Hydrogeochemical and Heavy Metals Characterization of River Niger at Lokoja, North Central Nigeria

Ekpe, E.P., Salubi, O.A. and Ohwoghere-Asuma, O.[1]

Department of Geology, Delta State University, Abraka

[1] corresponding author email: ooasuma@delsu.edu.ng

Abstract

River Niger is the longest river in Nigeria and more likely to be contaminated by anthropogenic activities than groundwater, especially the section situated in urban cities. Surface water that is contaminated has its quality compromised. Consumption of such water poses serious health challenge. The thrust of the paper is to assess the effect of urbanization on the quality and the suitability for irrigation of the water samples obtained from River Niger. The physiochemical analysis of water sampled collected was analyzed using Atomic Absorption Spectrometry (AAS) and Ion Chromatography. The results showed that 66.7% of water samples have pH that is within the World Health Organization (WHO) permissible limit. The alkalinity of water samples ranged from 8 to 15mg/l, hardness ranged from 10 to 19.4mg/l. Total dissolved solids, electrical conductivity and temperature of the water samples ranged from 25 to 42mg/1, 56 to 78µS/cm and 26 to 31.6℃, respectively. The concentrations of all representative cations and anions, except Mn^{2+} ion, are within the WHO permissible limit. 83.3% of the samples have Mn^{2+} concentration below the WHO permissible limit. Also, all the samples have concentration of Cd^{+} and Pb^{+} greater than the WHO permissible limit. 50% of samples have nickel concentration greater than the WHO permissible limit while Zn^{2+} has tolerable concentration in all samples. Piper diagram plot classified the water samples into Ca-Mg-SO_4 water type. The Sodium Absorption Ratio (SAR) ranged from 0.87 to 1.78, indicating low salinity hazard. This study concludes that although water samples indicate low salinity hazard and are thus good for irrigation, high concentrations of heavy metals observed in the water samples indicate that the surface water in the study area is unsafe for drinking.

Keywords: River Niger, Surface water, Major ions, Heavy metal, SAR, Nutrients

Introduction

Water is one of the most important and essential components for survival of both humans and plants Apart from drinking, it is also needed for irrigation of land for the purpose of supplying plant water requirement (Hernandez et al., 2003). The quality of water is essential for the health of those that consume it, because the effect of drinking contaminated water has resulted in the death of people. There are numbers of reported cases of typhoid, diarrhea and other water borne diseases arising from the consumption of contaminated water in Nigeria (Ocheri and Mile, 2006). Ocheri and Mile (2010) have showed from their study that drinking of contaminated water by people has led to more deaths than put together the numbers of people killed by diseases of cancer, AIDS and accidents. Water becomes unfit for its usage due to the influence of man on the environment. Urbanization and agricultural activities are some of the factors contributing to deterioration of water quality. There are different types of water existing on the earth and they are broadly categorized into surface water and subsurface waters. Surface water includes river water, wetlands and swamps etc. while subsurface water includes water that is found below the ground surface.

Surface water, such as rivers, is more susceptible to contamination unlike groundwater which is less contaminated by anthropogenic activities. Indiscriminate dumping of refuse and swages disposal into rivers are some of the activities that pollute river water (Ocheri and Mile 2006). This is very common in Nigeria, as rivers and other surface water bodies are poorly monitored and maintained. The lack of the implementation of the appropriate water policy, has led to the disposal of wastes and sewage into rivers and surface water bodies by both individuals and corporate organizations (Abimbola, and Sangodoyin, 1994).

River Niger and River Benue are the two longest rivers in Nigeria and they converged as Single River at Lokoja. The rivers of Niger and Benue sometimes overflow their banks. This flooding occurs infrequently. The last known flooding event occurred in 2012 and 2015 (Chiazor, 2016, Davidson et al., 2015). The flooding reduced the quality of water in the rivers. There was inflow of sewages and other contaminants from runoff into the rivers during flooding episodes. The many communities located in the floodplains of the river Niger and Benue at Lokoja lack basic portable drinking water, thus depend on both rivers for source of drinking water. These communities defecate on water and involved in other activities such as washing of clothes and bath in the water. This has been source of concerns because these activities are capable of polluting the water and consequently not suitable for their health and well beings.

The flow through most urban cities along is course may subject it to potential pollution caused by discharge of industrial wastes, agricultural wastes and runoff from the watershed. The level of pollution in the river may have affected the surface water quality of the River Niger at Lokoja area and thereby posing serious health threat to people, especially the communities without public water and private water supply, which relies on it as source of drinking water. WHO (2019) estimated that at least 2 billion people drink water whose source contaminated with faeces globally. Contaminated water can transmit diseases such diarrhea, cholera, dysentery, typhoid, polio, etc. Recent investigation by WHO (2019) showed that 485,000 people died globally from diarrhea as a result of drinking contaminated water. In Nigeria, surface water which is easily contaminated is heavily used for various domestic purposes. The use of contaminated water for drinking and domestic chores has increased the cases of diarrhea which has led to the deaths of more than 70,000 of Nigerian children under the age of five years annually (UNICEF, 2019). Also, 73% of the diarrhea and enteric disease burden is associated with poor access to adequate water, sanitation and hygiene (WASH) that is a common sight among poorer children according to UNICEF (2019). The thrust of the paper is to assess the effect of urbanization on the quality and the suitability of the water samples obtained from River Niger for irrigation purpose.

Location and description of study area

This study area is river Niger at Lokoja North Central Local Government of Kogi State (Figure 1). Kogi State is located in the North Central region of Nigeria. It occupies 29,833 square kilometers of Rivers Niger and Benue; it lies on 7°30N and 6°42E. It shares common borders with Federal Capital Territory (FCT) to the north, Benue State to the East, Anambra State to the South and Niger State to the north. It is popularly called the confluence state because of the convergence of River Niger and Benue at this location. It is the first administrative capital of modern-day Niger (Hamzat, 2013). It has a tropical climate (Iweana, 2012) and is characterized by two distinct seasons namely; the rainy season and the dry season. The rainy season lasts six months from May to October (Audu 2011). The dry season lasts six months from November to March. The average annual precipitation of Lokoja for a 10 years period ranged between 1000 and 1500mm (NIMET, 2011). Daily temperatures in the area vary with the seasons. The minimum temperature is 25^{0}C and the maximum is 35°C (NIMET, 2011). The relative humidity of the area ranges from 55% to 65% during the dry season and from 70% to 80% during the rainy season (Okumura and Xie, 2004). The vegetation of the study area is classified as Guinea Savanna of Nigeria. It is characterized by the presence of tall grasses and scattered short deciduous trees. The start of rainfall in the area marks the beginning of the growth of grasses. The rivers drain catchment of Lokoja and environs. The river has been used for various purposes such as agricultural and domestic purposes.

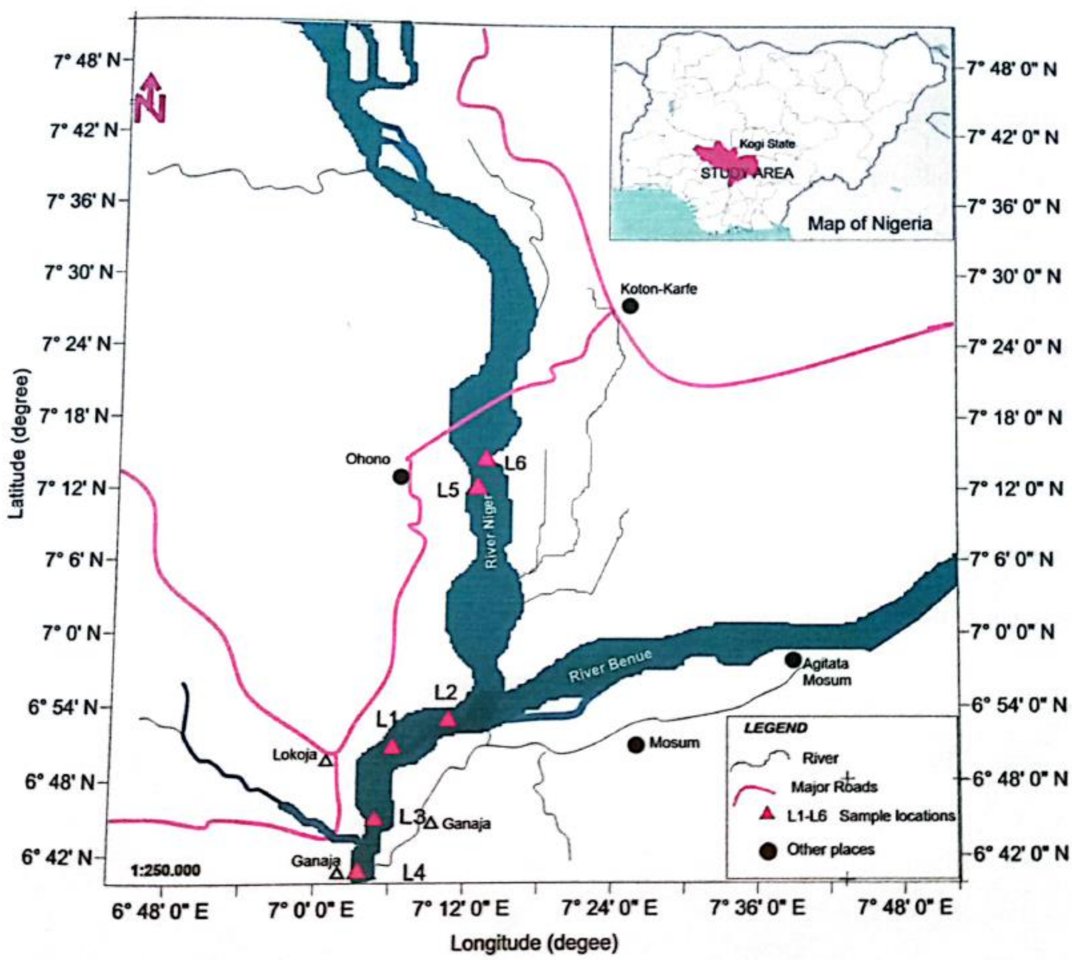

Figure 1: Location of the study area showing the distribution of sample locations

Geologic setting

Lokoja is part of the Southern Bida Basin of Nigeria, it is also known as the Nupe of Mid Niger Basin. It is a NW-SE trending intracratonic basin extending from Kontagora (North) to the south of Lokoja (Jerry and Jahswill 2013) (south). It stretches from the south of the confluence of Niger and Benue Rivers to Kanji, where the basin is separated from the Sokoto Basin (Jerry and Jahswill 2013).

The Bida Basin is bounded by Anambra Basin in the southeast, Dahomey Basin in the south, and Sokoto Basin in the North and joining the Sokoto and Anambra basin in the Southeast and Northeast respectively. The sedimentary fill of the Basin comprises of Post-Orogenic Molasse and thin unfolded marine sediments (Ladipo, 1988). It is a gently down-warped trough whose origin is closely connected with Santonian Orogenic movements in southeastern part of Nigeria and the Benue valley (Obaje et al. 2011). The basin is subdivided into the northern, central and southern Bida sub-basins (Obaje et al. 2009).

The lithostratigraphy of the Southern Bida Basin consists of Lokoja, Pati and Agbaja Formations. The Lokoja Formation consists of conglomerates, coarse to fine grained sandstones, siltstone and claystone (Obaji et al, 2011). In the Formation are sub-angular to sub-rounded cobbles, pebbles and granule sized quartz grains which are distributed in a clay matrix. The clay bearing unit of the Formation has been reported to be rich in some diverse Arenaceous Foraminifera, which suggest shallow marine origin (Petters, 1986). The Pati Formation consists of sandstones, siltstones, claystone and shales interbedded with bioturbated ironstones (Obaji et al, 2011). Petters (1986) have observed the presence of Arenaceous Foraminifera in the shales of the Patti Formation with an assemblage of Ammobaculites, Milliamina, Trochamina and Textularia. The Patti Formation, therefore, appears to have been deposited in marginal shallow marine to brackish water condition identical to the depositional environments of similar to those of the Mamu and Ajali Formations of the Anambra Basin (Ladipo, 1988). The Agbaja Formation consists of sandstone and claystone. In terms of environment of deposition, the sandstones and claystone are interpreted as abandoned channel sand over bank deposits influenced by marine reworking to form the massive concretionary and oolitic ironstones (Ladipo et al., 1994). Minor marine influences were also reported to have inundated the initial continental environment of the upper parts of the Lokoja Sandstone and the Pat Formation (Olaniyan and Olabaniyi, 1996).

Material and methods

Sample Collection

A total of six (6) water samples were collected in 600ml plastic containers from the river Niger. The samples were designated as S1, S2, S3, S4, S5 and S6 (which were collected from locations designated as L1-L6 (Figure 1). The sampling containers were washed prior to collection with distilled water and 0.1N nitric acid was used to reduce the pH to 2.00 for metal analysis. Those for anions were not acidified. The containers were rinsed at least three times with sampled water and samples were collected by immersing the sample containers deep into the river, and unstable parameters such as temperature, pH, TDS, EC were determined in-situ by Schott Gerate model pH meter and HACH model conductivity meter, respectively. In the field Samples were cool to 4°C by using ice blocks contained in a cooler.

Laboratory analysis

Major cations and heavy metals were analyzed by Atomic Absorption Spectrometry (AAS) in accordance with the standard method of APHA (2017). Nitrate (NO_3^-) was determined using the Cadmium Reduction Method in accordance with standard method (APHA, 2017). Chloride (Cl^-) was determined using the Ion Chromatography in accordance with APHA (2017). Bicarbonate (HCO_3-) was determined by the titrimetric method (API-RP45). Sulphate (SO_4^{2-}) was determined using the Ion Chromatography in accordance with standard method (APHA, 2017). Phosphate (PO_4) was determined using the Digestion Method in accordance with standard method (APHA, 2017).

Results and discussion

The results for the physiochemical, metals and nutrients composition of the surface water samples collected from the reaches of River Niger situated in Lokoja metropolis are presented in the bar charts showed in Figures 1-6. Temperature values are known to be influenced by the climatic condition prevailing at particular geographical location. The rates of biological and chemical processes depend on temperature. Therefore, temperature of water can determine the process of chemical weathering when in contact with surrounding rocks. Although, there is no standard for temperature for the purpose of drinking or irrigation, but it has great influence in water-rock interaction water, which may affect the chemistry of water. The temperature of the water samples ranged from 26^0C to 32^0C which is within the range of an ambient temperature of the area under investigation.

The pH of the water samples from different reaches of the river ranged from 7.1 to 8.00. The water is neutral and slightly alkaline. Samples S5 and S6 collected before the confluence showed pH values that were slightly higher than the WHO (2011) standard of 8.5. While samples S1, S2, S3 and S4 have pH values that ranged from 6.5 to 8.5, these values are within the permissible limit of WHO (2011). The change in pH could be explained by the mixing of River Benue and River Niger waters at the confluence.

The total concentration of dissolved solids (TDS) in water is generally an indication of its suitability for a particular use. Although high level of total dissolved solids in water is not a health hazard related, but it can affect domestic usage by staining laundry (WHO, 2008). The values of TDS above 1000mg/ may inflict taste to the water and may not be fit for drinking. TDS is also used to measure the salinity of irrigation water for agricultural purposes. According to FAO (1976), the amount of TDS in irrigation water is classified into three groups, values less than 450mg/l are generally safe for irrigation, and values of 450mg/l are characterized by slight to moderate risk, while those with TDS greater than 2000mg/l are referred to as of severe risk. Figure 2 reveals that the water samples from River Niger are characteristically within the safe zone and pose no hazard for irrigation purposes and also portable for consumption. There is no significant difference in TDS values of the water samples before and after the confluence.

The electrical conductivity (EC) of water is its ability to conduct electricity when an electrical current is passed through it. In most surface and groundwater, almost all major and minor dissolved chemical elements occur in ionic forms. The cation constituent of water is chemically charged positively and the anions are negatively charged. According to Tijani et al. (2018), water electrical conductivity less than 500µS/cm has low salinity hazard, electrical conductivity between 500 µS/cm and 1000µS/cm has medium salinity hazard, while electrical conductivity greater than 1000µS/cm has high salinity hazard (Figure 2). The electrical conductivity of the water samples ranged from 58µS/cm to 78µS/cm, these values no doubts fall within the low salinity hazard zone (Tijani el al., 2018). The water in each of the locations is therefore suitable for agricultural purposes.

The alkalinity of water is a measure of its ability to neutralize acid and very important to its corrosivity. The alkalinity of the water samples from the River Niger ranged from 8mg/l -15mg/l(Figure 2). All water samples in this study have low alkalinity when compared to 150mg/1 specified by (Shaw et al., 2009) as tolerable limit for portable water. There is no significant difference between the alkalinity of the water samples before and after the confluence.

There is no health concerns associated with drinking hard water or soft water. The hardness of any water is easily recognized by lime buildup, scaling in pipes and water heaters, and difficult to form lather with soap. The WHO (2011) classified water as soft with hardness <75mg/l, moderately soft has hardness greater 75-150mg/l, hard (150-300mg/) and very hard (>300mg/). The water sample of the River Niger is categorized as being soft. It is observed that all water samples from all the locations are characteristically soft water. Soft water is preferred to hard water for cleaning, as it doesn't tend to cause soap scum or mineral stains. There is no significant difference in terms of hardness of the water samples both from before and after the confluence. WHO (2011) noted that drinking soft water poses health challenge for people suffering from high blood pressure and those susceptible to high blood pressure. This type of water is capable causing a blood pressure-raising effect which is adduced to its higher sodium content similar to coastal aquifers affected by saltwater intrusion.

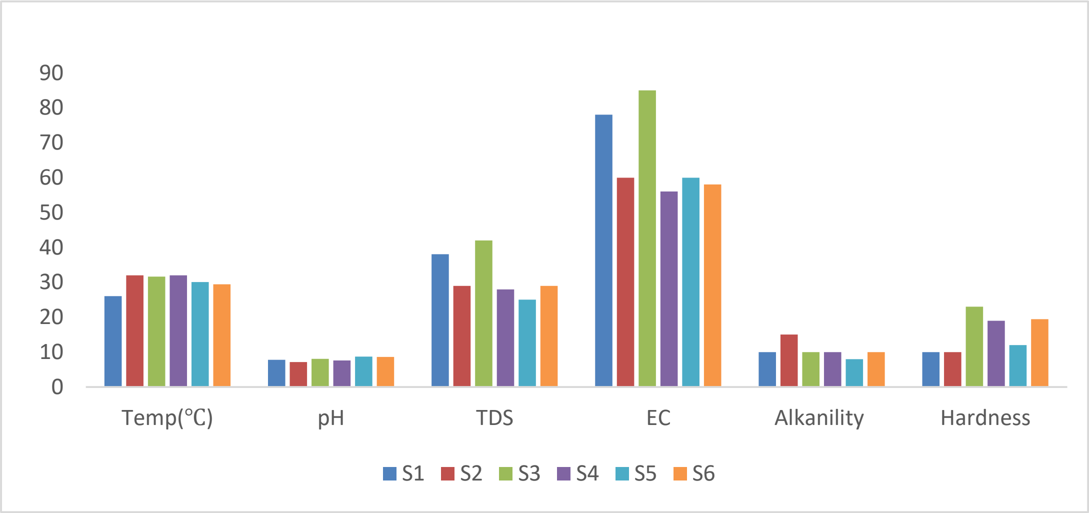

Figure 2: Physiochemical properties of surface water (all parameters are in mg/l excepts temperature, pH (EC, µS/cm)

Major Cations

Some ions found in water can be toxic if their concentrations are beyond the tolerable limit (WHO, 2011). According to Nigeria Standard for Drinking Water Quality (2007) and WHO (2011), the tolerable concentration of sodium (Na^+) constituents in water is 250mg/l. Water with concentration greater than this, is often termed, as unsafe for drinking. The concentration of Na^+ in the surface water samples in the study area ranged from 1.44 to 4.33mg/l (Figure3). The values depicted are abundantly below the desirable limit. These values of are consistent with those of Chiazor et al., (2016) for water from the river Niger at Lokoja. The concentration of K^+ in most drinking water seldom reaches 20mg/l. However, brines may contain high concentration of K^{+} ion more than 100mg/l (WHO, 2019). The concentration of K^{+} in the surface water samples investigated ranged from 0.15 to 0.59mg/l (Figure3). These values are all below the requisites standards stipulated by WHO (2011) and NSDWQ (2007), respectively. The concentration of potassium is not significantly different from Chiazor et al., (2016), whose result values ranged from 1.3 to 8.6mg/l.

Calcium (Ca^{2+}) is a vital element found in most natural water ranging from zero to several hundred of mg/l. Nkansah et al, (2010) reported that $Ca^{2+}$and Mg^{2+} are predominant minerals in surface and ground waters. It is reported that excess of Ca^{2+} contributes to formation of kidney and bladder stones. WHO (2019) has set a limit on the concentration of Ca^{2+} expected to be in water meant for drinking to be 200mg/l. Concentrations above 200mg/l is said to be excessive and unsafe for drinking. The concentrations of Ca^{2+} in this study ranged from 4.46 to 10.26mg/l (Figure3) and are therefore less than the WHO limit of 200mg/l (Figure 3). This result agrees with the work of Chiazor et al., (2016) which stated calcium ion concentration ranging from 1.09 to 46.97mg/l.

Magnesium (Mg^{2+}) contributes to the hardness and taste of water. Excessive presence of Mg^{2+} in water gives a bitter taste, but is normally not a health hazard issue. WHO (2011) set 150mg/l as the maximum limit for Mg^{2+}concentration in water. Mg^{2+} concentrations ranged from 0.99 to 1.97mg/l and are therefore considered as safe (Figure 3). The result agrees with Chiazor et al., (2016), whose result has Mg^{2+}concentration ranging from1.08 to10.74mg/l

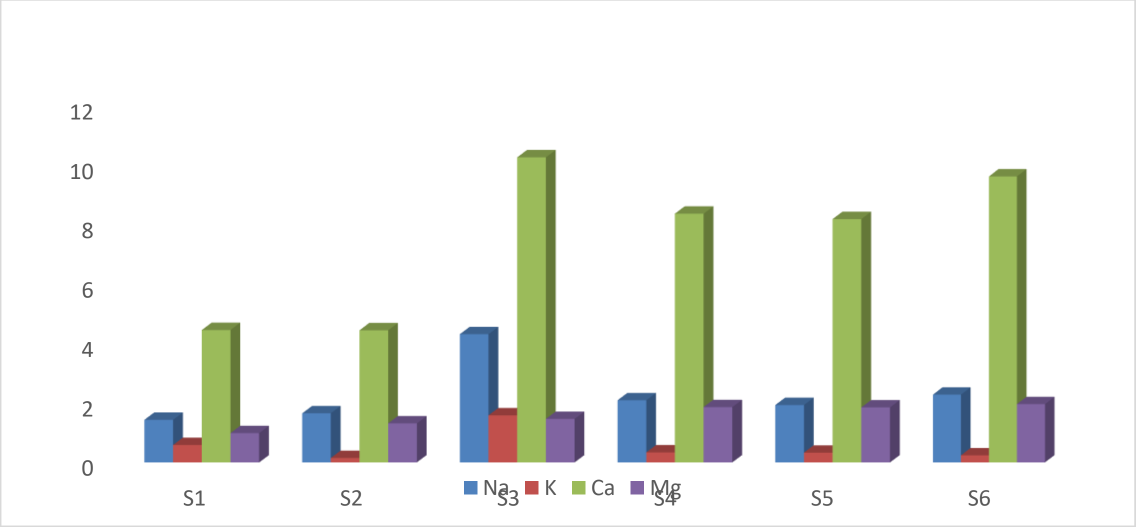

Figure 3: Major ions concentration in mg/l of surface water from the river Niger

Major Anions

Chloride (Cl^{-}) concentration in water increases rate of corrosion of metals in water distribution system, and it depends on the alkalinity of the water. High concentrations of Cl^{-} give a salty taste to water (WHO, 2006). The Nigeria Standard for Drinking Water Quality (NSDWQ, 2007) gives a maximum Cl^{-} concentration in water meant for drinking to be 250mg/l, while the WHO standard is 200mg/l. The concentrations of Cl^{-} in the water samples ranged from 0.110 to 1.013mg/l (Figure 4). This suggests that the water is relatively deficient in Cl^{-} and therefore very portable, since its values are below the permissible level set by NSDWQ (2007) and

WHO (2011). Sulphate (SO_4^-) occurs naturally in numerous minerals and is used principally in the chemical industry. They are discharged into water as industrial wastes and through atmospheric deposition by rain. SO_4^- is relatively more abundance in groundwater than surface water. The WHO (2011) permissible limit for drinking water suggests that concentrations of SO_4^- greater than 200mg/l would markedly impair the portability of the water. The concentration of SO_4^- in the water samples ranged from 2.32 to 10.47mg/l (Figure 4) and are all lower than the permissible level stated by WHO (Figure 17). The SO_4^- concentrations in this study are within those of Chiazor et al. (2016) for same river at Lokoja.

Bicarbonate (HCO_3^-) is a major element in human body as it helps in different body functions such as digestion. Natural minerals and spring waters have various concentration of HCO_3^- which range from tens to hundreds of mg/l. it ranges from several hundreds to thousands of mg/l for sparkling water. The WHO (2011) set a permissible limit of 200mg/l of bicarbonate in drinking water. Concentration above the limit may be harmful to human when such water is consumed. The concentration of HCO_3in the water samples ranged from 0.015 to 0.033mg/l (Figure4) which is considerably lower than the WHO (2011) permissible limit (Figure 4). The values obtained in this study are noticeably comparable to those Chiazor et al., (2016).

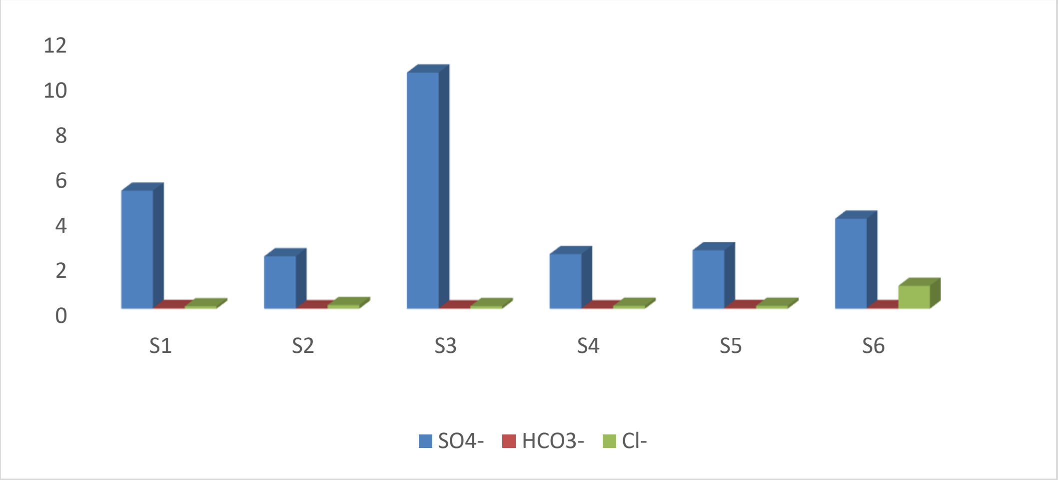

Figure 4: Major anions concentration in mg/l of surface water of the Niger

Nutrients

Nitrate (NO_3^-) and phosphate (PO_4^-) are regard as nutrient; their presence in surface water promotes eutrophication of the water. PO_4^- enters water through human and animal waste, weathering of phosphorus rich rocks, laundry and cleaning, industrial effluents and fertilizer runoff from farm lands (WHO, 2011). PO_4^- becomes hazardous in water when its concentration is above the health standards. WHO (2011) standard for drinking water is set at 10mg/l. Concentration above this limit is considered to pose health effect on those that drink it. The concentrations of PO_4^- in the water samples ranged from 1.20 to 6.14mg/l (Figure 5) and all are below the permissible limit of WHO (2011). The concentration of PO_4^- is anomalously high in location S3 compared to other location which are below 1.5mg/l. This could be due to runoff of materials enriched in PO_4^-, especially fertilizer used in rice cultivation in the bank of the river Niger or disposal animal waste in the river. NO_3^- is a naturally occurring ion which forms parts of the nitrogen cycle (Rollins, 2007). NO_3^- concentration in groundwater and surface water is normally low but can reach high levels as a result of leaching or runoff from farm lands or contamination from human or animal. The desirable limit for NO_3^- is 50mg/l, the concentration of NO_3^- in the water samples ranged from 0.23 to 1.14mg/l (Figure4), these values are consistent with those obtained by Chiazor et al. (2016) for the same river.

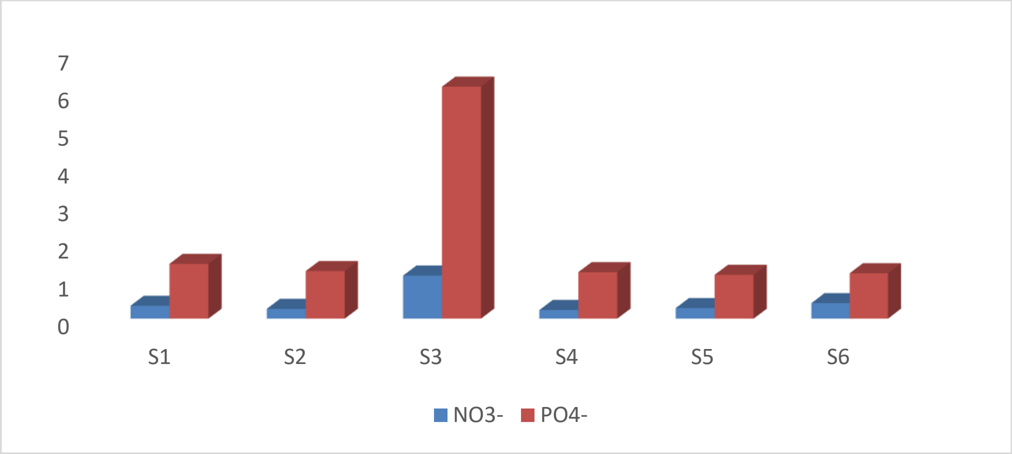

Figure 5: Nutrient concentration in mg/l of NO_3^- and PO_4^- in surface water of the River Niger

Heavy Metals

Cadmium (Cd^{2+}) is released to the rivers or surface water from wastewater, treatment plants and diffuse pollution which is caused by contamination arising from fertilizers and local air pollution (Stanistski,2000). Contamination of Cd^{2+} in drinking water may also be caused by impurities in the zinc of galvanized pipes, solders and some metal fittings. The tolerable limit of Cd^{2+} in drinking water is 0.003mg/l as stipulated by WHO (2011). The concentration of Cd^{2+} ranged from 0.003 to 0.006mg/1 (Figure 6), these values is slightly above the tolerable limits. These concentrations in water pose health challenges as Cd^{2+} is a dangerous element for human (WHO, 2011). The concentration of Cd^{2+} is slightly lower than the results of Chiazor et al. (2016).

Pb^{2+} is a general toxicant that accumulates in the skeleton of humans. Infants, children up to 6 years of age and pregnant women are most susceptible to the adverse health effects of Pb^{2+} contamination (WHO, 2011). The WHO (2011) guidelines for Pb^{2+} in drinking water quality recommended a maximum allowable concentration of 0.1mg/l. The concentration of Pb^{2+} in the river water samples in all the location are higher than WHO permissible level ranging from 0.222 to 0.412mg/l (Figure 6). Our values are relatively higher than those obtained by Chiazor et al. (2016). The elevated of Pb^{2+} concentration in the river samples may be caused by the discharge of industrial waste into the river bodies and weathering of rocks enriched with Pb^{2+} minerals carried in runoff.

Zn^{2+} is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. The concentration of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05mg/l respectively, but its concentrations in tap water can be much higher as a result its dissolution of distribution water pipes system (WHO, 2006). The concentration of Zn^{2+} in water samples ranged from 0.083 0.41mg/l (Figure 6) which are essentially lower than 5.0mg/l stipulated by WHO (2011). The

concentration of Zn^{2+} presented is higher than that of Chiazor et al. (2016). This could be due to increase of industrial waste discharge into the river and the weathering of rocks mineralized with Pb^{2+}- Zn^{2+} minerals.
One of the commonest sources of nickel (Ni) in among non-smoking and non-occupationally exposed population is food. Water is known as minor contributor of Ni^{2+} to human except contamination of water arising from oil spillage. The concentration of Ni^{2+} in the samples ranged from 0.002 to 0.06mg/l (Figure 6), some of the samples were somewhat above the 0.02mg/l stipulated by WHO (2011), especially S1 and S5. It may emanates from oil from speed boats used in ferry of people

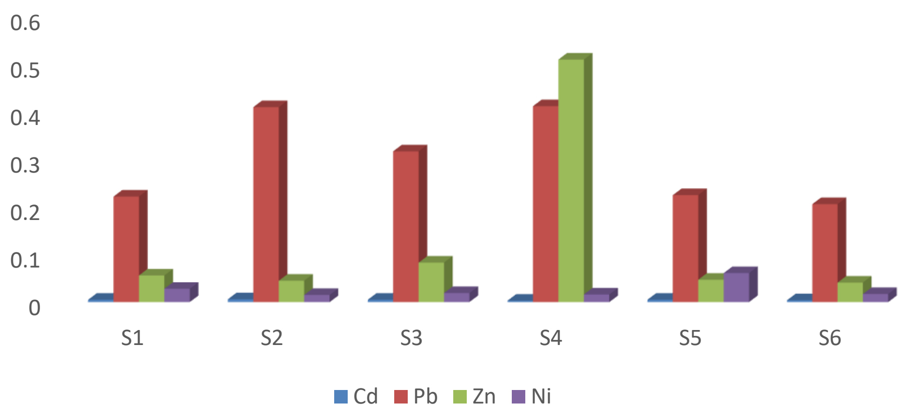

Figure 6: Concentration of heavy metals in mg/ l of surface water of river Niger

Water Types

Piper's Diagram is a graphic representation of water geochemically. it assists in interpreting water sources (Kahown et al., 2006), mixing of different water and geochemical evolution of water. The principle is based on the premise that cations and anions in water are generally in chemical equilibrium. Piper's diagram classifies the water samples from the six reaches of the river into Ca-Cl and Ca-Mg-SO4 water types (Figure 7). However, the sequence in the order of preponderance of cation is Ca>Na>Mg>K and anion is $SO_4^{-}>NO_3^{-}>Cl^{-}$ The Pipers diagram also reveals that alkaline earth metal of Ca^{2+} and Mg^{2+} in the water samples exceeded K^+ and Na^+.

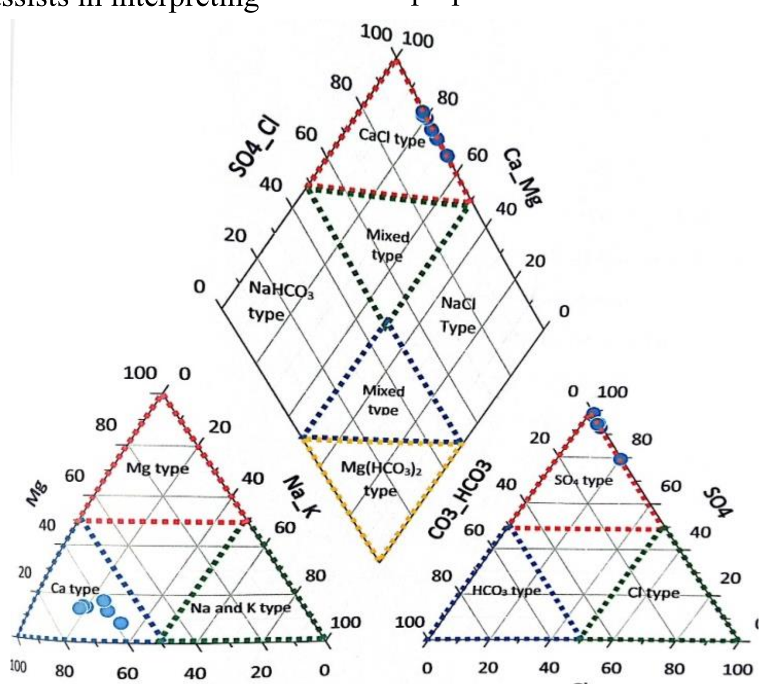

Figure 7: Surface water type depicted by Piper diagram

Sodium Absorption Ratio (SAR)

SAR is an irrigation water quality parameter used in management of Na^+ affected soil (Tijani et al., 2018). It is an indication of the suitability of water for agricultural irrigation, it is determined from the concentration of the main alkaline water for alkaline earth metals present in the water.

Sodium Absorption Ratio is given by the formula;

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Figure 8 shows the values of SAR for each the river reach and the values ranged from 0.87 to 1.78. The highest value is recorded in sample S2 and other less than 1.0. If irrigation water with high SAR is applied to a soil, the Na^+ in the water can displace the Ca^+ and Mg^+ in the soil. This can result in a low crop yield (Tijani et al., 2018). When the SAR is less than 3, it has a low salinity hazard and regarded good for irrigation water (Rollins, 2007). The SAR result obtained for the surface water suggests a low salinity hazard and therefore good for irrigation.

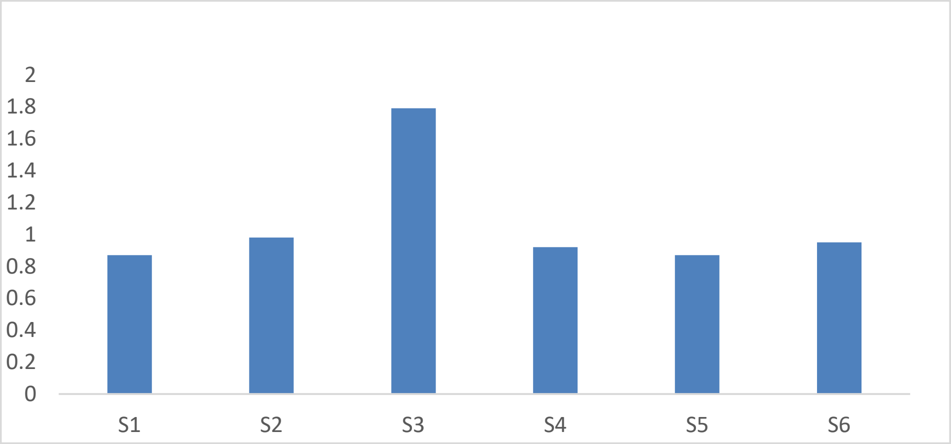

Figure 8: Sodium absorption ratios computed for surface water of the River Niger

Conclusions

Surface water samples collected from six reaches of the River Niger have been analyzed for major ions, selected heavy metals and nutrients. The concentration of both major cations and anions are mostly within the international and national requisite standards. The heavy metal concentrations in the surface water samples indicated that their concentration is significantly above the desirable limits of recognized international and national standards, excluding Zn^{2+}, which is satisfactorily below the tolerable limits. Furthermore, the elevated concentration of phosphate depicted by one of the surface water samples suggests contamination from fertilizers or human/animal wastes. The enhanced level in the concentrations of three heavy metals out of four analyzed, strongly suggests contamination. Why the surface water from the River Niger may not be aptly fit for consumption, nevertheless, its SAR calculated did indicates its suitability for irrigation of farm. The geochemical composition of all water samples collected from different reaches of the River Niger, situated in the heart of Lokoja metropolis has shown that urbanization has strongly impacted negatively on its quality. Further study is required to understand how the mixing of Rivers Benue and Niger affects the quality of the River Niger after the confluence.

References

Abimbola, Y. and Sangodoyin, A.B. (1994). Considerations on contamination of groundwater by waste disposal system in Nigeria. Environmental Technology, 14(14): 957-964.

Adeaga, O, Gil M., Claudine D. Francoise E., Nathalie R, Jean-Luc S. Eric S., (2017). Quality of water resources in the Niger basin and in the region of Lagos. Bulletin of Geography. Physical Geography Series, 13:51-60.

Adeaga O., Mahe G., Dieulin C., Elbaz-Poulichet F., Rouche N., Seidel J. L. and Servat E. (2013). Analysis of surface water quality upstream Niger Delta System.IAHS-IAPSO-IASPEI Assembly, Gothenburg, Sweden,124-125.

Adelana, S.M.A; Olasehinde, P.I; Bale, R.B Vrbka, P; Goni, I.B and Edet, A.E. (2008). An overview of the geology and hydrogeology of Nigeria. In: (Adelana SMA and MacDonald AM eds.). Applied Groundwater Studies in Africa. IAH Selected Papers on Hydrogeology, 13:171-197.

Ameyibor, K. and Wiredu, M.B. (1991). Senior Secondary Schools Chemistry Macmillan Education Ltd., London.126-128

Apeh, S. and Ekenta O.E., (2012). Assessment of Surface Water Quality of River Benue at Makurdi. Journal of Emerging Trends in Engineering and Applied Sciences, 3(6): 904-

APHA. American Public Health Association (1998) Standard Method for the examination of water and wastewater 18th edition, Washington, DC 45-60.

Audu, E.B. (2001).The Hydrological Consequences of Urbanization in Nigeria: Case Study of Lokoja, Kogi State. Unpublished M. Tech Thesis, Post Graduate School, Federal University of Technology, Minna, Niger State.

Ayodele, K. O. 2005. Assessment of the geology and sustainable borehole projects in Kogi State, unpublished Master in environmental management degree thesis. University of Ado-Ekiti.

Baryla, G., Genel, A. and Gary, R. (2011). Chemical partitioning of cadmium, copper, nickel and zinc in the soil and sediments containing high levels of heavy metals. Journal of environmental Quality, 4(8): 45-49.

Bhatia, S.C. (2009). Environmental pollution and control in the chemical process industries. 181-193.

Castano, I. A., 2010. "A study on the hydrological series of the Niger river at Koulikoro, Niamey and Lokoja stations". webcache.googleusercontent.com. Retrieved 28 April 2018.

Chiazor S. N., Kemah P. U., Obihan I. A., (2016). Assessment of Surface and Ground Water Quality in Ganaja, Lokoja, North-Central, Nigeria. Journal of Environment and Earth Science, 6(2):1-6.

Ekere N.R., Yakubu, N. M., Ihedioha J. N, (2018). Assessment of Levels and Potential Health Risk of Heavy Metals in Water and Selected Fish Species from the Benue-Niger River Confluence, Lokoja, Nigeria. Journal of Aquatic Food Product Technology, 27:772-782.

Frits, R., Vega, G. and Perez, L. (2000). Important Chemical Properties of Metals. CRC press Inc. Boca Raton.pp. 22-25.

Davidson S.A. Alaci, and Clement D. Chup, (2015). Reflecting on Green Urbanism for

Sustainable Urbanization in Nigeria". Journal of Contemporary Urbanology, 2:(1), Pp. 66

Hernández-Mora, N; Martinez-Cortina, L. and Fornés, J. (2003). Intensive Groundwater Aquifer Over-Exploitation. Implications for Water Policy in Southern Europe. In: Agricultural Use of Groundwater. Towards Integration between Agricultural Policy and Water Resources Management (ed. C. Dosi), Kluwer Academic Publishers, 107-125.

Hole, J.W. (1999). Human Anatomy and Physiology Journal of Environmental science, 6(23), 23-34.

Huckabee, D., Mark, S. and Kirk, T. (2011). Copper in soil and plants. Sydney, Academic Press, 265 285.

Osokpor, J and Okiti, J (2013). Sedimentological and Paleodepositional Studies of Outcropping Sediments in Parts of Southern Middle Niger Basin. International Journal of Science and Technology Vol. 2 No.12,839-846.

Kline, T., Lake, D. and Lester, P. (2010). Simultaneous sorption of Cd, Cu, Ni, Zn, Pb and Cr on soils treated with sewage sludge supernatant. Water, Air and Soil Pollution, 93: 331-345.

Ladipo K.O (1988). Paleogeography, sedimentation and tectonics of the Upper Cretaceous Anambra Basin, south-eastern Nigeria. Journal of Africa Earth Sciences, 7:865-871.

Ladipo, K. O., Akande S. O. and Mucke, A., 1994. Genesis of ironstones from the Mid-Niger sedimentary basin: evidence from sedimentological, microscopic and geochemical studies. Journal of Mining and Geology,30,161-168.

Meybeck M., E. Kuusisto, A. Mäkelä and E. Mälkki, (1996). Water Quality Monitoring – A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. Published on behalf of United Nations Environment Programme and the World Health Organization, p4.

Miller, J., and Junior, G.T. (1997). Environmental science working with the Earth. 6th edition Wadsworth Publishing Company, USA. 285-286.

Morgan, P. (1990). Assessments of Rural Water Supplies and Sanitation, Blair Research Laboratory, Macmillan Education Ltd. London. 4(27):275-280.

NIMET, 2011. Nigerian Metreological Society. "Climate Variability and Change: Impact, Science, Innovation and Policy".

Nkansah, M.A. Boadi, M. O. and Badu M. (2010). Assessment of the Quality of Water from Hand-Dug Wells in Ghana, Environmental Health Insights 4,7-12.

NSDWQ: Nigeria Standard for Water Quality (2007). Nigerian Industrial Standard NIS 554. Standard Organization of Nigeria, 1-46.

Nsi, E. W. (2007). Basic Environmental Chemistry. The Return press Ltd. 126-151.

Obaje, N. G., M. K. Musa, A. N. Odoma, and H. Hamza, 2011. The Bida Basin in North-central Nigeria: sedimentology and petroleum geology. Journal of Petroleum and Gas Exploration Research Vol. 1(1):001-013.

Obiri-Danso, K., Adjei, B., Stanley, K.N. and Jones, K. (2009) Microbiological quality and metals in wells and boreholes water in some peri-urbn communities in Kumasi, Ghana. African Journal of Environmental Science and Technology. 3(1): 055-066.

Obuobie, E., and Barry, H. (2008). Estimation of groundwater recharge in the context of future climate change in the White Volta River Basin, West Africa. Ecology and Development Series. No.62.168.

Ocheri, M.I and I.I. Mile.2010. Spatial and temporal variation in groundwater quality of Makurdi sedimentary formation. Journal of Geography, Environment and Planning, Vol.6, No.1,141-146.

Oke A.O and Sangodoyin A. Y (2015). Evaluation of Surface Water Quality Characteristics in Ogun Watershed of South Western Nigeria Using Principal Component Analysis. Journal of Science and Technology, 35(1): 89-101.

Okumura, Y., Xie, S. 2004. Interaction of the Atlantic equatorial cold tongue and the African Monsoon. Journal of Climate 17:3589- 3602.

Olaniyan, O. and Olobaniyi, S. B., (1996). Facies analysis of the Bida Sandstone Formation around Kajita, Nupe Basin, Nigeria. Journal of African Earth Sciences, 23,253-256.

Olasoji, S. O., Oyewole N. O, Bayode A. and Joshua N. E., (2019). Water Quality Assessment of
Surface and Groundwater Sources Using a Water Quality Index Method: A Case Study of a Peri-Urban Town in Southwest, Nigeria. Environment, 6 (23): 1-11.

Omada J.I, Omali, A. and Akuh, T. (2009). Groundwater resources of Lokoja metropolis, central Nigeria. Journal of Mining and Geology, Vol. 45, No. 1,41-41.

Petters, S. W., (1986). Foraminiferal biofacies in the Nigerian rift and continental margin deltas. In: OTI, M. N. and POSTMA, G. (Eds.) Geology of Deltas. AA Balkema, Rotterdam,219-235Pritchard, M., Mkandawire, T. and Oneil, J.G. (2007). Biological, Chemical and Physical
Drinking Water quality from shallow wells in Malawi. Physics and Chemistry of the earth. 32.1167-1177.

Rogers, D., Sam, G. and Matt, K. (2009). Is soil an appropriate dumping ground for our waste Australian Journal of Soil Research. 35-37.

Salami, S.T. and Okafor, K. (2003). Surface water quality in an Iron ore mining area, Itakpe, Nigeria. Environmental Science 7 (1): 12-17.

Self. Waskom, R.M. (2008). Nitrate in Drinking Water. Colorado State University Extension. 2(4):577-583.

Shaw, B., Mechernich C., Peterson J., Masarik K., (2009). Interpreting Drinking Water Quality Results: Identifying Problems and Solutions. WI Department of Natural Resources (DNR),1-6.

Silberberg, M.S. (2000). Chemistry, The Molecular Nature of Matter and Change, 2nd Edition. McGraw- Hill Companies, USA 123-126.

Stanistski, C. L., Eubanks L.P. Middlecamp, C.H, and Stratton, W.J (2000) Chemistry in context Third Ed. McGraw-Hill Com. 452-454.

Swanson H. A. and Baldwin H. L., (1965). A primer of water quality. United State Geological Survey, p67. UNICEF, United Nations International Children's Emergency Fund (2019). Nigeria: Contaminated Water as Major Cause of High Death Rate. Articles on All African Stories,
4th February,2019.

WHO, World Health Organization (2005) Guidelines for Drinking Water Quality, first Addendum to the third edition, Recommendations. Geneva, 1p.

WHO, World Health Organization (2008). Meeting the MDG drinking water and sanitation target: the urban and rural challenge of the decade.http://www.who.int/water_sanitation_health/monitoring/jmpfinal.

WHO,World Health Organization (2011).WHO Guidelines for drinking water quality, 4th ed.
World Health Organization, Geneva.219-229.

WHO, World Health Organization (2019). Newsletter on Drinking Water. Article on World Health Organisation, 14th July, 2019.

Zoeteman, B.C.(1980). Sensory assessment of water quality. Pergamon Press, Oxford