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Assessment of the Physicochemical and Bacteriological Properties in Polyethene Packaged Sachet Water Generally Known as "Pure Water" Produced and Sold in Sagamu Local Government Area of Ogun State, South West, Nigeria

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Abstract

In this research, polyethene packaged sachet water from various producers, sources and distributors were analyzed for its physicochemical and microbiological characteristics. Samples were collected randomly from six (6) different locations/towns in Sagamu Local Government. The samples were analyzed for its physicochemical and bacteriological parameters. The results of the analyses were compared with the permissible limit set by WHO, EPA, Canada, and NIS. It was found that most of the parameters, turbidity 0.08-0.16 with permissible limits of 0.1-5.0, alkalinity 9-17 mg/l with permissible of 5.00 mg/l, Total hardness 3-6 mg/l with permissible limits of <60-100 mg/l, Phosphate 0.12-0.51 mg/l with permissible limits of <5 mg/l, Iron 0.02-0.21 mg/l with permissible limits of <0.03 mg/l, Calcium 2.10-4.80 mg/l with permissible limits of <75-200 mg/l, Nitrate 0.00-2.50 mg/l with permissible limits of <45-50 mg/l, Chlorine 12.8-28.30 mg/l with permissible limits of <250 mg/l were in the expected range of the permissible limits set by WHO, EPA, Canada, and NIS. However, the pH 4.73-6.10 of the sachet water samples tends to be acidic below the expected range 6.5-10.5. The Total Heterotrophic Bacteria count and Enteric Bacteria count tends to be a little lower below the permissible limits, Total Enteric Bacteria 300-480 CFU/100 ml with permissible limits of <500 CFU/100 ml and Enteric Bacteria 280-380 CFU/100 ml. It was recommended that water producing industries should site their raw water site in a safe location free from contamination, the government should involve the participation of equipped private and government hospitals with good laboratory to monitor and report accordingly the situation of all water packaging industries in their vicinity, the government should also involve the participation of genuine and reputable individuals to produce and provide paid pipe borne waters to people in their community and regulatory bodies such as SON and NAFDAC should take responsibility by continually re-assessing the production and packaging quality of drinking water in every community.

Keywords: Sachet polyethene water • Sagamu • Drinking water • Enteric bacteria count • Total heterotrophic bacteria count • Bacteriological • Heterotrophic plate count

Introduction

Sachet water popularly referred to as ''Pure Water' in Nigeria is the major source and most affordable water form in Nigerian homes. People rely on it so much for rehydration and drinking after every meal. People also feel that it is very pure and safe for drinking. Sachet water business is a very lucrative business and the demands may not go down anytime soon. Majority of the pipe-borne water supplied by the government initially are no more functional due to fast rate of population growth, maintenance, and rot in the water production facility structures. The masses rely solely on water purchase for drinking, and borehole in their houses for laundry, washing and cooking.

Nigeria

Nigeria is a country in West Africa that shares borders with the Republic of Benin in the west, Cameroun and Chad in the east, and in the North, Niger. Nigeria also shares a border with the self-declared, but internationally not yet recognized state of Ambazonia in the southeast. Nigeria's coast lies on the Gulf of Guinea in the south and it borders Lake Chad to the northeast. Some very important geographical features in Nigeria include the Adamawa highlands, Mambilla Plateau, Jos Plateau, Obudu Plateau, the Niger River, River Benue and Niger Delta. Nigeria is located in the Tropics, where the climate is seasonally very humid and damp. Nigeria's climate is affected by four season types; these climate types are distinguishable, as one move from the Northern part of Nigeria to the Southern part of Nigeria through Nigeria's middle belt [1].

Sagamu

Sagamu or also calledIshagamu is a conglomeration of thirteen (13) towns located in Ogun State along the Ibu River and Eruwuru Stream between Lagos and Ibadan, founded in the mid 19th century by members of the Remo branch of the Yoruba people [2] in south-western Nigeria. The 13 towns that made it up are: Makun, Offin Sonyindo, Epe, Ibido, Igbepa, Ado, Oko, Ipoji, Batoro, Ijoku, Latawa and Ijagba. Sagamu is the capital of Remo Kingdom and the paramount ruler of the kingdom-Akarigbo of Remo's palace is in the town of Offin in there. The Sagamu region is characterized by under laying deposits of limestone, which is used in the city's major industry that is the production of cement. The major Agricultural products of the region include cocoa and kola nuts. Sagamu is the largest kola nut collecting centre in the country. The kola nut industry supports several secondary industries such as basket and rope manufacturing, which are used to store the kolanuts [3]. Also, Sagamu is surrounded by large multinational industries such as Larfage, Nestle, Olam, Honey Well, Emzor, WASOL, International Breweries, Apple and Pears, therefore making Sagamu to develop rapidly (Figure 1).

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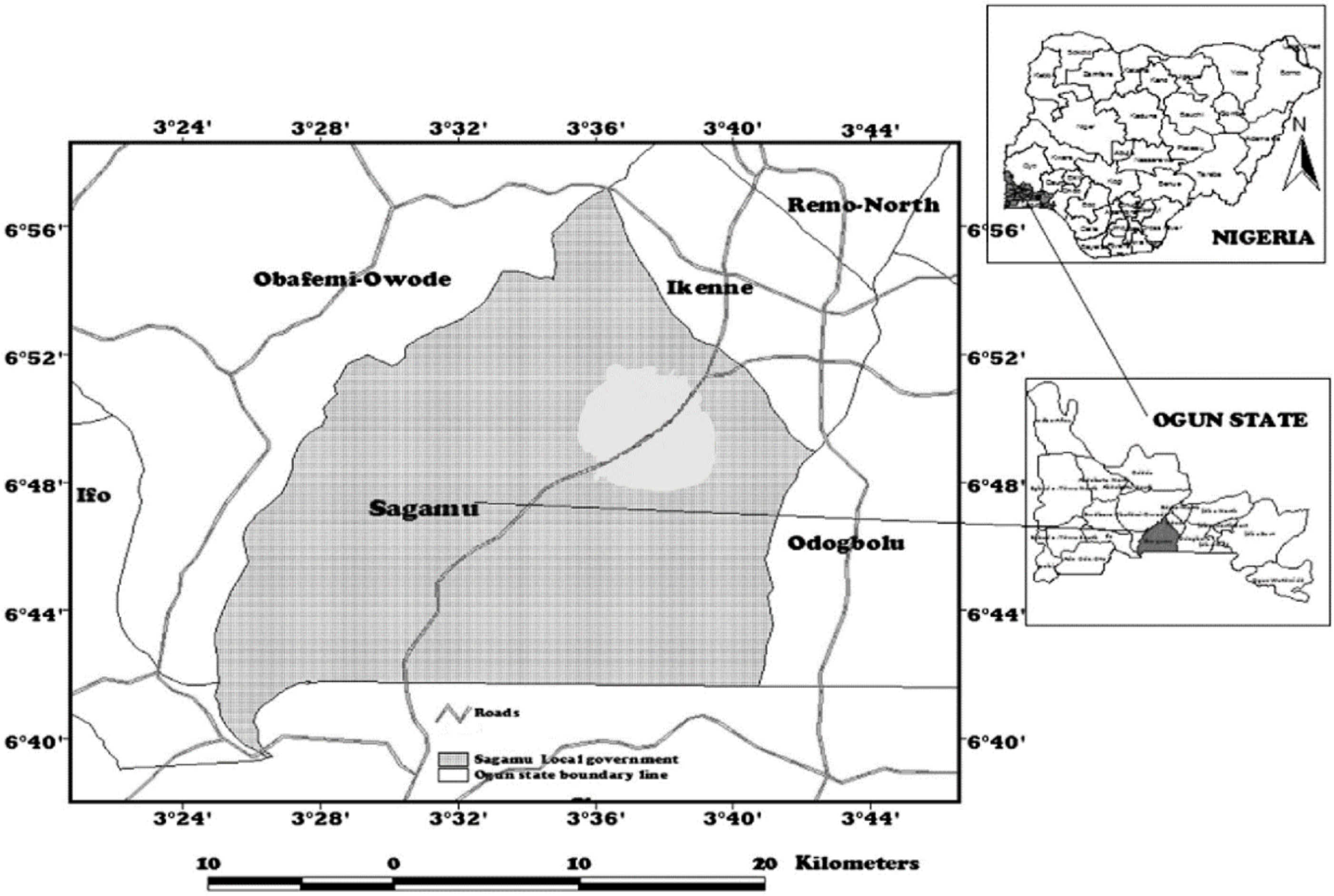

Figure 1. Map of Sagamu.

Drinking water

Drinking water is also known as portable water. Portable water is safe for drinking and cooking. Quality drinking water is very important and essential for all humans and it is one of the scarcest human commodities in the developing countries. Portable water is very important because it is essential to life and economical wealth of every human in a community. Safe, reliable and readily available water is important for public health, whether it is used for drinking, domestic use, food production or recreational purposes. Improved and quality water supply and sanitation, and better management of water resources, can boost a country's economic growth and can contribute greatly to poverty reduction. In 2010, the UN General Assembly explicitly recognized the human right to water and sanitation. Everyone has the right to sufficient, continuous, safe, acceptable, physically accessible, clean and affordable water for personal use and domestic use [4].

The indispensable nature of water, as a very important and vital requirement for human existence can never be over-emphasized. This fact, which predates these contemporary times, has been repeatedly validated from the evolution of the earliest human species (*'homo abalis'* and *'homo erectus'*) and transcends to the evolutionary eras of modern man's generic ancestral specie (the *'homo sapiens'*)-being the times, when human survival basically depended on three major critical elements-Water, Fire and Earth. Predating more importantly ahead of concrete, water is globally adjudged to be man's most used and consumed substance [5].

Portable water

Potable water simply means that the water is safer to drink and use for domestic purposes, and it is becoming scarcer in the world. Increasing use of water is stressing the freshwater resources worldwide, and a seemingly endless list of contaminants can turn once potable water into a health hazard or simply make it unacceptable aesthetically and for drinking. In a statistics and research by Fluence Corp [6], about more than two (2) billion people lack potable water at home, eight hundred and forty-four (844) million people do not have even the basic drinking water service, including two hundred and sixty three (263) million who must travel for about thirty (30) minutes per trip to get or fetch water. About one hundred and fifty-nine(159) million drink water from exposed or open surface that is not treated. Unclean drinking water is a major cause of diarrheal disease, which kills about eight hundred thousand (800,000) children under the age of five (5) a year, usually in developing countries, but ninety (90) countries are expected to fail to reach the goal of universal coverage by 2030 [6].

Water and health

Water that is contaminated and poor environmental sanitations are linked to transmission of diseases such as dysentery, diarrhea, cholera, hepatitis A, typhoid, and polio. Inadequate or inappropriately managed water and sanitation services expose individuals to preventable health risks. This is particularly the case in health care facilities where both staff and patients are placed at additional risk of infection and disease when water, sanitation, and hygiene services are lacking. Globally, 15% of patients develop an infection during a hospital stay, with the proportion much greater in low-income countries. Poor management of urban, agricultural and industrial waste water means that the drinking-water of hundreds of millions of people is dangerously contaminated or chemically polluted. More than 829 000 people are estimated to die each year from diarrhea because of unsafe drinking-water, poor sanitation, and poor hand hygiene. Diarrhea is largely preventable, and the deaths of 297 000 children aged under 5 years could be avoided each year if these risk factors were addressed. Where water is not readily available, people may decide handwashing is not a priority, thereby adding to the likelihood of diarrhea and other diseases [4].

Water availability

Water covers more than two-thirds of the earth's surface, but mostly salty and undrinkable. The available freshwater resource is only 2.7% of the available water on earth but only 1% of the available freshwater (in lakes, rivers and groundwater) is accessible. Most of the available freshwater resources are inaccessible because they are in the hidden part of the hydrologic cycles (*deep aquifers*) and in glaciers (*frozen in the polar ice*), which means safe drinkable water on earth has very small proportion (~3%) in the freshwater resources. Freshwater can also be obtained from the seawater by desalinization process. In some countries, sufficient freshwater is not available (*physical scarcity*). In some countries, abundant freshwater is available, but it is expensive to use (*economic scarcity*) [7]. As a criterion, an adequate, clean and safe drinking water supply has to be available for various users [8]. There is no universally accepted definition of "safe drinking water." Safe drinking water is defined as the water that does not represent any significant risk to health over a lifetime of consumption [9].

Water purification process

The water purification process has certain steps in increasing and different levels of severity, so that it will be purer after production. The steps involve sedimentation, filtration and disinfection, along with other steps in between. Different techniques are used to purify the water at each stage of production. The disinfection part of the process is when chemicals are used to completely kill bacteria and other microorganism in the water to make the water fit and safe for consumption. The treatment also involves acid control and adjusting of the pH to meet the standard specification. Pure water is neutral-it is neither acidic nor basic. Neither acidic nor alkaline water can be safely consumed by humans [10]. Chemicals commonly used for water filtration and purification are chlorine and its compounds, ozone, ultraviolet, etc. Despite the facts that these substances clean the water and make it consumable, it is highly controversial to say that filtered water is great for your health. In a nutshell, it seems like there was clean water, it got polluted with harmful compounds and elements, then it went through some severe treatment then it becomes clean and fit for consumption. In all of this, that water which was once fresh and clean has lost a huge percentage of its beneficial nature. Treating water with more chemicals to make it filtered and consumable might make it clean enough for safe drinking and survival, but it does not stand in comparison with fresh, natural water. Fresh water is not just good enough to help you survive, it is also beneficial to humans. Therefore, while water purification might be an ingenuous method to save humans from droughts and other dangers, it cannot be counted as equal to what humans have actually lost and are still losing-clean water (Figure 2) [10].

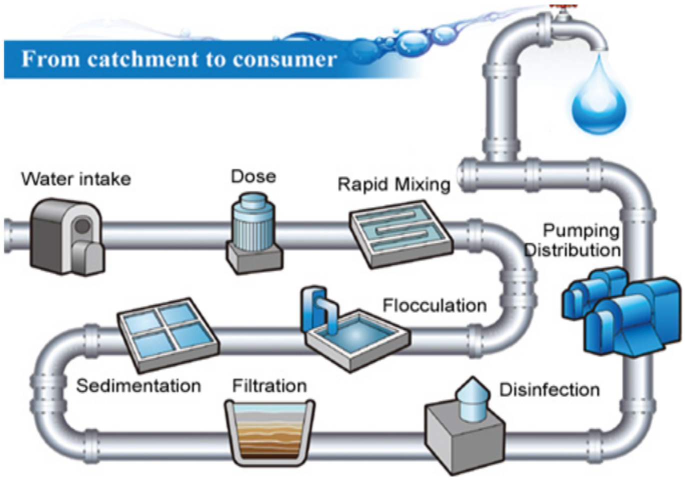

Figure 2. Water purification process.

Effects of chlorine on human health

Too much chlorine in drinking water can cause cancer. With all our technological advances, we essentially add bleach in our water to treat it before we drink. The long-term effects of chlorinated drinking water have just been recognized. According to the U.S. Council of Environmental Quality, cancer risk among people drinking chlorinated water is 93% higher than among those whose water does not contain chlorine. There is a lot of well-founded concern about chlorine. When chlorine is added to water, it combines with other natural compounds to form Trihalomethanes (chlorination byproducts), or THMs. These chlorine byproducts trigger the production of free radicals in the body, causing cell damage and which are highly carcinogenic. Although, concentrations of these carcinogens (THMs) are low, it is precisely and actually these low levels that cancer scientists believe are responsible for most human cancers [11]. Water can come from a variety of sources, such as lakes and wells, which can be contaminated with germs that can make people sick. Germs can also contaminate water as it travels through miles of piping to get to a community. To prevent contamination with germs, water companies add a disinfectant-usually either chlorine or chloramine [12] that kills disease-causing germs such as Salmonella, Campylobacter, and norovirus.

Bacteria (Enteric and Heterotrophs)

Enteric bacteria are bacteria of the intestines. The intestines of all animals are colonized with various microbes. Most of these are harmless and even beneficial. Others are harmless in normal individuals, but can produce diseases in young children, those with weakened immune systems, or in a new host that has no prior experience with the microbe. These are a few of the enteric bacteria most often associated with disease in humans: *Salmonella, Campylobacter jejuni, Eschericia Coli* (pathogenic strains) and *Shigella*. The single most effective preventive measure that we can take to protect ourselves would be thorough, regular hand washing with soap and warm water after handling animals, especially young animals with diarrhea [13]. Heterotrophs are a group of microorganisms (bacteria, molds and yeasts) that use organic carbon sources to grow and can be found in all types of water. In fact, most bacteria found in drinking water systems are considered heterotrophs. Heterotrophic plate count (HPC) is a method that measures colony formation on culture media of heterotrophic bacteria in drinking water. Thus, the HPC test (also known as Standard Plate Count) can be used to measure the overall bacteriological quality of drinking water in public, semi-public and private water systems [14]. As stated by Health Canada guidelines on HPC testing, "HPC results are not an indicator of water safety and, as such, should not be used as an indicator of potential adverse human health effects." The World Health Organization [15] (WHO, 2003) states that methods such as coliform testing are better indicators than HPC to test the sanitary conditions of water.

Water samples collection, sample design and water preparation

Sample design and collection: Sachet water samples (known as 'Pure Water') were collected from from six geographic sites spatially in the Sagamu local government area. The samples were collected and studied for five months and the average for each site was calculated for this study. Samples were preserved using standard specifications prior to the laboratory analyses. The names of the sachet waters were concealed in this research and will be labelled with area code SAG and numbers. The samples were drawn from different villages in Sagamu which are Makun along Awolowo market road, Ijagba, Sabo market area, Igbepa, Ipoji, and Ijoku. After collection, the samples were protected from direct sunlight and transported in a cooler box containing ice packs to the laboratory for analyses. All samples were stored at 4°C and analyzed within 4 hours of sample collection. Permissible limits/contaminant levels of the water samples after analyses were compared with the World Health Organization (WHO) standard, United State Environmental Pollution Agency (EPA) and Nigeria International Standard (NIS) to ascertain the level of compliance and how safe it is for public consumptions.

Quality assurance

Special precautions taken for quality assurance were as follows; all reagents were of analytical grade, and the test kits are from Merck Group, Germany. Samples for pH was preserved in a cooler with ice and analyzed within two hours of sampling. Samples for Coliform count and bacteria analyses were analyzed in less than 2 hours of sampling. Samples for NO_3^-, phosphate, Iron, Calcium, Nitrate, Alkalinity and Chloride were analyzed in less than two hours of sampling. All chemicals used are of analytical grade and all samples were at temperated to 20˚ before being analyzed. All glassware used for this research are properly washed and soaked overnight in chromic acid.

Analyses of the sachet water samples

The pH meter (Thermofisher Scientific Orion Dual Star) was calibrated using buffer 4, 7 and 10. The water sample was attemperated to 20˚C. The electrodes were rinsed with the samples and subsequently immersed into the water samples, and the pH was recorded. For turbidity, the sample was attemperated to 20˚C and analyzed using Sigrist Haze Meter. For alkalinity, 100 mls of the water sample was titrated against 0.02 N Sulphuric acid using methyl orange as indicator. For Total Hardness, a Merck kits hardness tablet is dropped in 100 mls of the sample, two drops of 32% Ammonia was added to the mixture and it was titrated against Merck Titriplex B. For Phosphate, Iron, Calcium, Nitrate and Chloride were analyzed using standard Merck reagents and read in a spectrophotometer (Spectroquant ® Prove 600, Merck). For microbiological analyses (Total Heterotrophic Bacteria and Enteric Bacteria), the samples were cultured using membrane filter method in a laminar flow hood, then transferred into the incubator for 48 hours and the plates were read. All plates were incubated at 28 ± 2°C for 48 hours.

Statistical analysis and Chart

Microsoft excel was utilized in the statistical analyses and chart designs.

Results and Discussion

From the Table 1 we can draw the analyses as below:

Turbidity

In this study, the maximum average turbidity value for all the water samples is 0.16 NTU which is only higher than the specification for Canada 0.1 NTU. Turbidity isa good indication of the purity of the water, that it is free from bacteria, because high turbidity in filtered water can indicate poor removal of pathogens. According to WHO [16], water quality and health document, the turbidity of a good drinking water should be 0.3 nephelometric turbidity units (NTU) in 95% of measurements taken each month from combined filter effluent, with none to exceed 1 NTU. Comparing EPA (0.2NTU), Canada (0.1 NTU) and NIS (5.0 NTU) as their maximum permissible limits, it appears that NIS allows for a larger range compare to the present research. Turbidity describes the cloudiness of water caused by suspended particles such as clay and silts, chemical precipitates such as manganese and iron, and organic particles such as plant debris and organisms [17,18]. As turbidity increases, it reduces the clarity of water to transmitted light by causing light to be scattered and adsorbed. Typically expressed in NTU, turbidity is a practical parameter that can be measured using online devices, and bench top and portable meters or turbidity tubes (e.g., in small communities where resources are limited). Turbidities below 4 NTU can only be detected by instruments; however, at 4 NTU and above, a milky-white, muddy, red-brown or black suspension can be visible and can reduce the acceptability of drinking-water [16]. It appears that all the water meets the turbidity requirements and standard (Figure 3).

pH

The pH range for this study in the Table 1 above is 4.73-6.10 which tends to be very acidic and below the permissible limits for EPA, WHO, NIS and Canada. The sachet drinking water may not be safe for consumption due to its acidic nature. The pH of a solution is the negative common logarithm of the hydrogen ion activity:

$\mathbf{pH}=-\log(H^+)$

$\mathbf{K_w}=[H^+]\times[OH^-]$ ………………… (Eqn 1)

$=1.01\times10^{-14}$ at 25˚C and $[H^+]=[OH^-]=1.005\times10^{-7}$

Where: $[H^+]$ is the activity of hydrogen ions (mol/L); and $[OH^-]$ is the activity of hydroxide ions (mol/L).

The activity of hydrogen ions, also called an effective concentration, refers to the ions that participate in the reaction and is different from the actual concentration of ions in a solution. A logarithmic scale is a convenient way to express the ionic activities:

$(-\log_{10}[H^+])+(-\log_{10}[OH^-])=-\log_{10}K_w$ ……… (Eqn 2)

$=14$ at 25°C (or)

$pH+pOH=pK_w$ …………….. (Eqn 3)

Where:

- $\mathbf{pH}=-\log_{10}[H^+]$
- $\mathbf{pOH}=-\log_{10}[OH^-]$; and
- $\mathbf{pK_w}=-\log_{10}K_w$

Exposure to extreme pH values results in irritation to the eyes, skin, and mucous membranes. Eye irritation and exacerbation of skin disorders have been associated with pH values greater than 11. In sensitive individuals, gastrointestinal irritation may also occur. Exposure to low pH values can also result in similar effects. Below pH 4.0, redness and irritation of the eyes have been reported, the severity of which increases with decreasing pH. Below pH 2.5, damage to the epithelium is irreversible and extensive. In addition, because pH can affect the degree of corrosion of metals as well as disinfection efficiency, it may have an indirect effect on health [19]. The optimum pH will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but it is often in the range 6.5-9.5. Extreme pH values can result from accidental spills, treatment breakdowns, and insufficiently cured cement mortar pipe linings (Figure 4) [20].

Table 1. Physicochemical and microbiological analyses of the samples.

Samples		Samples						Standard and Permissible Limits			
		SG1	SG2	SG3	SG4	SG5	SG6	WHO	Canada	EPA	NIS
Turbidity	NTU	0.12	0.12	0.08	0.16	0.12	0.08	0.3	0.1	0.2	5
pH		4.89	6.1	5.71	5.14	4.97	4.73	6.5-8.5	7.0-10.5	6.5-8.5	6.5-8.5
Alkalinity	mg/l	12.00	10.00	9.00	12.00	17.00	19.00	500	NA	NA	NA
T. Hardness	mg/l	5.00	6.00	3.00	6.00	4.00	3.00	<60	<80-100	NA	NA
Phosphate	mg/l	0.29	0.12	0.34	0.51	0.32	0.44	5	NA	5	5
Iron	mg/l	0.03	0.02	0.13	0.15	0.21	0.19	0.3	0.3	0.3	0.3
Calcium	mg/l	2.80	3.50	4.80	2.10	3.30	4.21	75	75	75	200
Nitrate	mg/l	2.50	2.20	2.30	2.31	0.00	2.40	50	50	45	50
Chloride	mg/l	12.80	18.60	17.80	26.70	18.00	28.30	250	250	250	250
THBC	Cfu/100 ml	400.0	300.0	420.0	480.0	470.0	450.0	<500	<500	<500	NA
EB	Cfu/100 ml	280.0	310.0	280.0	380.0	310.0	280.0	NA	NA	NA	NA

Notes: 1 EBC: 4.081NTU, EBC: European Brewery Convention, NTU: Nephelometric Turbidity Units, THBC: Total Heterotrophic Bacteria Count, EB: Enteric Bacteria Count, CFU: Colony Forming Unit, Data: All samples data in this table are calculated mean from five consecutive analyses, NA: Not available.

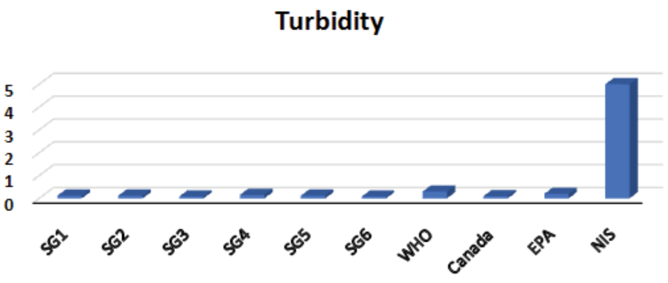

Figure 3. Turbidity of the water samples.

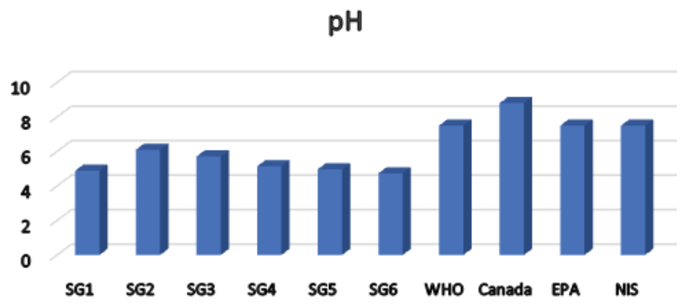

Figure 4. pH of the water samples.

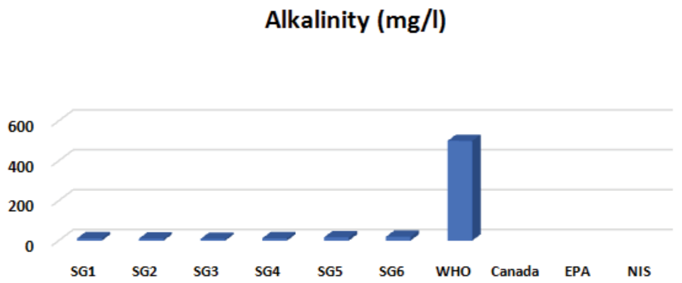

Figure 5. Alkalinity concentration in the water samples.

Alkalinity

The average alkalinity in this study ranges from 9 mg/l to 19 mg/l, which is below the permissible limits 500 mg/l for drinking water. If the alkalinity concentration is too high in the water, the side effects may include impaired digestion, worsening of a kidney disorder and dry, itchy skin. Generally, experts consider mildly high alkalinity safe, but research on the long-term effects is extremely limited [21]. Alkalinity is not a chemical in water, but, rather, it is a property of water that is dependent on the presence of certain chemicals in the water, such as bicarbonates, carbonates, and hydroxides. A definition of alkalinity would then be "the buffering capacity of a water body; a measure of the ability of the water body to neutralize acids and bases and thus maintain a fairly stable pH level" (Figure 5) [22].

Total hardness

The average total hardness ranges from 3 mg/l to 6 mg/l which is less than the WHO and Canada permissible limit of total hardness in drinking water. Calcium and magnesium are essential minerals and are beneficial to human health in several respects. Inadequate intake of either nutrient result in adverse health consequences. Recommended daily intakes of each element have been set at national and international levels. Individuals vary considerably in their needs for and consumption of these elements (Figure 6) [23].

Phosphate

The average phosphate concentration ranges from 0.12 mg/l to 0.51 mg/l which are very much below the permissible limit levels for WHO, NIS and EPA. Phosphorus is one of the key elements necessary for growth of plants and animals. Phosphorus in elemental form is very toxic and is subject to bioaccumulation. Phosphate exists in three forms: Orthophosphate, metpho sulfate, and organically bound phosphate. Each compound contains phosphorus in a different chemical formula ortho form are produced by natural processes and are found in sewage. Poly forms are used for treating boiler water and in detergents water they change into the ortho form, organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. They may exit in solution, as particles, loose fragments, or in the bodies of aquatic organisms. Rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways. Digestive problem could occur from extremely high level of phosphate (Figure 7) [24].

Iron

The average iron concentration in this study ranges between 0.02 mg/l to 0.21 mg/l. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status [25]. The average lethal dose of iron is 200-250 mg/kg of body weight, but death has occurred following the ingestion of doses as low as 40 mg/kg of body weight [26]. Autopsies have shown hemorrhagic necrosis and sloughing of areas of mucosa in the stomach with extension into the submucosa. Chronic iron overload results primarily from a genetic disorder (haemochromatosis) characterized by increased iron absorption and from diseases that require frequent transfusions [27]. It was also discovered that adults who have often taken iron supplements for extended periods of time did not observed any deleterious effects [27], and an intake of 0.4-1 mg/kg of body weight per day may unlikely cause adverse effects in healthy persons (Figure 8) [28].

Calcium

In this study, the average range concentration of Calcium was found to be 2.10 mg/l to 4.8 mg/l. It was below the permissible limits suggested by WHO, Canada, NIS, and EPA. Calcium is naturally present in water. It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite, and apatite. Calcium is a determinant of water hardness because it can be found in water as Ca^{2+} ions. Magnesium is the other hardness determinant. When one takes up large concentration of calcium, this may negatively influence human health. The lethal dose of oral uptake is about 5-50 mg/ kg body weight. Metallic calcium corrodes the skin when it comes in contact with skin, eyes, and mucous membranes (Figure 9) [29].

Nitrate

In this study, the average nitrate concentration falls in the range of 0.00 mg/l to 2.50 mg/l and which are well below the permissible limits. Nitrate is

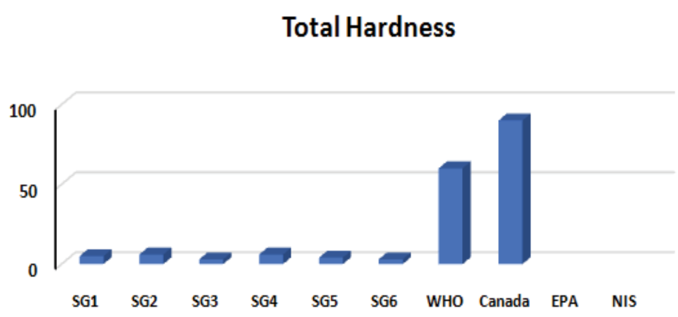

Figure 6. Total hardness concentration in the water samples.

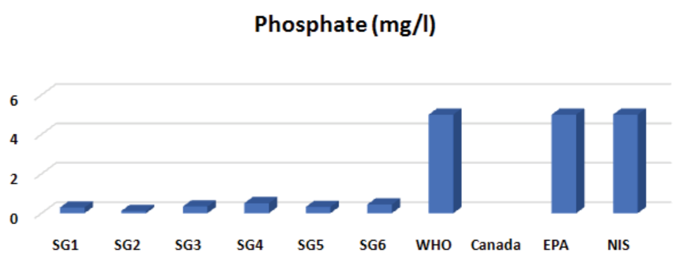

Figure 7. Phosphate concentration in the water samples.

one of the most common groundwater contaminants in rural areas. It sources might be as a result of soil by-product of agricultural fertilization and human and animal waste leaching to ground water [30]. It is regulated in drinking water primarily because excess levels can cause methemoglobinemia, or "blue baby" disease. Although nitrate levels that affect infants do not pose a direct threat to older children and adults, they do indicate the possible presence of other more serious residential or agricultural contaminants, such as bacteria or pesticides [31]. Potential health risks are often unknown or hard to predict, many drinking water standards are set at some fraction of the level of "no-observed adverse-health effects." In general, the greater the uncertainty about potential health effects, the greater the margin of safety built into the standard. In the case of nitrate, there may not be a large safety factor. A 1977 report by the National Academy of Science concluded that "available evidence on the occurrence of methemoglobinemia (*blue baby syndrome*) in infants tends to confirm a value near 10 mg/l nitrate as a maximum no-observed adverse-health-effect level, but there is little margin of safety in this value." (Figure 10).

Chloride

The average range of Chloride in this study falls between 12.8 mg/l to 28.3 mg/l and it is below the permissible limit proscribed by WHO, EPA, Canada and NIS. A normal adult human body contains approximately 81.7 g chloride. On the basis of a total obligatory loss of chloride of approximately 530 mg/day, a dietary intake for adults of 9 mg of chloride per kg of body weight has been recommended (equivalent to slightly more than 1 g of table salt per person per day). For children up to 18 years of age, a daily dietary intake of 45 mg of chloride should be sufficient [32]. A dose of 1 g of sodium chloride per kg of body weight was reported to have been lethal in a 9-week-old child [33]. Chloride toxicity has not been observed in humans except in special case of impaired sodium chloride metabolism, e.g., in congestive heart failure [34]. Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet. As in experimental animals, hypertension associated with sodium chloride intake appears to be related to the sodium rather than the chloride ion (Figure 11) [32].

Total enteric bacteria and enteric bacteria

The Total Enteric Bacteria and Enteric Bacteria are a little below the permissible limits of less than 500 colony forming unit (CFU) stipulated by WHO, Canada and EPA. This may indicate improper personal hygiene and poor sanitation levels. The value may go higher with time if the sachet water is stored in an improper condition. The presence of fecal coliform bacteria in drinking water indicates that the water has been contaminated with fecal material of man or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease producing bacteria or

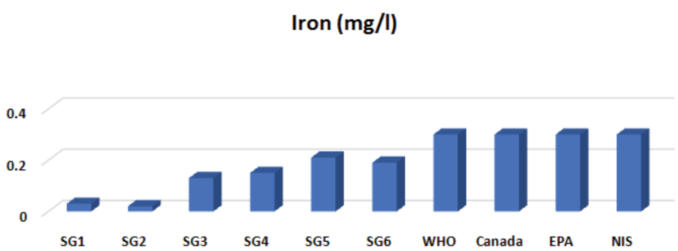

Figure 8. Iron concentration in the water samples.

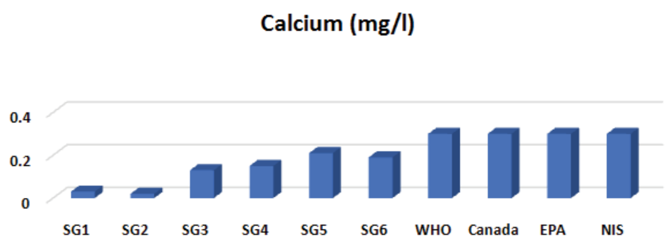

Figure 9. Calcium concentration in the water samples.

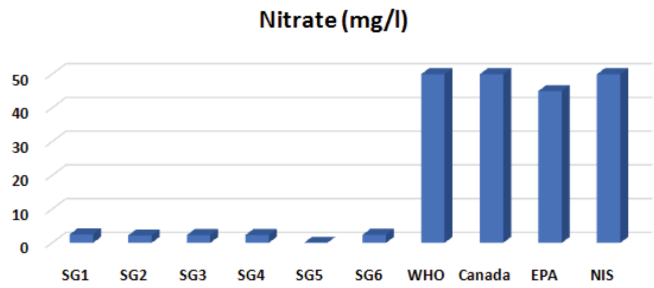

Figure 10. Soil ingestion dose for Cd at Eggon.

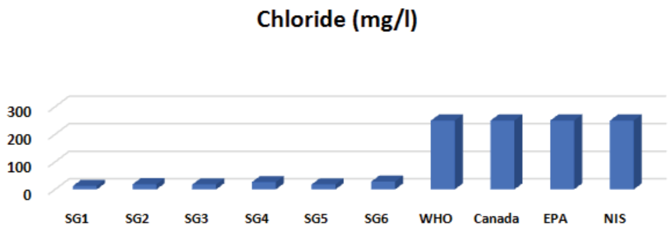

Figure 11. Chloride concentration in the water samples.

viruses which can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water because of the overflow of domestic sewage or nonpoint sources of human and animal waste [35].

Conclusion

Based on the findings in this research, the pH 4.73-6.10 with permissible limits of 6.5-10.5, analyzed did not fall between the permissible limits as expected and it is very important that water producers ensure acid control in their water system. Other physicochemical parameters analyzed, turbidity 0.08-0.16NTU with permissible limits of 0.1-5.0 NTU, alkalinity 9-17 mg/l with permissible of 500.00 mg/l, Total hardness 3-6 mg/l with permissible limits of <60-100 mg/l, Phosphate 0.12-0.51 mg/l with permissible limits of <5 mg/l, Iron 0.02-0.21 mg/l with permissible limits of <0.03 mg/l, Calcium 2.10-4.80 mg/l with permissible limits of <75-200 mg/l, Nitrate 0.00-2.50 mg/l with permissible limits of <45-50 mg/l, Chlorine 12.8-28.30 mg/l with permissible limits of <250 mg/l and bacteriological analyses, Total Enteric Bacteria of 300-480 CFU/100 ml with permissible limits of <500 CFU/100 ml and Enteric Bacteria of 280-380 CFU/100 ml of the water samples above falls within or below the permissible limits as stated by WHO, EPA, Canada and NIS. There were growths in the microbiological analyses which are below the permissible limit, and if it is not properly managed, the growth will go above the permissible limits prescribed by EPA, NIS, Canada and WHO when it is being stored improperly before consumption. Proper hygiene condition, good sanitation and personal hygiene should be concentrated on by the producers of the sachet 'Pure Water'. Also, if the borehole for the raw water is cited close to the toilet or waste dump site, the water may come out not clean, contaminated and if it is not properly treated, fecal coliform may infect the water.

Recommendations

Water production facility should comply with proper housekeeping; site their raw water source in a very safe location free from latrines, chemical waste dump sites and drainages. The government should involve the participation of reputable private hospitals with equipped laboratory to monitor and report the analyses of each water factory in it environ, the government should involve the participation of qualified individual with equip laboratory to run and manage township water supply through pipes to homes around its environment and nearest communities, thereby, installing a meter and charging each house for water usage monthly. Also, the regulatory body such as NAFDAC and SON should continuously assess and monitor the production of water by each vendor. Individuals can also help by storing water properly and reporting any illegal practices by water production companies.

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