ ve	+ ve	*S. aureus*
Yneb	Pink	Rods	-ve	+ve	+ve	-ve	-ve	+ve	+ve	-ve	*E. aerogenes*
Yneb	Green	Rods	-ve	+ve	-ve	-ve	+ ve	+ ve	-ve	-ve	*Pseudomonas aeruginosa*

Key:-ve = negative, +ve = positive, *E. aerogenes= Enterobacter aerogenes; S. aureus=Staphulococcus aureus.*

coagulase positive), and Pseudomonas aeruginosa (green-pigmented rod). These identifications are based on the reported Gram reaction and biochemical tests (citrate, MR, indole, oxidase, catalase, Voges-Proskauer, coagulase) reported in this study. Shigella (a faecal pathogen) indicates direct faecal contamination and is associated with gastroenteritis/dysentery. Enterobacter and Pseudomonas are environmental/opportunistic organisms that can reflect inadequate treatment, biofilm formation in bottling equipment, or post-treatment contamination; Pseudomonas aeruginosa in particular is a concern in immunocompromised people. Staphylococcus aureus (coagulase positive) frequently signals handling contamination (human skin, workers) or poor hygiene.

DISCUSSION

The results of this study indicate that both sachet and bottled water samples generally met World Health Organization (WHO) standards for most physicochemical parameters. However, a recurring concern was the acidity (low pH values) of several samples, particularly bottled water, which recorded pH values between 5.0 and 6.0. Acidic water has been associated with the leaching of metals and potential gastrointestinal irritation (Okpara, Anyadike, & Okafor, 2020). Similar findings of slightly acidic sachet water were also reported in Awka and Onitsha, where average pH values ranged from 5.56 to 6.86 (Okpara et al., 2020). In terms of Total Dissolved Solids (TDS), both sachet and bottled water in this study showed low values, ranging from 3.27–154 mg/L for bottled water and 5.51–66.5 mg/L for sachet water. This aligns with the findings of Okpara et al. (2020), who reported TDS values below 100 mg/L for sachet water brands in Anambra State, and with Agbendeh and Ogbonna (2022), who found sachet and bottled water in Makurdi to be within WHO and NSDWQ limits. Although low TDS values are generally considered safe, they may indicate reduced mineral content, particularly calcium and magnesium, which are important for human health.

Microbiological analysis revealed that sachet water samples were free from coliforms and Escherichia coli, making them microbiologically safe. This result is consistent with Airaodion, Ogbuagu, Adekitan, Airaodion, and Osemwowa (2019), who also found sachet and bottled waters in Ogbomoso to be largely free of microbial contamination. However, findings from other regions diverge: Oyedeji, Olutiola, and Moninuola (2015) reported total coliforms in 100% of sachet water samples and E. coli in 20% of brands in Ibadan and Ile-Ife. Similarly, Agbendeh and Ogbonna (2022) detected pathogens such as E. coli, Salmonella spp., and Staphylococcus aureus in both sachet and bottled water in Makurdi.

These contrasting outcomes highlight the variability in production standards and regulatory enforcement across Nigeria. Despite common perceptions, that bottle water is safer this study found, this study detected microbial contamination in two bottled brands (Dzuba and Yneb), which recorded coliform counts of 10 CFU/mL and 20 CFU/mL respectively. This agrees with the findings of Oyedeji et al. (2015), who observed high heterotrophic plate counts in one bottled water brand in Ile-Ife, and with Akinnibosun and Ugbawa (2017), who found that sachet water in Edo State often had higher microbial counts than bottled water, though both types of water could occasionally fall below safety standards.

Overall, these results emphasize that both sachet and bottled waters in Nigeria show high variability in quality, depending on the brand, production practices, and regional oversight. While the sachet water samples in this study were microbiologically safe, other studies have documented substantial contamination in sachet waters from different regions (Oyedeji et al., 2015; Agbendeh & Ogbonna, 2022). This underscores the importance of regular inspections by NAFDAC and public awareness campaigns.

Conclusion

The results of this study revealed that while most sachet and bottled water brands complied with WHO and NSDWQ standards for key physicochemical parameters such as turbidity, conductivity, hardness, and chloride, several samples had pH values below the WHO and NSDWQ recommended range which may have long-term health and infrastructural implications. Microbiological analysis further demonstrated that sachet water samples tested were free of coliforms and E. coli, indicating relative microbiological safety. However, two bottled water brands showed contamination by pathogenic and opportunistic organisms such as Enterobacter aerogenes, Shigella spp., Staphylococcus aureus, and Pseudomonas aeruginosa, highlighting the need for stricter hygiene protocols and improved bottling standards. The findings suggest that consumer perception of bottled water as inherently safer than sachet water may not always hold true. Both sachet and bottled water require consistent monitoring, adherence to regulatory standards, and improved handling and storage practices to ensure safety. Strengthening the oversight role of NAFDAC and other regulatory bodies, coupled with consumer awareness, will be essential in reducing the risk of waterborne diseases and promoting public health in Nigeria.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. NAFDAC and other relevant agencies should intensify routine inspections and strict enforcement of water quality standards for both sachet and bottled water producers.
2. Continuous microbiological and physicochemical testing of packaged water brands should be conducted to ensure compliance with WHO and NSDWQ guidelines.
3. Manufacturers should adopt good manufacturing practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) to minimize contamination during processing, packaging, and storage.
4. Consumers should be educated on the importance of purchasing certified brands and checking for NAFDAC registration numbers and expiry dates before consumption
5. pH Adjustment Producers should ensure that packaged water pH levels fall within the acceptable range (6.5–8.5) to prevent adverse health and infrastructural effects.
6. Vendors and distributors should be trained on hygienic storage and handling practices to avoid secondary contamination of packaged water.

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