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Health Risk Assessment of the Drinking Water from Sagbama River, Bayelsa State, Niger Delta, Nigeria

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Abstract— Sagbama River is a source of drinking water and the place for open defecation for communities in Sagbama. The river has also been subjected to crude oil pollution like other rivers in Niger Delta, Nigeria. This study sought to determine the levels of the physiochemical and bacteriological parameters of biochemical relevance in Sagbama River (SR). The prevalence of water borne diseases in Sagbama communities was also evaluated. Water samples were randomly collected from three sampling points in Sagbama River and analysed using standard procedures. Hospital records on water borne diseases were randomly collected from the Primary and Secondary Health care Centers in Sagbama communities and analysed. The Colour, odour, taste and turbidity of SR samples did not comply with the Nigerian standard for drinking water quality (NSDWQ) and WHO guidelines. Expressed in mg/ml, Al-(0.41 ± 0.06), CN-(0.31 ± 0.06), Nitrate-(98.49 ± 1.67), Nitrite-(13.32 ± 1.24) and the following heavy metals; As-(0.090 ± 0.060), Cd-(0.040 ± 0.040), Fe-(0.480 ± 0.230) and Pb-(0.090 ± 0.070) exceeded the limit set by the NSDWQ and WHO. *E. coli* ($2.4 \times 10^2 \pm 4.9 \times 10^1$ cfu/ml), fecal coliform ($2.5 \times 10^2 \pm 5.1 \times 10^1$ cfu/ml), total coliforms ($1.3 \times 10^4 \pm 1.0 \times 10^4$ cfu/ml), *Salmonella spp*. ($2.1 \times 10^4 \pm 4.1 \times 10^3$ cfu/ml) and *Vibrio cholerae* ($1.3 \times 10^3 \pm 9.1 \times 10^2$ cfu/ml) were found in all the samples, signifying faecal contamination. Overall, the prevalence of water borne diseases in Sagbama communities was 88%. Typhoid (64%) was the most prevalent followed by diarrhoea (25%). Compared with the older age groups, children under-five had the highest prevalence of water borne diseases (35%; $p < .05$). This study showed that Sagbama River poses serious health risk to its consumers. These findings may have implications for health promotion activities against drinking untreated Sagbama river water, open defecation and crude oil pollution

Index Terms— Children under-5, drinking water, *E. coli*, heavy metals,Niger Delta, Sagbama River, typhoid

1 Introduction

Access to safe drinking water, aside from been essential to health, is also a basic human right. However, 884 million people worldwide, lack access to potable water, including 159 million people worldwide who are dependent on surface water [1]. Most rural communities use rivers for drinking, open defecation and domestic purposes. This predisposes them to the risk of contracting water borne diseases like diarrhoea, cholera, dysentery, typhoid, and polio [2]. According to World Health Organization, about 827 000 people in low- and middle-income countries die as a result of inadequate water, sanitation, and hygiene each year [3]. Also, according the United Nations International Children's Emergency Fund (UNICEF), poor access to improved water and sanitation in Nigeria remains a major contributing factor to high morbidity and mortality rates among children under five. In addition, UNICEF reported that only 26.5 per cent of the population use improved drinking water sources and sanitation facilities in Nigeria and 23.5 per cent of the population defecate in the open in Nigeria [4]. A previous study carried out by Abdulkadir *et al*., [5] in Bodinga Local Government Area of Sokoto State, Nigeria, found dysentery, typhoid, gastroenteritis, diarrhoea, skin infection and cholera to be the most prevalent water borne diseases in the area. Also another study carried out by Raji and Ibrahim [6], found a high incidence of waterborne infections in North West Nigeria. The water borne infection they found were also typhoid, cholera, dysentery, diarrhoea and gastroenteritis.

Crude oil contains heavy metals, inorganic and organic chemical constituents most of which are carcinogenic, cause neurological disorder, renal toxicity, hypertension and anaemia [7]. The presence of these chemical constituents in surface water beyond a certain level, renders them unfit for drinking. The Niger Delta region of Nigeria has experienced crude oil pollution of its surface water for decades. However, left with no other choice, most communities in the rural Niger Delta region of Nigeria drink these polluted surface water and also use them for domestic activities. The devastating effect of crude oil spill in the lower Niger (Sombriero River) has been reported in a previous study carried out by Frank and Boisa [8]. In addition to the problem of crude oil pollution, open defecation on surface waters is another major source of surface water pollution in the Niger Delta region of Nigeria. Residents of riverine communities in Niger Delta, Nigeria, defecate on the surface water that also serve as their source of drinking water thereby, increasing their risk of contracting water borne infections. Like every other riverine community in Niger Delta Nigeria, communities in Sagbama Local Government Area also engage in the same practice of open defecation on surface water and they carry out this activity on Sagbama River. Other Sagbama residents defecate in the bushes and forests around them, only a few of the Sagbama residents have basic sanitary facility [9]. However the degree of health risk that the consumers of Sagbama river water are exposed to has not been evaluated.

Two main approaches to health risk assessment of drinking water quality have been previously described. The first of these is the parameter approach, in which the estimation of the risk related to the use of water is based upon the presence of different parameters (i.e. chemicals and microorganisms) and the compliance of each parameter with a reference / standard concentration. The second is the approach of studying the effect of the water on test organisms or on the human population consuming it [10]. Majority of the previous studies carried out on drinking water quality assessment in other regions, only assess the parameters in drinking water [11], [12], [13]. Thus the resultant human health effect consumers are exposed to by drinking such water cannot be fully ascertained. The present study used both the parameter approach and the effect on Sagbama population approach to assess the health risk of drinking Sagbama River water.

2 MATERIALS AND METHODS

2.1 Study Location

The study location was Sagbama Local Government Area (LGA), Bayelsa State, Nigeria. Bayelsa is a core state in the Niger Delta region of Nigeria. The headquarters of Sagbama LGA is Sagbama town and it is located on latitude 5.152239 and longitude 6.192479. Sagbama LGA is on the left bank of Forcados River and along its course at Sagbama, Forcados River is commonly referred to as Sagbama River. Forcados River, a major navigable channel in the Niger Delta is formed when river Niger splits into two, namely; Forcados River and Nun River. The several communities in Sagbama LGA are clustered around the concave bank of Sagbama River. Sagbama LGA is predominantly a riverine fishing and farming settlement and the indigenes are mainly Ijaws. The LGA occupies an area of 945 km² with a population of 187,146 as at the 2006 census. The Sagbama LGA has 38 communities some of which are: Ofoni, Toru - Oua, Sagbama, Bulou - Orua, Tungbo, Adagbabiri, Adoni, Asamabiri, Angalabiri, Ebedebiri, Osekwenike, Agoro and Trofani [14].

2.2 Collection of Water Samples

Three communities along the stretch of Sagbama river namely; Sagbama town, Toru – Orua, and Angalabiri were randomly selected as sampling points for this study. Water samples were randomly collected from each sampling point using a 500 ml sterile plastic bottle in July 2020. The odour, taste, temperature and total dissolved solids of the water samples were analysed in situ, while the other parameters were analysed in the laboratory within 24 hrs. The samples were transported on ice to the laboratory and were kept in the refrigerator at 4^0C prior to analysis [11].

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2.3 Physiochemical Analysis

The odour, taste, temperature, colour, electrical conductivity, total dissolved solids, turbidity, Alkalinity, Al, Ba, Cl^-, CN, fluoride, hardness, pH, Mg, Mn, Na, Ni, Nitrate, Nitrite, Sulphate and heavy metals (As, Cd, Cr, Cu, Fe, Pb and Zn) were analysed using standard methods described by APHA and WHO [1], [15]. Table 1 gives a brief description of these standard methods.

Table 1
Methods and Instruments used for Physiochemical Analysis [1], [15]

Parameter	Instrument / Method
Odour	Sense of smell
Taste	Sense of taste
Temperature	Thermometer
Colour	Platinum-Cobalt Scale
EC	Electrical Conductivity Meter
TDS	TDS Meter
Turbidity	Nephelometer
Al, Ba, Mg, Mn, Na, Ni	Atomic absorption spectrophotometry
Heavy Metals: As, Cd,	Atomic absorption spectrophotometry
Cr, Cu, Fe, Pb, Zn	Atomic absorption spectrophotometry
Cl	Titrimetric method: Silver nitrate used as titrant
Hardness	Titrimetric Method: Disodium EDTA Complexometric Titration
Alkalinity	Titrimetric Method: HCl used as Titrant
CN, Nitrate, Nitrite	Spectrophotometric Technique
F^-	Ion Selective Electrode Method
pH	pH meter
Sulphate	Gravimetric method

2.4 Bacteriological Analysis

The standard membrane filtration technique was used for bacteriological analysis of the river water samples. Exactly 100 ml of each water sample was passed through a separate filter of 0.45 µm pore size and 47 mm diameter. The bacteria present in the water samples remained concentrated on the surface of the filter. The filter was placed in a sterile Petri dish with a selective medium specific for each bacteria to be analysed. Each of the filter for the enumeration of total coliform, E. coli and faecal coliform were placed in a Petri dish containing Eosin-methylene-blue (EMB) Agar, Levine, and were incubated for 48 hours at 35 ± 0.5 °C for total coliform and for 24 hours at 44 ± 0.5 °C for faecal coliform and E. coli. This elevated temperature heat shocked non-fecal bacteria and suppressed their growth. The presence of a characteristic greenish metallic sheen indicated the presence of E. coli [15]. The filter for Salmonella sp. was placed on a 100 ml buffered peptone water (BPW) (37°C/24 hours), followed by incubation in 10 ml of Rappaport-Vassiliadis medium (42°C/24 hours) and subsequent subculturing on brilliant green agar and bismuth sulphide agar at 37°C for 24h [16]. The filter for Vibrio cholerae was transferred to a pre-enrichment alkaline peptone water media and incubated for six hours followed by streaking for isolation onto Thiosulfate-citrate-bile salts-sucrose agar and incubation for 24 hours at 35 ± 0.5 °C [17]. Colonies were counted and expressed as coliform forming unit (cfu)/ml [15.

2.5 Data Collection on Water Borne Diseases in Sagbama LGA from August 2019 to July 2020

A total of 1000 records of patients that have been diagnosed of water borne diseases were randomly collected from Sagbama General Hospital Medical Laboratory register and the outpatient department register of the Primary Health Care Centers in Sagbama LGA. Out of the 1000 records collected, the records of 132 patients without complete data were excluded from the study. Only the complete records of a total of 868 patients diagnosed with water borne diseases in the Health Care Centers from August 2019 to July 2020 were analysed. [5]. The water borne diseases of interest in the present study were typhoid, diarrhoea, dysentery and cholera

2.3 Data Analysis

The concentrations of the physiochemical and bacteriological parameters from each sampling point were recorded and the mean was computed and presented as mean ± standard error of mean (SEM). Data obtained from the Primary and Secondary Health Care Centers in Sagbama LGA were analysed using SPSS version 20. The prevalence of water borne diseases at Sagbama was stratified by age and sex. The relationship between age and water borne disease infections was analysed using Pearson Chi-Squared ($\chi 2$) test and the statistical level of significance was set at $p < .05$.

3. RESULTS

3.1 Physical Parameters of Sagbama River Water, Bayelsa State, Nigeria

The levels of the physical parameters present in Sagbama River is showed in Table 2. None of the physical-organoleptic parameters (odour, taste, colour and turbidity) met the standards set by NSDWQ and WHO guidelines forndrinking water.

Table 2

Physical parameters of Sagbama River, Bayelsa State, Nigeria

Parameter (Unit)	Level of parameter	Standards WHO	NSDWQ
Odour	obj	unobj	unobj
Taste	obj	unobj	unobj
Tempt (°C)	25.67 ± 0.33	ambient	ambient
Colour (TCU)	19.0 ± 0.60	15.00	15.00
EC (μS/cm)	119.00 ± 37.50	1000.00	NA
TDS (mg/l)	191.67 ± 15.88	500.00	600.00[a]
Turbidity	10.30 ± 1.11	5.00	5.00

Results are presented as mean of triplicate determinations from the three sampling points ± SEM; EC = Electrical conductivity; TDS = Total dissolved solids; Tempt = temperature; obj = objectionable; unobj = unobjectionable; Turbidity measured in Nephelometric turbidity unit (NTU); TCU = True colour unit; NA = Not available; NSDWQ = Nigerian Standard for Drinking Water Quality; WHO = World Health Organization;
[a]acceptability threshold, no health-based guideline value has been proposed.

3.2 Levels of Chemical Constituents in Sagbama River, Bayelsa State, Nigeria

The result of the concentrations of the chemical parameters in Sagbama River is presented in Table 3. Most of the chemical constituents were within the permissible limit set by WHO and NSDWQ except for Aluminium, Cyanide, Nitrate and Nitrite. pH was below the standard range.

Table 3
Levels of Chemical Constituents (mg/l) in Sagbama River, Bayelsa State, Nigeria

Parameter	Level of Parameter	Standards WHO	NSDWQ
Al	0.41 ± 0.06	0.20[a]	0.20
Ba	0.13 ± 0.08	1.30	0.70
Cl^-	11.30 ± 2.86	250.00	250.00[a]
CN	0.31 ± 0.06	0.17[a]	0.01
F	0.73 ± 0.35	1.50	1.50
Hardness	41.40 ± 5.14	200.00[a]	150.00
Mg	2.40 ± 0.40	NA	20.00
Mn	0.23 ± 0.06	0.10[a, b]	0.02
NO_3^-	98.49 ± 1.67	50.00	50.00
NO_2^-	13.32 ± 1.24	3.00	0.20
pH	5.67 ± 0.54	NA	6.50–8.50
Na	18.01 ± 1.40	200.00[a]	200.00[a]
Sulphate	22.07 ± 5.93	250.00	100.00
Alkalinity	12.98 ± 1.44	NA	150.00

Results are presented as mean of triplicate determinations from the three sampling points ± SEM; NSDWQ = Nigerian Standard for Drinking Water Quality; WHO = World Health Organization; NA = Not available
[a]acceptability threshold; no health-based guideline value has been proposed;
[b]The health-based value of 0.4 mg/l for manganese is higher than its ac-

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ceptability threshold of 0.1 mg/l; pH which has no unit.

3.3 Levels of Heavy Metals in Sagbama River, Bayelsa State, Nigeria

Presented in Table 4 are the heavy metals found in Sagbama River and the concentration of each heavy metal. All the heavy metals exceeded their maximum permissible limit in drinking water as stipulated by WHO and NSDWQ except for chromium, copper and Zinc.

Table 4
Levels of heavy metals (mg/l) in Sagbama River, Bayelsa State, Nigeria

Parameter	Level of Parameter	Standards WHO	NSDWQ
As	0.090 ± 0.060	0.010	0.010
Cd	0.040 ± 0.040	0.003	0.003
Cr	0.030 ± 0.010	0.050	0.050
Cu	0.420 ± 0.290	2.000	1.000
Fe	0.480 ± 0.230	0.300[a]	0.300
Pb	0.090 ± 0.070	0.010	0.010
Ni	0.01 ± 0.010	0.070	0.020
Zn	2.870 ± 0.830	4.000[a]	3.000

Results are presented as mean of triplicate determinations from the three sampling points ± SEM; NSDWQ = Nigerian Standard for Drinking Water Quality; WHO = World Health Organization;
[a]acceptability threshold; no health-based guideline value has been proposed.

3.4 Levels of Faecal Pathogens in Sagbama River, Bayelsa State, Nigeria

Table 5 shows the faecal pathogens present in Sagbama River and the level of each faecal pathogen. Salmonella spp. had the highest count while E. coli had the lowest count.

Table 5
Levels of Faecal Pathogens (cfu/ml) in Sagbama River, Bayelsa State, Nigeria

Pathogen	Level of Feacal Pathogen	Standards WHO	NSDWQ
E. coli	$2.4 \times 10^2 \pm 4.9 \times 10^1$	0.0	0.0
FCC	$2.5 \times 10^2 \pm 5.1 \times 10^1$	0.0	0.0
TCC	$1.3 \times 10^4 \pm 1.0 \times 10^4$	10.0	0.0
SSC	$2.1 \times 10^4 \pm 4.1 \times 10^3$	0.0	0.0
VCC	$1.3 \times 10^3 \pm 9.1 \times 10^2$	0.0	0.0

TCC = Total Coliform count; FCC = Fecal coliform count; SSC = *Salmonella spp.* count; VCC = *Vibrio cholerae* count; WHO = World Health Organization; NSDWQ = Nigerian Standard for Drinking Water Quality; cfu = colony forming unit.

3.5 Prevalence of Water Borne Diseases in Sagbama LGA, Bayelsa State, Nigeria

Presented in Table 6 is the result of the prevalence of water borne diseases in Sagbama LGA from August 2019 to July 2020. The overall prevalence of water borne diseases in Sagbama LGA was 766 (88%). Typhoid fever and Diarrhoea were the most prevalent water borne diseases in the LGA. Compared with other age groups, children under five had the highest prevalence of water borne diseases ($p < .05$).

Table 6
Prevalence of Water Borne Diseases in Sagbama LGA, Bayelsa State, Nigeria

Water Borne Disease	Age Category (years) < 5 N (%)	5 – 17 N%	18 – 64 N%	65+ N%	Total N%
Typhoid					
Male	55 (6)	54 (6)	77 (9)	21 (2)	207 (24)
Female	64 (7)	45 (5)	203 (23)	34 (3)	346 (40)
Diarrhoea					
Male	87 (10)	15 (2)	0 (0)	0 (0)	102 (12)
Female	97 (11)	14 (2)	0 (0)	0 (0)	111(13)
Dysentery					
Male	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Female	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cholera					
Male	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Female	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	**303 (35)**	**128 (15)**	**280 (32)**	**55 (6)**	**766 (88)** ***p*** < .05

N = frequency; data from the medical records of 868 patients were analyzed in the present study. Only 102 (12%) records showed no water borne disease.

3 DISCUSSION

In assessing the acceptability and quality of drinking-water, consumers rely principally upon their senses. Microbial, chemical and physical constituents of water may affect the colour, turbidity, total solids, odour and taste of water. Objectionable appearance, taste or odour of drinking water like the one found in this study may be regarded by consumers as unsafe and rejected [1]. Similar objectionable physical and organoleptic parameters of drinking water from surface water have been reported in previous studies by Shukla et al., [11] and Frank & Boisa [8]. Guideline values have not been established for constituents influencing water quality that have no direct link to adverse health impacts. Appearance, taste and odour of drinking water may be indicative of some form of pollution or maybe an indication of the presence of potentially harmful substances. It is therefore wise to be aware of consumer perceptions and to take into account both health related guideline values and aesthetic acceptability values and criteria when assessing drinking water supplies and when developing regulations and standards [1].

In the present study, most of the chemical constituents found in Sagbama River were within the permissible limit set by NSDWQ and WHO guidelines except for heavy metals, nitrate, nitrite, aluminium and cyanide. High level of nitrite causes methaemoglobinaemia and thyroid effects in humans especially in the most sensitive subpopulations and bottle-fed infants and thus should not be allowed to exceed its maximum limit in drinking water. Methaemoglobinaemia is a consequence of the reaction of nitrite with haemoglobin in the red blood cells to form methaemoglobin, which binds oxygen tightly and does not release it, thus blocking oxygen transport [1]. High levels of aluminum and cyanide are potential risk factors for neurodegenerative disorder and cyanide is very toxic to the thyroid [18], [1]. Heavy metals cause a range of adverse health effect which include cancer, hypertension, renal disorder, gastrointestinal disorder, neurodegenerative disorder, cardiovascular disorders, diabetes and interference with vitamin D metabolism. Reactive oxygen species generation and oxidative damage to cells, tissues and organs of the body have been reported as mechanisms of action of heavy metal toxicity [18], [19].

In addition, this study found a high level of faecal pathogens in Sagbama River. The presence of faecal pathogens such as *E. coli,* Fecal coliform, *Salmonella spp*. and *Vibrio cholerae* in Sagbama River is indicative of faecal contamination of the drinking water from Sagbama River. The source of faecal contamination of Sagbama River is primarily the practice of open defecation taking place in Sagbama River by the residents of Sagbama communities. The presence of faecal pathogens in surface water used for drinking has also been reported in previous studies carried out by Akrong & Amu-Mensah [12] and Eluma & Onaji [13]. The control of faecal contamination in drinking water systems and sources, where it occurs, is of primary importance [1]. Nigeria ranks third position in the world on the list of countries with high prevalence of open defecation [20]. Open defecation exist in all regions of Nigeria with the highest been North Central. Aside from defecating in the open surface water, most people living in the riverine rural communities in Niger Delta, Nigeria, also defecate in the bushes and forests around them [9].

Furthermore, a high prevalence of water borne diseases in Sagbama LGA, Bayelsa State, Nigeria was found in this study. This is in agreement with the findings of similar previous studies carried out by Abdulkadir *et al*., [5] and Raji [6]. However, unlike the cases of cholera and dysentery which were reported in these previous studies, no case of cholera and dysentery was found in the present study. This suggests a region specific approach in tackling water borne diseases. Also it is not surprising that the most prevalent water borne disease was typhoid given that *Salmonella spp*. had the highest microbial load in Sagbama river water samples. Again, this also suggests an association between the faecal pathogens in Sagbama River and the type of water borne disease most prevalent in the community. Children under-five had the highest prevalence of water borne diseases in the present study as well as in the previous study carried out by Raji and Ibrahim [6] and an association ($p < .05$) between age under five and water borne diseases was found in this study. According to the United Nations Children's Fund, the use of contaminated drinking water and poor sanitary conditions result in increased vulnerability to water-borne diseases, including diarrhoea which leads to deaths of more than 70,000 children under five annually [4]. Thus, the need to provide safe and hygienic potable water for children under five was re-emphasized in this study.

5 CONCLUSION

The present study suggests that untreated Sagbama River water should not be used as a source of drinking water because of the presence of high concentrations of heavy metals and other harmful chemical constituents which are toxic to the body. The presence of faecal pathogens in Sagbama River also makes it unfit for drinking. Behavioural change health promotion campaigns against open defecation on surface water should be mounted in this region of Nigeria. Also, it is suggested that children under five should not be given untreated Sagbama Riverwater to drink in order to prevent the incidence of typhoid and diarrhoea in children under five which was observed in this study. Thus from the results of this study it can be concluded that Sagbama River poses serious health risk to its consumers. These findings may have implications for various health promotion activities against open defecation, drinking untreated Sagbama river water and crude oil pollution

REFERENCES

[1] World Health Organiation, WHO, "Guidelines for drinking-water quality," Geneva 27, Switzerland, 2017.

[2] J. O. Okullo, W. N. Moturi, and G. M. Ogendi, "Open defaecation and its effects on the bacteriological quality of drinking water Sources in Isiolo County, Kenya," *Environmental health insights*, vol. *11*, 2017.

[3] WHO, "Sanitation and Health," Geneva 27, Switzerland, 2019.

[4] United Nations International Children's Emergency Fund (UNICEF). Nigeria, "Water sanitation and hygiene, UNICEF, Nigeria, 2018.

[5] N. Abdulkadir, R. O., Afolabi, H. M., Usman, G., Mustapha, and U. A. Abubakar, "Epidemiological Studies of Waterborne Diseases in Relation to Bacteriological Quality of Water," *Microbiology Research Journal International*, vol. 28(4), pp. 1-12, 2019.

[6] M. I. O. Raji, "Prevalence of waterborne infections in Northwest Nigeria: A retrospective study," *Journal of Public Health and Epidemiology*, vol. 3(8), pp. 382 – 386, 2011.

[7] W. J. O. Oti, "Profile of heavy metals in crude oil commonly consumed for medicinal purposes in Abakaliki," *IOSR Journal of Pharmacy and Biological Sciences*, vol. 11(3), pp. 43-44, 2016.

[8] O., Frank and N. Boisa, "The effect of crude oil spill on the surface water of the Lower Niger Delta (Sombriero River)," *Journal of Industrial and Environmental Chemistry*, vol. 2(2), pp. 19-24, 2018.

[9] R. Kalu, D. K. Etim, O. A. Jonathan, and M. E. Eja, "Open defecation profile of rural communities in Cross River and Akwa Ibom States of the Niger Delta, Nigeria," *International Journal of Current Microbiology and Applied Sciences*, vol. 8(12): pp. 2332-2340, 2019.

[10] C, Thoeye, E. K. Van, D. Bixio, M. Weemaes, G. DeGueldre, "Methods used for health risk assessment" World

Health Organization, Copenhagen, 2003.

[11] D. Shukla, K. Bhadresha, N. K. Jain, H. A. Modi, "Physico-chemical analysis of water from various Sources and Their comparative studies," IOSR Journal Of Environmental Science, Toxicology And Food Technology, vol. 5(3), pp. 89 – 92, 2013.

[12] M. O. Akrong, F. K. Amu-Mensah, "Seasonal analysis of bacteriological quality of drinking water sources in communities surrounding Lake Bosomte in the Ashanti region of Ghana," *Journal of Applied Water Science*, vol. 9(82), 2019.

[13] M. Eluma, and A. I. Onaji, "Microbiological and physico-chemical analysis of pure water samples from 5 villages in Borgu L.G.A of Niger State, Nigeria," *IOSR Journal of Pharmacy and Biological Sciences, vol.* 10 (3), pp. 15-18, 2015.

[14] P. C. Mmom, and A. Akpi, "Spatial analysis of flood vulnerability levels in Sagbama Local Government Area using geographic information systems (GIS)," *International Journal of Research in Environmental Studies,* vol. 1, pp. 1 – 8, 2014.

[15] American Public Health Association, APHA, "Standard methods for the examination of water and wastewater," 22nd. Washington, DC, USA: American Public Health Association, American Water Works Association, Water Environment Federation, 2012.

[16] A. Chauhan, P. Goyal, A. Varma, "Microbiological evaluation of drinking water sold by roadside vendors in Delhi, India," *Applied Water Science*, vol. 7, pp. 1635 – 1644, 2017.

[17] M. F. Al-Helali, N. Y. Al-Kahtani, and H. A. Al-Shamahy, "Detection of Vibrioes in the Aquatic Environment and the Sewage System by Culture Method in Selected Areas in Yemen," *American Journal of Biomedical Science and Research*, vol. 3 (6), pp. 564 -568, 2019.

[18] Nigerian Industrial Standard, NIS, "Nigerian standard for drinking water quality," 52, Lome Street, Wuse Zone 7, Wuse, Abuja, Nigeria, 2015.

[19] K. Rehman, F. Fatima, I. Waheed, M. S. H. Akash, "Prevalence of exposure of heavy metals and their impact on health consequences," *Journal of Cellular Biochem*. Vol. 119: pp. 157–184, 2018.

[20] I. R. Abubakar, "Exploring the determinants of open defecation in Nigeria using demographic and health survey data," *Science of the Total Environment*. Vol. 637-638C, pp. 1456-1465, 2018.