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Assessment of Ground Water Quality in Flooded and Non-Flooded Areas

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Abstract: *The quality parameters of well and borehole water from flooded and non-flooded areas were determined by a combination of instrumental and classical methods and thereafter compared with a view to ascertaining the effect of flooding on ground water quality. With boreholes, the conductivity, total dissolved solid (TDS), alkalinity, chloride and zinc levels in the flooded part were statistically comparable to their corresponding values in the non-flooded part. With wells, chloride (106.2 mg/L), alkalinity (72.6 mg/L), hardness (118.6 mg/L), conductivity (952.3 $\mu\delta/cm$), TDS (577.0 mg/L), pH (7.21), total and fecal coliform counts (236.6 MPN/100mL and 11.0 MPN/100mL respectively) in water from the flooded parts were higher than their corresponding values in the non-flooded part (70.33 mg/L, 63.3 mg/L, 75.6 mg/L, 946.3 $\mu\delta/cm$, 576.0 mg/L, 7.15, 8.6 MPN/100mL and fecal coliform not-detected respectively). Contamination with harmful coliforms was found to be the most negative effect of flooding on ground water from wells as most of the quality parameters assessed were within permissible limits in drinking water except for total and faecal coliform counts. The quality of ground water from boreholes appeared to be least affected by flood proving that flooding exerts its most adverse effect on well water and if epidemiological studies show that most of the clinical cases of waterborne diseases are individuals who drink well water, then*

Keywords: Ground water quality, flooded areas, non-flooded areas, well water, Borehole water.

1. Introduction

There have been reports of an alarming increase in cases of water borne disease in Nigeria [1-3], especially cholera, typhoid, and diarrhoea in rural communities within Nigeria, and this is despite the many initiatives to provide portable water from boreholes in many communities. What is interesting and of growing concern is that a similar trend is beginning to be observed in urban communities where largely better hygiene is observed in the handling of drinking water and water supply is mainly from better constructed wells and boreholes. This phenomenon has strong implications for public health if good health and wellbeing for everyone – a key item of the sustainable development goals [4] is to be attained.

This paper assesses the impact of flood on ground water quality in flooded and non-flooded areas with a view to ascertaining the effect of flood on ground water quality. This could serve as empirical evidence for or against claims that the rising cases of water borne diseases may be connected to the growing contamination of ground water sources in both rural and urban settlements, via contaminant-bearing flood-water. Such claims continue to gain traction among environmentalists and public health practitioners due to the rising incidence of floods attributed to global warming and the attendant melting of glacial ice.

In developing countries, groundwater from wells and boreholes constitutes the major source of water for both domestic and industrial uses [5]. Wells are dug in many homes due to inadequate supply of public treated water [6]. Water quality is of key importance to man and nature and it has become an irrefutable fact that it is a basic requirement for the survival of humanity [7].

A careful review of the literature shows that, several studies [8-13] have been carried out on the quality of ground water, and many more studies have reported on the impact of floods on surface water [14-18], ground water [19-22], and even on the economic and social lives of people [23-27] in the areas where they occur. Most of such studies agree that flood water carries with it all sorts of liquid and solid pollutants from municipalities, farmlands etc and deposits them into surface water bodies [28, 29], and this may collect in low-lying areas from where it gradually seeps downwards into the ground to pollute ground water such as wells and boreholes [7, 19]. Flood water is often contaminated with pathogens from sewage, farm and animal wastes [30]. The kind and level of contamination found in flood water varies considerably from one location to another and it changes over time [31]. It is also a function of sophistication and affluence. Abandoned or inactive mine sites, landfills, septic tanks, application of fertilizers and agrochemicals, if not properly managed could also result in the contamination of groundwater. The quality of water in boreholes and wells are also affected by the presence of heavy metals such as, Pb, Ni, V, As, Mn, Zn, and Mg [32]. Heavy metals can enter ground water supply system through industrial and consumer waste, or even from acid rain, the breakdown of rocks and soils to release heavy metals into streams, lakes, rivers etc [33-35].

A careful review of the literatures on urban flooding reveals an emphasis on describing the nature of urban floods, listing the causes of such floods and their destructive consequences on life and property [28]. However, there appears to be a dearth of literature on the comparative assessment, of the quality of ground waters in flooded and adjacent non-flooded areas. Such studies would be expected to show the actual impact of floods on ground water quality in flooded areas when compared with ground water quality in adjacent areas not affected by flood. It is why this study seeks to assess groundwater quality in flooded and non-flooded parts of flood-prone areas with a view to ascertain the effect of flood on ground water quality and hence the safety of ground water in such areas for human consumption.

2. Materials and Methods

2.1 Study Location

Makurdi metropolis is located in the North-central part of Nigeria. It was selected for the study because, floods have become an annual occurrence in several parts within the metropolis. Some of the most flood-prone parts of Makurdi include; Nyiman layout, Media village, Idye, Wadata, Katungu, Achusa, Gyado Villa, and Wurukum, [36]. Wurukum, is located in the central part of Makurdi and is often the worse hit by flood. The annual rainfall in Makurdi is about 1,290 mm [Akintola, [37]. Most times, flood in Wurukum is associated with annual rainfall, which may trigger changes in ground water quality, and as such, it was the area chosen for sample collection and is shown in the map of Makurdi metropolis presented below.

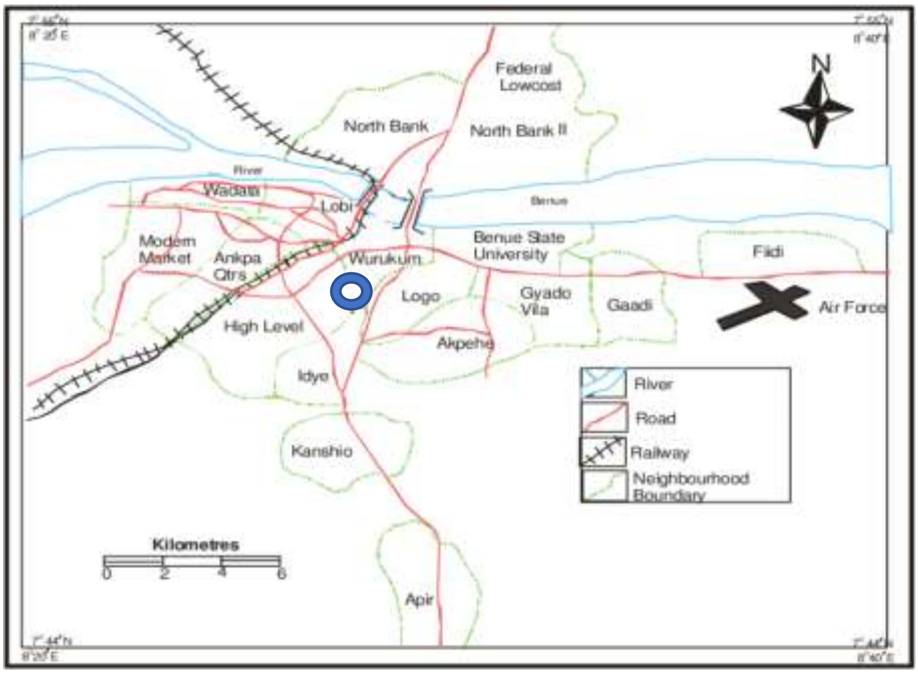

Figure 1: Map of Makurdi metropolis, Nigeria [38], showing location of study area

2.2 Sample Collection

Water samples were collected in sterile sample bottles from 9 wells and 9 boreholes in a flooded part of Wurukum in Makurdi metropolis between the months of July and September, 2019. July and September have been reported in literature, to lie within the season of extreme rainfall in Makurdi and the total amount of monthly extreme precipitation between July and September ranges between 428.7 mm to 466. mm [37]. Precipitation during this period is mainly caused by the warm, moist, rain-bearing south-west wind. During this period, daily temperatures in Makurdi can vary between 22.5 0C to 34.2 ^{o}C. Thereafter, 3 composite samples were generated from the well water samples by merging equal volumes of water (20 mL) from three separate wells in order to ensure a wider area of sample coverage. Three composite samples were also generated for boreholes in the flooded area in a similar manner. The above procedure was then repeated for an adjacent, non-flooded part of the study location (200m away from the flooded area) to obtain 3 composite samples each for wells and boreholes.

2.2 *Determination of Total Dissolved solids (TDS)*

TDS was determined by instrumental method [39]. The probe of a pre-calibrated HACH TDS meter (Model no. 50150) inserted into the water sample and the value of TDS was read and recorded directly from the display. Each measurement was repeated 3 times and the result was reported as mean ± standard deviation.

2.3 Determination of pH

pH was determined by instrumental method [39]. The probe of a pre-calibrated pH meter (HORIBA U-53) was inserted into the water sample and the pH displayed was recorded [40]. Each measurement was repeated 3 times and the result was reported as mean ± standard deviation.

2.4 Determination of Conductivity

Conductivity was determined by instrumental method [39]. This involved inserting the probe of a calibrated HACH conductivity meter (Model no. 50150) into the water sample and recording the result displayed. Each measurement was repeated 3 times and the result was reported as mean ± standard deviation.

2.5 Determination of Turbidity

A HACH UV visible spectrophotometer (Model no. DR/2000) was used to determine turbidity. The instrument was switched to turbidity mode and the wavelength adjusted to 450 nm. A 25 mL amount of deionized water was measured into the sample cell holder and used as blank to calibrate the equipment to 0.00 NTU and thereafter, 25 mL of water sample was measured into the sample cell and the turbidity measurement recorded from the display [41]. Each measurement was repeated 3 times and the result was reported as mean ± standard deviation.

2.6 Determination of Hardness

Hardness was determined by EDTA titration method [40]. Twenty-five milliliters of the water sample were diluted to 50 mL with deionized water in a conical flask and 1 mL of a pH 10 acetate buffer solution was added followed by 2 drops of Eriochrome Black T. The resulting solution was titrated with standard EDTA. Color change from wine red to blue marked the end point. The above procedure was repeated for deionized water as blank, and the volume of EDTA used for the blank was subtracted from the volume of EDTA used for the sample to get the actual volume used for the sample and thus obtaining the amount of hardness present in the sample [40]. Each measurement was repeated 3 times and the result was reported as mean ± standard deviation.

2.7 Determination of Alkalinity

Three drops of Bromocresol-green Methyl-red indicator was added to 2 mL of water sample in a conical flask and titrated with 0.01 N sulphuric acid until the solution turned light violet-grey. The titre value was used to calculate the total alkalinity in mg/L [40].

2.8 Determination of Heavy Metals

A 100 mL amount of the water sample was digested using 5 mL concentrated nitric acid. The digest was allowed to cool before filtering into a 200 mL volumetric flask and diluting to the mark with de-ionized water. The concentration of Pb, Ni, V, As, Mn, Zn, and Mg were then measured using an atomic absorption spectrophotometer (Phoenix 929 Unicam UK) operating at 0.001 mg/L limit of detection, with a hollow cathode lamp and an air-acetylene flame, at the following wavelengths; 217 nm, 232 nm, 318 nm, 193.7, 279.5 nm, and 213.9 nm respectively [40]. All other instrument settings were as specified by the manufacturer in the instrument's Manual.

2.9 Determination of Total Coliform and Fecal Coliform Counts

In the determination of total coliform count, the multiple tube fermentation technique was used. Ten milliliter of water sample was dispensed into 10 mL sterile double strength MacConkey broth in test tubes containing inverted Durham tubes for gas collection. The same process was repeated using 1 mL of the water sample and 5 mL single strength sterile MacConkey broth, 0.1 mL of the water and 3 mL sterile single strength MacConkey broth in triplicate. All tubes were then incubated at 35 ºC for 24 hours and total coliform count was determined from the gas and acid produced using the most probable number (MPN) Table.

To determine fecal coliform, a loop from the tubes in the differential coliform test was cultured into sterile single MacConkey broth in test tubes with inverted Durham tubes for the collection of gas. All test tubes were incubated at 44.5 ^{O}C for 24 hours. Test tubes showing the production of gas which indicate the presence of E. coli were confirmed via their characteristic colonies showing a metallic sheen in Eosin method blue. Fecal coliform count was estimated using the most probable number (MPN) Table and expressed in MPN/100 mL [40].

2.10 Statistical Analysis of Data

Mean and standard deviation were computed for each water quality parameter assessed and these were thereafter compared for flooded and non-flooded areas at p=0.05 level of probability using student T-test.

3. Results and Discussion

Table 1 shows the quality parameters of borehole water from flooded and non-flooded areas. Table 2 shows the water quality parameters of well water from flooded and non-flooded areas.

Table 1: Quality parameters of borehole water from flooded and non-flooded areas

S/No	Water Quality Parameters	Flooded area	Non-flooded area	WHO's limits [42]	NIS Limit [43]
1	pH	$7.01^{a}\pm0.39$	$7.28^{a}\pm0.56$	6.5-8.5	6.5-8.5
2	TDS (mg/L)	$356.33^{u}\pm226.09$	$399^{u}\pm169.39$	1500	500
3	Conductivity (µδ/cm)	$544.33^{e}\pm362.36$	$650.33^{e}\pm281.73$	500	1000
4	Turbidity (NTU)	$3.81^{n}\pm0.97$	$3.68^{n}\pm3.73$	5.00	N/A
5	Alkalinity (mg/L	$41.33^{d}\pm12.22$	$42.33^{d}\pm9.29$	500	100
6	Chloride (mg/L)	$49.93^{s}\pm15.51$	$53^{s}\pm9.85$	600	100
7	Hardness (mg/L)	$55.67^{r}\pm36.91$	$26.67^{r}\pm6.11$	500	100
8	Lead (mg/L)	ND	ND	0.05	0.01
9	Vanadium (mg/L)	ND	ND	-	-
10	Arsenic (mg/L)	ND	ND	0.01	0.01
11	Nickel (mg/L)	ND	ND	0.07	0.05
12	Manganese (mg/L)	$0.20^{x}\pm0.21$	$0.07^{x}\pm0.015$	0.30	0.20
13	Zinc (mg/L)	$0.21^{b}\pm0.14$	$0.20^{b}\pm0.26$	5.00	5.00
14	Total coliform (MPN/100mL)	44 ± 8.54	ND	0.00	0.00
15	Fecal coliform (MPN/100mL)	ND	ND	0.00	0.00

Key: Values are means $\pm$ standard deviation of triplicate determinations.
Means with identical superscript in a row are not significantly different.
WHO: World Health Organization
NIS: Nigerian Industrial Standard
ND: Not Detected.

Table 2: Quality parameters of well water from flooded and non-flooded area

S/No	Parameter	Flooded area	Non-flooded area	WHO limits [42]	NIS Limits [43]
1	pH	7.21^{a}±0.1	7.15^{a}±0.39	6.5-8.5	6.5-8.5
2	TDS (mg/L)	577^{u}±306.0	576^{u}±33.2	1500	500
3	Conductivity (μδ/cm)	952.3^{e}±461.14	946.33^{e}±57.01	500	1000
4	Turbidity (NTU)	10.22^{n}±4.52	6.97^{n}±2.04	5.00	N/A
5	Alkalinity (mg/L	72.67^{d}±19.66	63.33^{d}±5.03	500	100
6	Chloride (mg/L)	106.2^{s}±86.3	70.33^{s}±6.8	600	100
7	Hardness (mg/L)	118.6^{r}±109.3	75.66^{r}±9.71	500	100
8	Lead (mg/L)	0.006±0.032	ND	0.05	0.01
9	Vanadium (mg/L)	ND	ND	-	-
10	Arsenic (mg/L)	ND	ND	0.01	0.01
11	Nickel (mg/L)	ND	ND	0.07	0.05
12	Manganese (mg/L)	0.312^{x}±0.172	0.099^{x}±0.01	0.30	0.20
13	Zinc (mg/L)	0.273^{b}±0.061	0.153^{b}±0.034	5.00	5.00
16	Total coliform (MPN/100mL)	236.66^{g}±11.55	8.60^{p}±5.97	0.00	0.00
17	Fecal coliform (MPN/100mL)	11.0±2.0	ND	0.00	0.00

Key:
Values are means ± standard deviation of triplicate determinations.
Means with identical superscript in a row are not significantly different
WHO: World Health Organization
NIS: Nigerian Industrial Standard
ND: Not Detected.

The result in Table 1 shows that the conductivity, TDS, alkalinity and chloride levels in ground water from boreholes in the flooded area (544.3 μδ/cm , 356.3 mg/L, 41.3 mg/L and 49.9 mg/L respectively) are less, but still comparable to their corresponding values in ground water from boreholes in the non-flooded area (650.3 μδ/cm, 399.0 mg/L, 42.3 mg/L and 53.0 mg/L respectively), especially since there is no significant difference between their corresponding values at p=0.05 level of probability. Also, with respect to zinc and manganese levels in groundwater from boreholes, there is no significant difference between the levels in flooded (0.21 mg/L and 0.20 mg/L respectively) and non-flooded areas (0.20 mg/L and 0.07 mg/L respectively). The implication is that flood does not significantly affect the ground water quality of boreholes in flooded areas. The result in Table 1 also shows that Pb, Ni, As and V were not detected in borehole water from the flooded and non-flooded areas. This suggests that these heavy metals are either absent in the sampling points and the area along the path of the flood, or present at much lesser concentrations than the instrument's limit of detection (0.001 mg/L).

Also, all water quality parameters determined in borehole waters from the flooded and non-flooded areas fall within their corresponding WHO and NIS permissible limits in drinking water except the total coliform count (44.0 MPN/100mL) and chloride levels. This is indicative of the high saltiness of borehole water in both the flooded and non-flooded areas as well as microbial contamination of borehole water in the flooded part alone by some unknown means.

Table 2 shows that chloride levels in well water from the flooded area (106.2 mg/L) was higher than that in well water from the non-flooded area (70.33 mg/L). This implies that the flood incidence in the study area had a negative impact of making ground water in the flooded area saltier compared with the non-flooded area. Table 2 also, reveals that the turbidity of ground water in the flooded area (10.22 NTU) is higher than that in the non-flooded area (6.97 NTU), thus implying that the flood incidence had decreased the penetration of light into well water in the flooded area. A similar trend was also observed with respect to alkalinity, hardness, conductivity, TDS, pH, Mn, Zn, Pb, as well as the total and faecal coliform counts. However, it is important to note that in most cases, the observed differences between water quality parameters of the flooded and non-flooded areas were not statistically significant except in the case of total coliform count. Also, most of the water quality parameters determined fell within their corresponding WHO and NIS permissible limits in drinking water except for turbidity, chloride, Zn, total and faecal coliform counts.

The total coliform count in well waters from the flooded part (236.6 MPN/100mL) and non-flooded part (8.6 MPN/100mL) both exceed the WHO and NIS requirement for potable water (0.00 MPN/100m) and this is indicative of a further contamination of an already polluted ground water supply by polluted flood water. This implies that both water samples are unsafe for drinking. The result in Table 2 also shows the presence of faecal coliform in well waters from the flooded area (11.0 MPN/100 mL). This is indicative of faecal contamination of ground water sources owing to open defecation. This implies that the water is unsafe to drink.

4. Conclusion

It is clear that the impact of flooding on the physicochemical parameters of water quality assessed were not statistically significant enough to make ground water unfit for drinking, as the values for these parameters in well and borehole waters from the flooded areas were within their WHO and NIS permissible limits. However, with respect to the biological parameters assessed (faecal and total coliform counts) it was found that flooding increased the total coliform count and introduced faecal coliforms into well water, thus contaminating it and making it unfit for drinking. This is suggestive of open defecation in the study area. However, flooding had no such effect on borehole water in the study area. This lends credence to a possible link between the growing number of flood cases and the alarming increase in water-borne diseases witnessed in the study area. But it must be pointed out that epidemiological studies are required to completely confirm this.

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REFERENCES

[1] O.F. Nwabor, N.E. Ikechukwu, M.P. Emenike, O.C. Ani. Water and Water-borne Diseases: A Review International Journal of Tropical Disease and Health 12 (2016) 1-14.

[2] D.O. Omole, C.P. Emenike, I.T. Tenebe, A.O. Akinde, A.A. Badejo. An Assessment of Water-Related Diseases in a Nigerian community. Research Journal of Applied Sciences, Engineering and Technology 10 (2015) 776- 781.

[3] F.C. Ogenyi, An Appraisal of Water-borne Diseases in Nigeria: Focus on Effective Management. IDOSR Journal of Experimental Sciences 9 (2023) 5-10.

[4] United Nations in Nigeria. Our work on the sustainable Development Goals in Nigeria. Culled on 19th November, 2024 from; http://nigeria.un.org/en/sdgs?afd_azwaf_tok

[5] M. Pedro, M. Miguel, D. Silvia, D. Kerstin. Manual borehole drilling as a cost- effective solution for drinking water access in low-income contexts, Water 12 (2020) 1-17.

[6] S. A Stephen, Ground-water quality of Oakland County, Michigan. U.S. Geological Survey. *Water-Resources Investigation Report,* 2000, Pp. 409-412.

[7] U. Tariq, A. Haleema. Impact of extreme floods on groundwater quality in Pakistan. *British journal of environment and climate change,* 4 (2014) 133-151.

[8] Q. Zhang, P. Xu and Hui Qian. Assessment of groundwater quality and human health risk (HHR) evaluation of nitrate in the Central-Western Guanzhong Basin, China, International Journal of Environmental Research and Public Health 16 (2019), 4246

[9] H. Annapoorna, M.R. Janardhanab. Assessment of groundwater quality for drinking purpose in rural areas surrounding a defunct copper mine, Aquatic Procedia 4 (2015) 685 – 692

[10] O.I. Ojo, F.A.O. Otieno, G.M. Ochieng, Groundwater: Characteristics, qualities, pollutions and treatments: An overview, International Journal of Water Resources and Environmental Engineering 4 (2012) 162-170.

[11] M.N. Ibrahim, Assessing groundwater quality for drinking purpose in Jordan: Application of water quality index, Journal of Ecological Engineering 20 (2019) 100-111.

[12] A.E.M. Celestino, D.A.M. Cruz, E.M.O. Sánchez, F.G. Reyes, D.V. Soto, Groundwater quality assessment: An improved approach to k-means clustering, principal component analysis and spatial analysis: A case study, Water 10 (2018) 1-21.

[13] A. M. Nottmeier, Groundwater quality assessment from domestic water wells in the Fayetteville shale gas play area in Central Arkansas, Theses and Dissertations 541 (2012) 1-124.

[14] R. Yuhan, F. Dafang, H.D. Minh, M. Radhakrishnan, C. Zevenbergen, A. Pathirana, Urban surfacewater quality, floodwater quality and human health impacts in Chinese Cities. What do we know? Water 10 (2018) 1-18.

[15] A.C. Okoye, E.E. Ezenwaji, K.A. Awopeju, the impact of urban flooding on surface water quality of Awka town, Journal of Environmental Protection 5 (2014) 60-64.

[16] J.T. Utsev, C.C. Nnaji, M.C. Nnennaya, Effect of Flood on Water Resources in North-Central Nigeria, Asian Journal of Water, Environment and Pollution, 12 (2015) 59 –71.

[17] S. Merolla, The effect of floods and high rainfall on the water quality in selected sub-areas of the upper Vaal catchment, M.Sc. dissertation in the University of Johannesburg (2011) 1-117

[18] C.C. Tawari, J.F.N. Abowei, E. Charles, Effects of flooding on surface water physical and chemical characteristics in Amassoma flood plain; Niger Delta, Nigeria, Annals of Biological Sciences, 2 (2014) 33-41.

[19] T. U. Saeed, H. Attaullah, Impact of Extreme Floods on Groundwater Quality (in Pakistan), British Journal of Environment & Climate Change, 4 (2014) 133-151.

[20] M. Kamalanandhini. R. Kalaivizhi, G.V.P. Percy, S. Srividhya, S. Dheepak. K. Thiyaneshwaran, Effect of flood event on water quality. Rasayan Journal of Chemistry, 12 (2019) 849-854.

[21] S. Rubao, A. Daizhi, L. Wei, S. Yun, L. Wang, C. Zhang, P. Zhang, Q. Hongjuan, Q. Wang, impacts of flash flood on drinking water quality: case study of areas most affected by the 2012 Beijing flood. Heliyon (2016) 1-14.

[22] R.M. Kuppuraj, D. Selvaraj, S.Govindaraj, M. Rangaswamy, J.R. Narayanasamy, K.Kuppanagounder, Assessment of groundwater quality in the flood plains of upper Palar River, India, Chinese Journal of Geochemistry, 31 (2012) 15– 23.

[23] M. Allaire, Socio-economic impacts of flooding: A review of the empirical literature, Water Security 3 (2018) 18–26.

[24] E. Vlachos, Socio-economic impacts and consequences of extreme floods, U.S.- Italy Research Workshop on the Hydrometeorology, Impacts, and Management of Extreme Floods, (1995) 1-18.

[25] Y.P. Mwape, An impact of floods on the socio-economic livelihoods of people: a case study of Sikaunzwe community in Kazungula district of Zambia, M.Sc. dissertation in the University of the Free State, (2009) 1-87.

[26] D. Svetlanaa, D. Radovana, D. Jánb, The economic impact of floods and their importance in different regions of the World with emphasis on Europe, Procedia Economics and Finance 34 (2015) 649 – 655.

[27] E. Euripides, V. Murray, Public health impacts of floods and chemical contamination, Journal of Public Health, 26 (2004) 376–383.

[28] C. Anthony, E. Ezenwaji, K. Awopeju. The impact of urban flooding on surface water quality of Awka town. *Journal of environmental protection.* 2013, 5: 50- 64.

[29] C. Jeong. Effect of landuse and urbanisation on hydrochemistry and contamination of groundwater from Taejon, Korea. *Journal of Hydrology,* 2001, 253: 194-210.

[30] G. Nickerson, V. Grubinger, L. Nwadike, L. Blevins, frequently asked questions about handling flooded produce, University of Vermont Extension 1 (2011) 1-7.

[31] G. Clark, D. Mueller, M. Mast. Nutrient concentrations and yields in undeveloped stream basins of the United States. *Journal of the American Water Resources Association,* 2000, 36 (4) 849-860

[32] S. Foster, R., Hirata, D., Gomes, M. Paris. *Groundwater quality protection: a guide for water utilities, municipal authorities and environment agencies.* World Bank, Washington DC. 2002, 41-52.

[33] L. Hurley, C. Ken Trace elements in human and animal nutrition 5th ed. New York, NY Academic Press. (1987) pp. 185-223

[34] E. Marian, Metals and their compounds in the environment; occurrence, analysis and biological relevance. UCH, Weinheim, New York Basel Cambridge, (1991) pp. 102-122.

[35] World Health Organization (WHO), Lead in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, WHO (2003) (WHO/SDE/WSH/03.04/9).

[36] IRIN. Worst flooding in decades. 2012. Retrieved from http://www.irinnews.org/news/2012/10/10-0 on 10th November, 2018.

[37] Ologunorisa, T.E., Tersoo, T. The Changing Rainfall Pattern and Its Implication for Flood Frequency in Makurdi, Northern Nigeria. *Journal of Applied Sciences and Environmental Management* (10) 97-102.

[38] Ministry of Lands and Survey, Makurdi, Map of Makurdi metropolis (2015).

[39] HACH. DR/2000 Spectrophotometer Instrument Manual. 1991, p37-51.

[40] APHA. American Public Health Association Methods 9221: *Standard Methods for the Examination of Water and Wastewater.* 22nd ed. Washington D. C. 1992, p.945-953.

[41] APHA. *Standard methods for the Examination of water and waste.* 18th ed. American Public Health Association Washington D.C. 1992, p 72-265.

[42] WHO. Guidelines for Drinking-water Quality 4th Edition. World Health Organisation Press, Geneva 2003, p117- 442.

[43] NIS. (Nigerian Industrial Standards) Nigerian Standard for Drinking Water Quality NIS-554-2015. Nigerian Industrial Standards. Lagos 2015, p 16-18.