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Hazard Identification and Risk Assessment-Based Water Safety Plan for Packaged Water Production Companies in Abeokuta, South West Nigeria

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Abstract

Provision of quality drinking water is paramount for sustaining good public health in urban residents. Packaged water produced and consumed across cities in Nigeria lacks integrity in protecting Health. Water safety plan based on hazard identification and risk assessment in each component of the water production system is essential in providing quality water by packaged water producing companies in Nigeria. This study aims at developing water safety plan for selected packaged water manufacturing companies in Abeokuta, Ogun State, Nigeria. Hazard identification and risk assessment were carried out based on site inspection studies, key informant interview, questionnaire survey and water sample analysis, and risk analysis using semi-quantitative risk matrix approach. The results revealed a total of 26 possible hazardous events which may compromise water quality such as on-site septic tanks and effluents discharged at source water and improper maintenance and hygiene practices within the system. Based on these, appropriate mitigation and monitoring plans were drawn for action. The research found that water safety plan is feasible for the packaged water systems, and therefore calls on the relevant stakeholders for urgent implementation towards ensuring clean drinking water and protecting public health as more and more people are opting for packaged waters due to uncertain public water safety.

Keywords

Risk Management, Water Safety Plan, Packaged Water, Abeokuta

1. Introduction

Provision of good quality drinking water is paramount for sustaining public health in urban residents; access to safe drinking is considered an essential need for existence, livelihood and well being [1] [2] [3].

The conventional method of drinking water quality control based on final product monitoring is becoming outdated, as water safety plan (WSP) concept of World Health Organisation (WHO) based on hazard identification and risk management from catchment to consumers is now considered as the most reliable means of safe water supply [4]. Water safety plan relies on the fact that there are several issues concerning the drinking water safety, such as the quality issues regarding raw water source, fluency of the water treatment processes and maintenance, distribution integrity and proper handling of waters at usage point. As such, source to tap approach to water quality management is the most efficient means of protection against potential health risks associated with exposure to water borne contaminants, which have often led to diseases, like diarrhoea, cholera, dysentery, typhoid fever and parasitic diseases [5] [6] [7].

Water safety plans are being promoted by WHO since 2004, however to date, little experience exists to their implementation in developing countries especially for small water systems, whereas the WHO WSP guide can be developed and implemented to any form of water supply system and improve their qualities regardless of size or shape [8] [9] [10]. WSP is simply a documented plan that *Identifies* hazards; *Assesses* risks from catchment to consumers; *Prioritizes* risks, with focus on highest risks and *Mitigates* risks, through control measures [5]. The aim and objectives of this research work are to identify hazards and assess risk in packaged water (sachet water) production companies in Abeokuta, south-west, Nigeria, towards implementing control measures as part of water safety plan development.

Packaged water (sachet water) is any commercially treated water, manufactured, packaged and distributed for sale in sealed polythene containers and is intended for human consumption [11]. In Nigeria, this water is popularly referred to as "pure water" or sachet water by the general public. It is affordable, good looking and widely accepted [12], making sachet water production a booming business in Nigeria [13]. In addition, low capital investment is required in the production of packaged water.

Consumption of sachet water in Nigeria is on the increase irrespective of whether they have the National Agency for Food and Drug Administration and Control (NAFDAC) Certification or not. However, despite the strong effort by NAFDAC in the regulation and quality assessment of sachet water, there are a growing number of reported public illnesses after drinking sachet water, mainly resulting from lack of proper treatment and adhering to standard hygiene practices [14] [15]. Various researchers have found disease-causing microorganisms in packaged waters sold in most part of the country [2] [14] [16] [17] [18] [19] [20]. Since sachet water is sealed then it is enough to say that contamination might have occurred during the production or storage process by virtue of its packaging, thus the need for the present study with a view to identifying hazards, analysing the risk towards providing a mitigation plan and ensuring quality sachet water production meeting health based targets.

2. Materials and Methods

2.1. Study Area

2.1.1. Abeokuta

Abeokuta is the capital of Ogun State, Southwest Nigeria, is situated within the rainforest belt of the tropics lying between latitude 7˚06' and 7˚13' North and longitude 3˚15' and 3˚25' East. It occupies a geographical area of 1256 sq·km with a population of about 449,088 inhabitants according to 2006 Nigerian population census (projected to 524,000 in 2019). The city is approximately 100 km north of Lagos and 80 km southwest of Ibadan, the Oyo State capital [21].

2.1.2. Packaged Water Production System

Commonly, the process of packaged water production consists of a series of physical and chemical steps that starts from the source of raw water (boreholes, rivers, lakes, etc.) through the treatment stages to the final product. The treatment process typically includes sand and activated carbon filtration or reverse osmosis, the disinfection is carried out using chlorine, ozone or ultraviolet light (UV). There are 10 packaged water companies selected for the study. Depending on the source water and production processes design, the study grouped the packaged water companies into three. **Figures 1-3** below illustrates a simple flow diagram of the three groups.

Group I: This group has three stages; Company **6**, and Company **7**

Stage 1: Source of raw water; Municipal Water Supply from Ogun State Water Corporation

Stage 2: Filtration; Sand and Carbon Filter

Stage 3: Final: UV Steriliser and Micro filters

Group II: This group has three stages; Company **1, 2, 3, 10** and Company **4**

Stage 1: Source of raw water; Boreholes

Stage 2: Filtration; Sand and Carbon Filter

Stage 3: Final: UV Steriliser and Micro filters

Group III: This group has four stages; Company **5** and Company **8**

Stage 1: Source of raw water; Boreholes

Stage 2: Filtration; Sand and Carbon Filter

Stage 3: Membrane filtration; Reverse Osmosis

Stage 4: Final; UV Steriliser and Micro filters

2.2. Study Design

The study is analytical and cross-sectional consisting of key informant interview, field observation, questionnaires and Laboratory analysis. All the ten companies

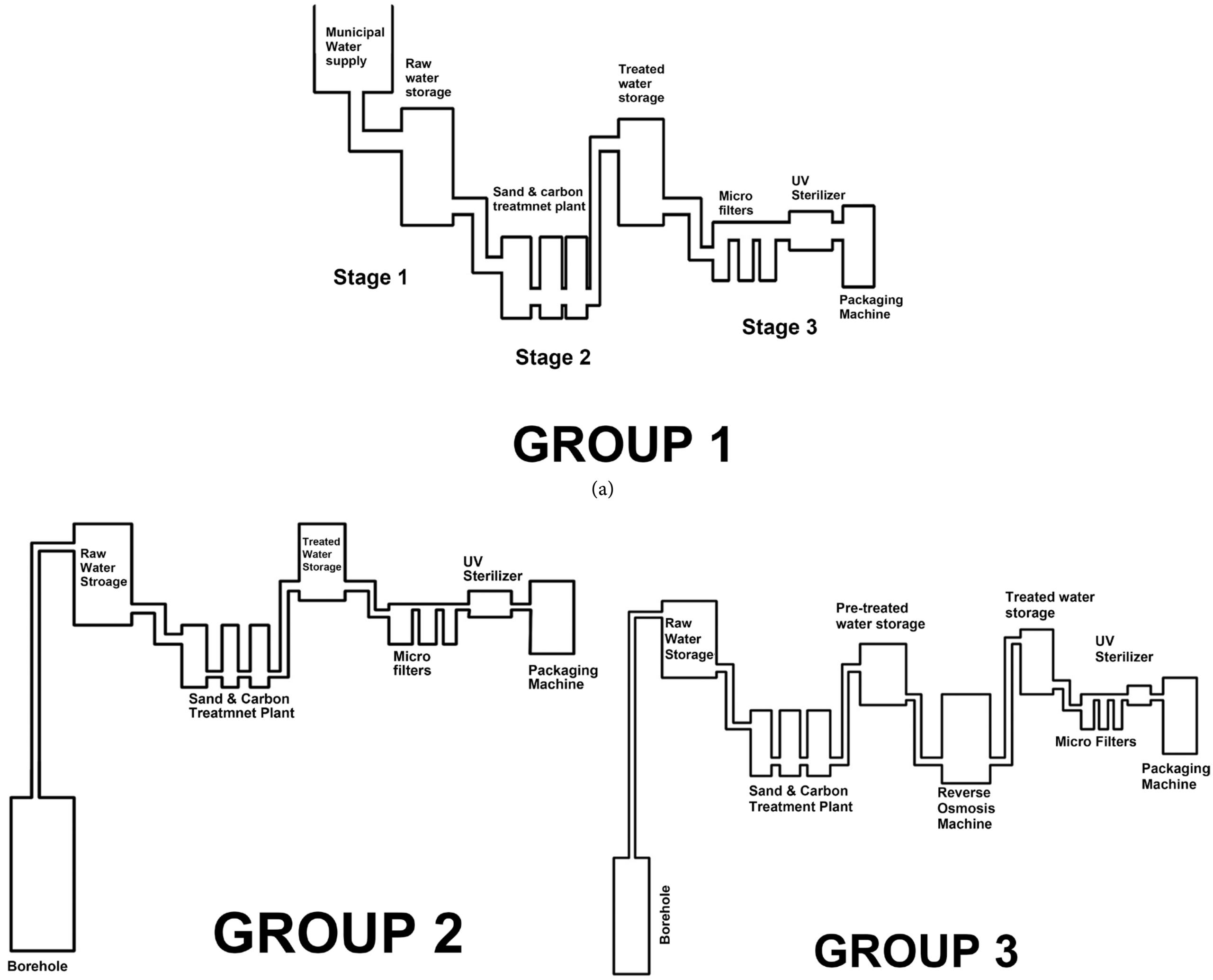

Figure 1. Flow diagram of the different groups of packaged water production systems in Abeokuta.

were included for interview and site inspection study while six prominent ones were selected for water quality analysis and questionnaire.

2.2.1. Key Informant Interview

An interview meeting were conducted with the president of the Packaged Drinking Water Association of Abeokuta to extract information on the manufacturers who were registered with NAFDAC.

2.2.2. Field Observation

Reconnaissance surveys of the ten registered packaged water manufacturing companies were carried out to determine the source and treatment procedures used by the various packaged water manufacturers, including their hygienic practices.

2.2.3. Questionnaire Survey

The questionnaire was drafted in English Language, and it included to derive information about their socio-demographic characteristics, raw water source; Capacity of the source in relation to demand, Protection measures applied, known water quality problems, storage facilities; number of storage reservoirs, volume of storage reservoirs, filtration and purification mechanisms; Processes applied, number of individual units, age of plant, known design faults, and their knowledge regarding the importance of quality water and hygiene behaviour. The right person was selected and questions were designed in a simple way to be understood and answered by the target population, most of the questions were one of two types; the yes or no questions, which offers a dichotomous choice and the multiple choice question which offers several fixed alternatives. The questionnaires were administered to the person in-charge of the factories visited.

2.2.4. Field Sampling and Water Quality Analysis

1) Sample collection

Using standard procedure, Grab water samples were collected from the raw water source, water samples after passing through each stages of sand and carbon filter, reverse osmosis machine and after passing through the UV light which is the final stage of treatment. New plastic bottles (PET) were used for the sampling and a complete identification and descriptive data was written on each sample accurately, which included; collection location, date, treatment stage and sample number. The samples collected were subjected to physical, chemical and bacteriological analysis at the Ogun State Water Corporations' Quality Control Laboratory, Abeokuta.

2) Parameters measured

a) ***Physical***: temperature, electrical conductivity, turbidity, colour, odour, total solids, total suspended solids,

b) ***Chemical***: pH, dissolved oxygen, total dissolved, acidity, alkalinity, total hardness, calcium hardness, magnesium hardness, chloride, iron, chlorine residual.

c) ***Biological***: bacterial count, *E. coli*.

2.3. Hazard Identification and Risk Assessment

Hazard identification and Risk assessment is an integral part of a Water Safety Plan development, it is a method used in determining hazards and hazardous events based on their probability and severity towards evaluating adverse consequences, including potential loss and injury [5]. Hazard is any physical, chemical, biological or radiological agent that has the potential to cause harm. Hazardous event is an incident that can introduce hazards into the system [6].

Hazard Identification is a proactive process to identify hazards and eliminate or minimize the risk of an epidemic and damage to property, equipment and the environment. It also allows us to show our commitment and due diligence to providing safe drinking water. Hazards and potential hazards must be identified so as to provide control measures [8]. ***Risk assessment*** is an in-depth look into the likelihood of an identified hazard causing harm to an exposed population in a given period including the magnitude of the harm and the consequences. Likelihood is determined by frequency and probability of a hazard or a hazardous event occurring.

2.3.1. Hazard and Hazardous Event Identification

The three classes of hazards which can compromise potable water delivery were looked into, namely;

1) Physical Hazards
2) Chemical Hazards
3) Biological Hazards

The identification was carried out based on the knowledge of the questionnaire, water quality assessment and visual field inspection of the treatment process and production line.

2.3.2. Risk Assessment

This was done by multiplying the derived likelihood ratings with the derived consequence ratings using the semi-quantitative risk matrix (Table 1) approach recommended for WSP risk assessment [22] to produce a risk rating with a score range of (1 - 9) as detailed in Table 1, where:

$$\text{Risk Rating} = \text{Likelihood} \times \text{Consequence}$$

A higher score implies that a bigger risk of a hazardous event occurring and hence should be prioritized. The impact of the hazard were characterised by assessing the severity of the likely health outcome and the probability of occurrence.

Table 1. The matrix table used for estimating the risk.

Matrix		Severity categories		
		I (1)	II (2)	III (3)
Likelihood Categories	A (3)	3	6	9
	B (2)	2	4	6
	C (1)	1	2	3
Risk score rating		Low (<3)	Moderate (3 - 6)	High (>6)

Risk analysis definition parameters: ***Likelihood categories*** A = daily to weekly (almost certain); B = monthly to seasonally (possible); C = yearly and above (rare); ***Severity categories*** I = significant risk/catastrophic: public health impact or regulation compliance impact, death or illness expected. II = medium: aesthetics or water quantity (consumers acceptance), damage to facilities; III = NO impact or insignificant: ***Risk score categories*** High risk = urgent management attention needed; Moderate risk = management attention needed; Low risk = routine procedures and; ***Colours*** Low (L): < 3 (Denoted by Green Colour); Medium (M): 6 - 9 (Denoted by Yellow Colour); High (H): > 6 (Denoted by Red Colour).

3. Results and Discussion

3.1. Water Quality Analysis

The analysis of the physical and chemical qualities showed that their sources of water were less polluted and the final treated water was within the limit of the Nigeria Standard for Drinking Water Quality (NSDWQ), except for a high turbidity (6.70 NTU) in Company 5 (**Figure 2**) which is above the standard of 5.0 NTU as recommended by NSDWQ. However many water quality parameters seems to be fluctuating negatively across the treatment stages as observed in the (**Figures 2-6**), such as the final results of Colour in company 5 (**Figure 2**) indicating the presence of hazardous events which need to be mitigated. For the microbiological analysis (**Table 2** and **Table 3**), though also final water quality found within target, but significant fluctuations in water qualities exist too particularly at the treatment stage of carbon filtration for most of the Companies with numerous increase in bacterial count mainly due to improper maintenance such as irregular backwashing. Thus failures in treatment at any point in time may pose consumers at risk of contamination. The results also indicated that boreholes sources are more polluted and reverse osmosis is more effective.

3.2. Questionnaire Survey

The result of the questionnaire is shown in **Tables 4-10**, which of the respondents; (83.3%) were males. The study showed that (83.3%) had higher education while (16.7%) had elementary certificates showing a high literacy level among heads of the companies, hence quality produce is expected. (66.7%) were owners of the manufacturing companies while 33.3% were managers. Most (66.7%) people were into the business for several years. Field observation indicates the need for upgraded facilities and enhanced maintenance and hygiene practice within the companies, which corresponds with the water quality results of bacterial count increase in the treatment stages which is hazardous (**Table 2** and **Table 3**). Boreholes were found to be the major (66.7%) source water for the production and source waters were protected to some extent as observed. However majority (83.3%) do not undergo regular water quality analysis which WHO water safety plan is strongly against.

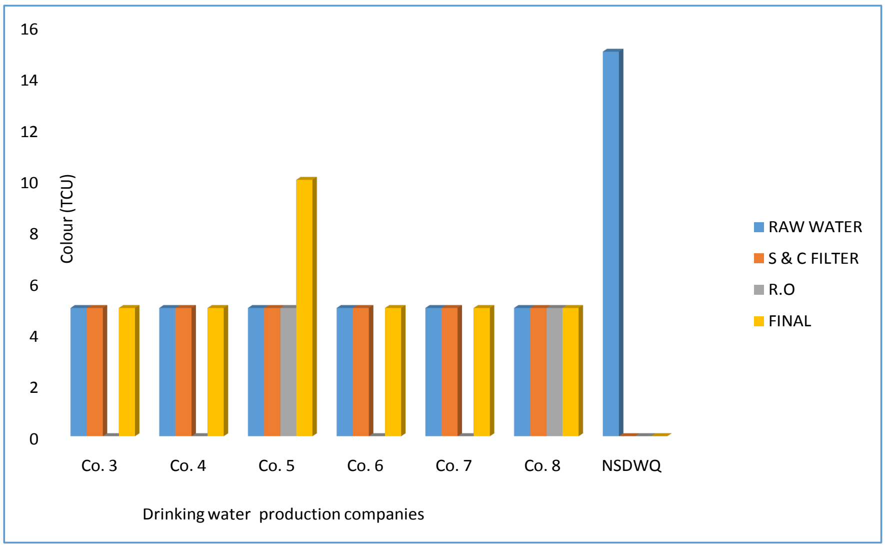

Figure 2. Colour readings of water samples from the packaging water companies.

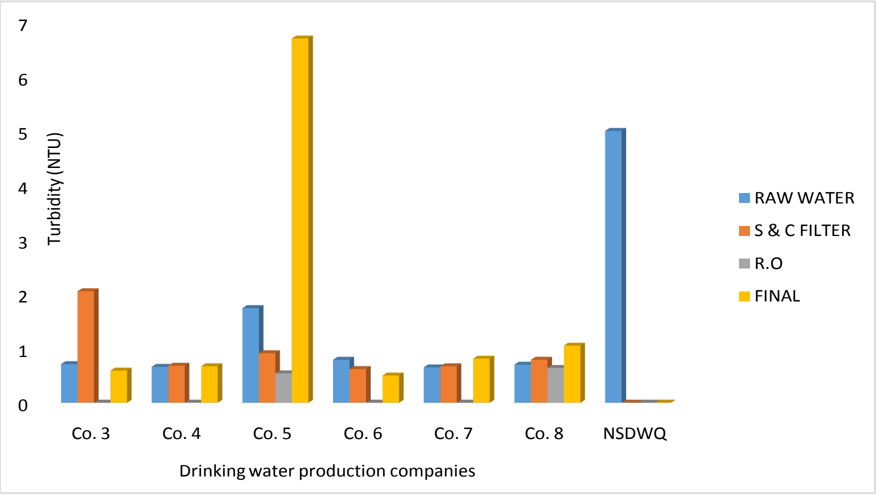

Figure 3. Turbidity of water samples from the packaging water companies.

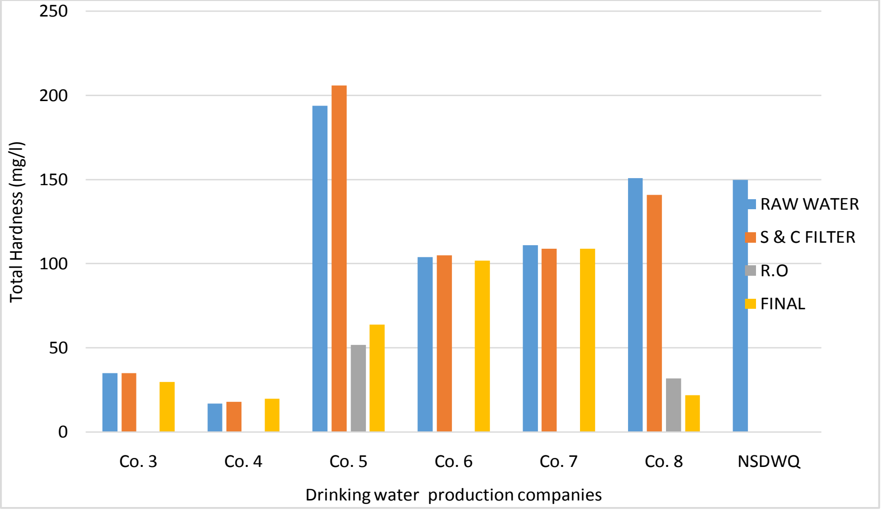

Figure 4. Total hardness of water samples from the packaging water companies.

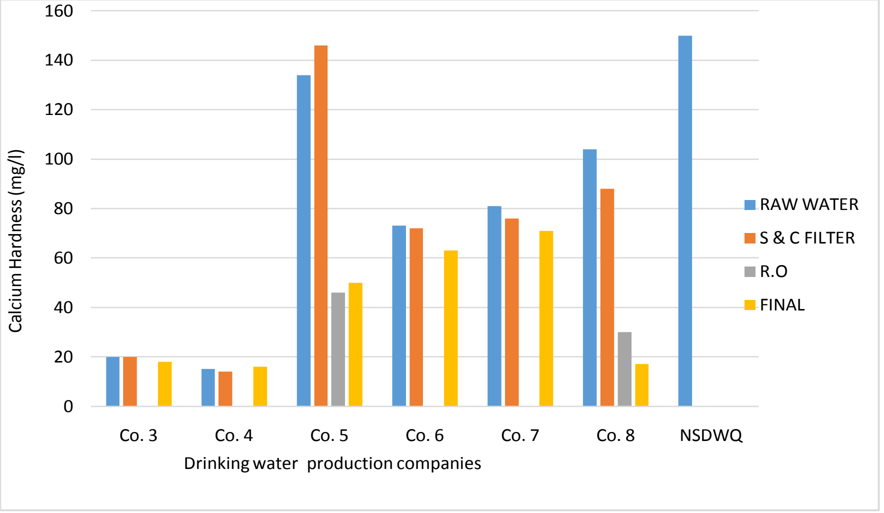

Figure 5. Calcium hardness of water samples of the packaging water companies.

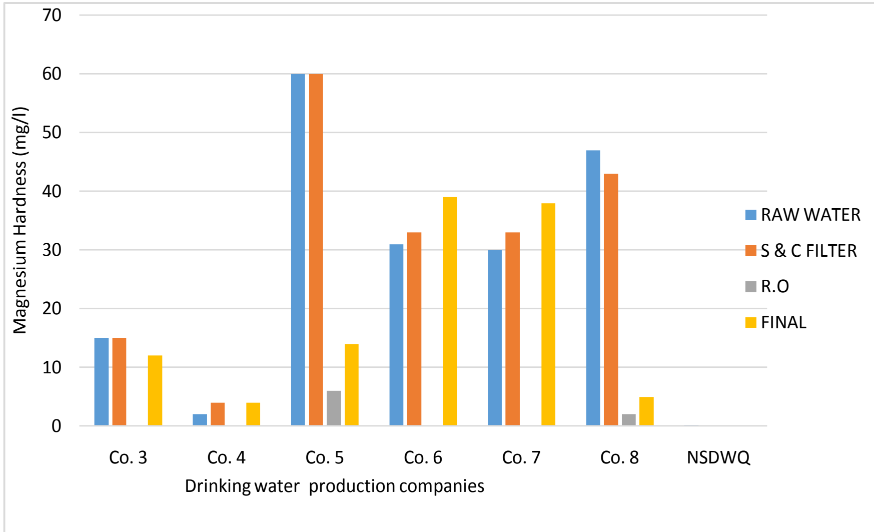

Figure 6. Magnesium hardness of water samples of the packaging water companies.

Table 2. Physio-chemical and biological characteristics of water samples from the drinking water packaging companies.

NATURE OF SAMPLE	RAW WATER	S & C FILTER	R.O	FINAL	(NSDWQ)
		Third			
Odour	-	-		-	
Iron mg/l	NIL	NIL		NIL	0.3 mg/l
Chlorine Residual mg/l	NIL	NIL		NIL	0.2 - 0.25 mg/l
Heterotrophic Plate Count/100 ml	2	50		NIL	10
E. coli (24 Hours)	NIL	NIL		NIL	Zero
		Fourth			
Odour	-	-	-	-	
Iron mg/l	NIL	NIL		NIL	0.3 mg/l
Chlorine Residual mg/l	NIL	NIL		NIL	0.2 - 0.25 mg/l
Heterotrophic Plate Count/100 ml	NIL	10		NIL	10
E. coli (24 Hours)	NIL	NIL		NIL	Zero
		Fifth			
Odour	-	-	-	-	
Iron mg/l	NIL	NIL	NIL	NIL	0.3 mg/l
Chlorine Residual mg/l	NIL	NIL	NIL	NIL	0.2 - 0.25 mg/l
Heterotrophic Plate Count/100 ml	50	TNTC	NIL	5	10
E. coli (24 Hours)	NIL	>160	NIL	NIL	Zero

Table 3. Physico-chemical and biological characteristics of water samples from the drinking water packaging companies continued.

NATURE OF SAMPLE	RAW	S & C FILTER	R.O	FINAL	(NSDWQ)
		SIXTH			
Odour	-	-		-	
Iron mg/l	NIL	NIL		NIL	0.3 mg/l
Chlorine Residual mg/l	NIL	NIL		NIL	0.2 - 0.25 mg/l
Heterotrophic Plate Count/100 ml	25	TNTC		4	10
E. coli (24 Hours)	NIL	NIL		NIL	Zero
		SEVENTH			
Odour	-	-		-	
Iron mg/l	NIL	NIL		NIL	0.3 mg/l
Chlorine Residual mg/l	NIL	NIL		NIL	0.2 - 0.25 mg/l
Heterotrophic Plate Count/100 ml	NIL	5		NIL	10
E. coli (24 Hours)	NIL	NIL		NIL	Zero
		EIGHT			
Odour	-	-	-	-	-
Iron mg/l	NIL	NIL	NIL	NIL	0.3 mg/l
Chlorine Residual mg/l	NIL	NIL	NIL	NIL	0.2 - 0.25 mg/l
Heterotrophic Plate Count/100 ml	10	NIL	5	NIL	10
E. Coli (24 Hours)	NIL	NIL	NIL	NIL	Zero

Table 4. Level of education.

	Frequency	Percent	Valid Percent	Cumulative Percent
BSc/HND	3	50.0	50.0	50.0
ND	2	33.3	33.3	83.3
Others	1	16.7	16.7	100.0
Total	6	100.0	100.0	

Table 5. Number of employees.

	Frequency	Percent	Valid Percent	Cumulative Percent
0 - 5	4	66.7	66.7	66.7
5 - 10	1	16.7	16.7	83.3
15 and above	1	16.7	16.7	100.0
Total	6	100.0	100.0	

Table 6. How long have you been in the packaged water production?

	Frequency	Percent	Valid Percent	Cumulative Percent
10 years	1	16.7	16.7	16.7
15 years	1	16.7	16.7	33.3
2 years	1	16.7	16.7	50.0
5 years	1	16.7	16.7	66.7
8 years	2	33.3	33.3	100.0
Total	**6**	**100.0**	**100.0**	

Table 7. Source of water.

	Frequency	Percentage	Valid %	Cumulative %
Municipal	2	33.3	33.3	33.3
Borehole	4	66.7	66.7	66.7
Surface Water	0	0	0	0
Total	**6**	**100**	**100**	

Table 8. Protected water source.

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	6	100.0	100.0	100.0
Total	6	100.0	100.0	

Table 9. How satisfied are you with the water quality?

	Frequency	Percent	Valid Percent	Cumulative Percent
Satisfied	3	50.0	50.0	50.0
Moderate	3	50.0	50.0	100.0
Total	6	100.0	100.0	

Table 10. How often do you carry out water quality analysis.

	Frequency	Percent	Valid Percent	Cumulative Percent
Frequently	1	16.7	16.7	16.7
Sometimes	2	33.3	33.3	50.0
Never	3	50.0	50.0	100.0
Total	6	100.0	100.0	

3.3. Water Safety Plan

3.3.1. Hazard Assessment and Risk Analysis

Based on the knowledge of the questionnaire, water quality analysis and field observation, A total of 26 hazardous events were identified through the treatment and production processes; 12 at the raw water source, 3 in the raw water storage, 4 in the sand and carbon filter, 2 in the reverse osmosis, 1 in the treated water storage, 4 in the micro filters, 1 in the UV light. The risk analysis showed 1 event had high risk, 16 events had medium risks and 9 events had low risks. The hazardous event with the high risk score was at the raw water source: on-site septic tank systems, which is more prevalent in the study the areas. While the other events with medium and low risks identified within the production and treatment processes were mostly associated with catchment use, hygiene behaviour, maintenance and upgrade of facilities. Table 11 shows the results of the hazard identification and risk analysis.

Table 11. Hazard identification and risk analysis.

Treatment Process	Hazardous Events	L	C	S	Risk Rating	Potential Hazards (General)
Water Source	On-site septic tank systems	3	3	9	H	• *Escherichia coli, Cryptosporidium* and other infectious organisms • Turbidity, dissolved solids, colour and other physical contaminants • Pesticides, heavy metals, nitrates, iron and other chemical contaminants
	Domestic waste dumping	2	2	4	M	
	Municipal sewage effluent	2	3	6	M	
	Graveyards	2	2	4	M	
	Industrial activities	2	3	6	M	
	Leaking pipelines	1	2	2	L	
	Pesticide use	1	3	3	L	
	Petroleum refineries	1	3	3	L	
	Highway, railway accidents and spills	1	2	2	L	
	Recreational activities	3	2	6	M	
	Natural events—flooding, droughts, etc.	2	2	4	M	
Raw Water Storage	Corrosion of storage tank	2	2	4	M	• Iron contamination • Turbidity, dissolved solids
	Settled sediments	2	2	4	M	
	Algae growth	2	3	6	M	
Sand and Carbon Filter	Corrosion of filter tanks	2	2	4	M	• Iron contamination • Turbidity, algae, dissolved solids
	Insufficient backwashing	2	3	6	M	
	Incorrect backwash procedure	2	3	6	M	
	Spent Sand and Carbon	2	3	6	M	
Reverse Osmosis	Inadequate or inappropriate quality of pre-treatment	2	3	6	M	• Membrane fouling • pH levels above normal range. • Conductivity above normal range. • Cleaning chemical concentrations at a level of possible health concern.
	Poor flushing of cleaning chemicals from the membrane module.	2	3	6	L	
Treated Water Storage	Algae growth	2	3	6	M	• Biological contamination
Micro Filters	Clogging of filters	1	3	3	L	• Turbidity, dissolved solids • Biological contamination
	Incorrect positioning of filter cartridge.	1	3	3	L	
	Contamination of filter housing when changing the cartridge	2	3	6	M	
	Algae growth around the filters	1	3	3	L	
UV Steriliser	Faulty UV light	1	3	3	L	• Biological contamination

3.3.2. Identifying Control Measures

Control measures are actions taken which reduces the level of hazards within water treatment process either by preventing hazard entry, reducing hazard concentration, or by preventing their production. Hence for all the identified risk, control measures were proposed as shown in Table 12 as part of the water safety plan. The plan included all the categories of risk (≥3).

3.3.3. Operational Monitoring (Define Monitoring of Control Measures)

The objectives of operational monitoring are for the packaged water manufacturers to monitor each control measure in a timely manner to enable effective system management and to ensure that health-based targets are achieved consistently, and to avoid risk of exposure to health issues from water quality compromise at any time. Some simple water quality parameters were selected for operational monitoring within the system (Table 13).

3.3.4. Effective Water Safety Plan Implementation Way Forward

In accordance with the WHO WSP guide, management and communication procedures (documentation of the implementation experience), development of supporting programs (training, education and awareness), verification plan (a general routine of water quality analysis from the source water to the final packaged product) and Periodic Review of the Water Safety Plan are key for success

Table 12. Proposed control measures.

Treatment Process	Control Measures
Water Source	• Regular inspection of the source and pipe fittings • Locate boreholes far away from septic tanks, grave sites. • Use of planning and environmental regulations to regulate potential water polluting developments • Flood prevention around the water source • Control of sewage effluents
Raw Water Storage	• Regular washing and disinfection of the storage tanks • Use of PVC tanks in place of stainless tanks
Sand and Carbon Filter	• Increase frequency of media and filter inspection • Backwashing should be done regularly • Change procedure for backwash cycles • Proper staff training
Reverse Osmosis	• Change pre-treatment processes to produce water that complies with membrane specifications. • Manual checks on the finished water quality directly after flushing the membrane
Treated Water Storage	• Regular washing and disinfection
Micro Filters	• Change filters when due • Make sure the filter is fitted the correct way round • Ensure that filter housing is disinfected during filter installation, and flush to remove residual disinfectant
UV Steriliser	• Link UV sensor to alarm to show when UV is faulty • Regular replacement of UV lamp

Table 13. Operational monitoring Matrix for packaged water companies.

What	Where	When	How	Who	Critical Limit	Corrective action in case critical limit is exceeded
Raw water source						
Conductivity	Raw water storage	Daily	Conductivity meter	Water analyst/manager	6.0 - 9.0	Re-assess catchment area
Turbidity	Raw water storage	Daily	Turbidity meter	Water analyst/manager	Not exceeding 5 NTU	Cleaning of the storage tank, Borehole flushing
pH	Raw water storage	Daily	pH meter	Water analyst/manager	6.0 - 9.0	Regulate activities
E. coli	Raw water storage	Monthly	MPN test	Microbiologist/Water analyst	<10	Regulate activities
Sand and Carbon Filter						
Turbidity	Filtration outlet	Daily	Turbidity meter	Water analyst/manager	Not exceeding 5 NTU	Backwash
Total dissolved solids	Filtration outlet	Daily	TDS meter	Water analyst/manager	600 mg/l	Backwash
Bacterial count	Filtration outlet	Weekly	Tube method	Microbiologist	10/l	Back wash
Reverse Osmosis						
Electrical Conductivity	Treated water Outlet	Daily	Conductivity meter	Water analyst/manager	1000 μ/cm	Membrane flushing
Micro filters						
Total dissolved solids	Filtration outlet	Daily	TDS meter	Water analyst/manager	500 mg/l	Change micro filters
UV Steriliser						
E. coli	Final treated water	Monthly	MPN test	Microbiologist/Water analyst	<10	Replace the UV light
Bacteria count/100 ml	Final treated water	Monthly	Plate count	Microbiologist/Water analyst	<10	Replace the UV light

and sustainability of WSP, hence should be strictly adhered to. Based on the study, it is proposed that a team of experts consisting of the production manager, quality control manager, water engineer, operational staff, NAFDAC representative, relevant state ministries representative and consumers representative is to be setup for the implementation, this team should put in place to work together to ensure successful implementation of the water safety plan. Operational staff involvement is essential as they often have the greatest knowledge about problems in the production system.

4. Conclusion and Recommendations

Several research findings revealed that packaged water qualities across most part of Nigeria are thread to public health. This study developed a water safety plan for packaged water manufacturing companies in Abeokuta, south western Nigeria, using hazard identification and risk assessment to improve its water quality. From the study, Hazard identification and risk assessment helps identify possible ways by which packaged water gets contaminated towards providing measures for hazardous events as part of water safety plan focus. It is found that most hazards are at the stages of sand and carbon filtration within the treatment system and reverse osmosis is more effective in eliminating hazards; hence recommended for packaged water manufacturers. Considering the restriction placed by NAFDAC in selecting a choice for the source of raw water, which are either municipal or borehole supply, there was drastic reduction in the level of pollution at the source water. From the study, WHO water safety plan is feasible for packaged water production, and therefore calls on the relevant stakeholders for commitment and participation to effectively implement the water safety plan to avoid water quality incidents leading to health of consumers being affected in Abeokuta.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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