Water Pollution and Quality Assessment of Lakes Gerio and Njuwa in Yola, Adamawa State, Nigeria

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Abstract

The study focuses on water pollution and quality assessments of Lakes Gerio and Njuwa and its consequent effects on the water and the live that exist in and around the lakes basins. The effects of anthropogenic activities and particulate matter on water quality of the lakes were assessed. The objective is to analyse the physical properties of the water, conduct pH and coliform test in order to assess water quality. Water samples were subjected to microbial analysis in order to test for faecal contamination as well as pH test. Both waters turned out to contain coliforms and are acidic with Lake Gerio (pH of 6.5) and Lake Njuwa (pH of 6.0). The activities taking place around the lakes include; farming in which farm inputs like fertilizers, herbicides affect the water quality, fishing, washing, bathing, as well as deposition of human and animal urine and faeces due to open defaecation. Sedimentation and siltation of River Benue as well as the lakes also introduce more challenges that need particular attention. Conclusively, both lakes were unfit for human consumption. It is therefore recommended that there should be public enlightenment of the lake users about the dangers of inappropriate usage and consumption of the contaminated waters. Farmers around the lakes should be encouraged to minimise the use of chemicals through advocacy and incentives, for the application of sustainable conservation farming practices to conserve the ecosystem so as to improve on the quality of the water of the two lakes.

INTRODUCTION

Lakes are surface water features on land. Lake Gerio and Lake Njuwa are where runoffs and wastewater drainages converge to empty their contents. Several studies have shown evidence that the effects of human activities contaminate freshwater resources. The effects of human activities on water quality differ in magnitude from one place to another. Changes in the physical, chemical, and biological characteristics of water negatively affect both human and ecosystem health (Al-Anzi *et al*, 2012).

In recent years, the volume of wastewater produced in urban areas has increased substantially because of rapid growth in the human population, industrial and commercial activities, leading to changes in water consumption behaviour (Mishra *et al*., 2017). In most urban areas in the developing nations, excess wastewater is disposed-off directly (without effective treatment) into surface water bodies, resulting in their severe degradation (Choubey, 2012; Ismail & Abed, 2013).

Water pollution threatens the sustainability of urban systems. Untreated disposal of effluents directly contaminates surface water supplies with heavy metals. According to Goulding, (2002), heavy metals are metallic elements with an atomic number greater than 20, which exhibit metallic properties. Such contaminants are wastes that come from pharmaceuticals, insecticides, surfactants, endocrine disruptors including hormones (Petrovi *et al*, 2003; Pal *et al*, 2010). In developing countries, people have little or no option than to accept water sources of doubtful quality, due to lack of better alternative sources or due to economic and technological constraints to treat the available water adequately before use.

The scarcity of clean water and pollution of fresh water have therefore led to a situation in which one-fifth of the urban dwellers in developing countries and three-quarters of their rural dwelling population lack access to clean and safe water supplies (Taiwo *et al*, 2012). Factors that have contributed to the over-exploitation and hence the degradation of fresh water are largely human. These include; urbanisation, industrialisation and agricultural technologies among others. Therefore, water requires proper utilisation and management through cost-effective ecosystem services. The water quality from the rivers and lakes has a considerable importance. In Jimeta and Yola, Lake Gerio and Lake Njuwa are sources for domestic, irrigated farming, fishing, transportation, tourism, recreation, and many other socio-economic ways (Dunca, 2018). Since the past four decades, settlements have faced consistent challenges caused by droughts, water pollution and water quality degradation (Sodhi & Ehrlich, 2010).

Water quality monitoring is therefore a fundamental tool in the management of freshwater resources. To underpin its importance, World Health Organization (WHO), United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO) and World Meteorological Organization (WMO) launched in 2012, a water monitoring programme to collect detailed information on the quality of global ground and surface water. According to National Bureau of Statistics (NBS, 2009), at least 27% of Nigerians depend absolutely on streams, pond, river and rainfall as their sources of drinking water. Research has shown high prevalence of water-borne diseases such as cholera, diarrhoea, dysentery, hepatitis etc. among Nigerians (Oguntoke *et al*, 2009), mostly gotten from these sources of water. Quality of river is modified mainly through human activities; such include discharge of domestic waste from households into the river, deposition of agricultural waste such as organic matter, carbon, nitrogen, phosphorus, compounds, dumping of industrial waste such as trace elements and complex organic matter; urbanization has also contributed to the deterioration of water around the world and making it unfit for domestic purpose (Mumba *et al*, 2005;Chimwanza *et al*, 2006; Aradhna *et al*, 2008; Oginni, 2013; Alausa *et al*, 2015; Ehichioya *et al*, 2018).

Increase in atmospheric temperature and altered weather patterns have contributed to water scarcity over the years, these changes will continue to adversely affect human health, water supply, economy and quality of life (Melillo *et al*, 2014). In addition, farm inputs such as fertilizer and herbicide form the major contaminants of the lakes through runoff (Hoff, 2013). Other indiscriminate activities around the lakes include open laundry services and animal open defecation that affected water quality of these lakes. The study critically examines the impact of wastewater and anthropogenic activities on the Lakes Gerio and Njuwa through conducting microbial analyses and pH test of water samples from both lakes. The pH of the water is important because it affects the solubility and availability of nutrients, and how they can be utilized by aquatic organisms (Stone *et al*, 2013).

Study area

The study area is Lake Gerio and Lake Njuwa located besides the dual city of Jimeta and Yola respectively, the capital city of Adamawa state, in the Semi-Arid, drylands climate of north-eastern Nigeria. The Land mass of the two urban centres are 111.85km^2 Jimeta and 719.0 km^2 Yola, having a total of 830.85 km^2 and their populations are 199,674 and 196,197 people for Jimeta and Yola respectively (Tukur & Barde, 2014). The area is geographically located between Longitudes 12° 20' E and 12° 30' and Latitude 9° 06' N and 9° 19' N along the bank's of River Benue. Lake Gerio is located at latitude 9°18'29''N and longitude 12°26'55''E and Lake Njuwa is located at latitude 9°06'31''N and longitude 12^0 30'20''E. The altitude of the basin area varies from 145 to 149 m above mean sea level (Barde et al, 2019). The two lakes are important sources of water for drinking, irrigation, recreational, and cultural uses.

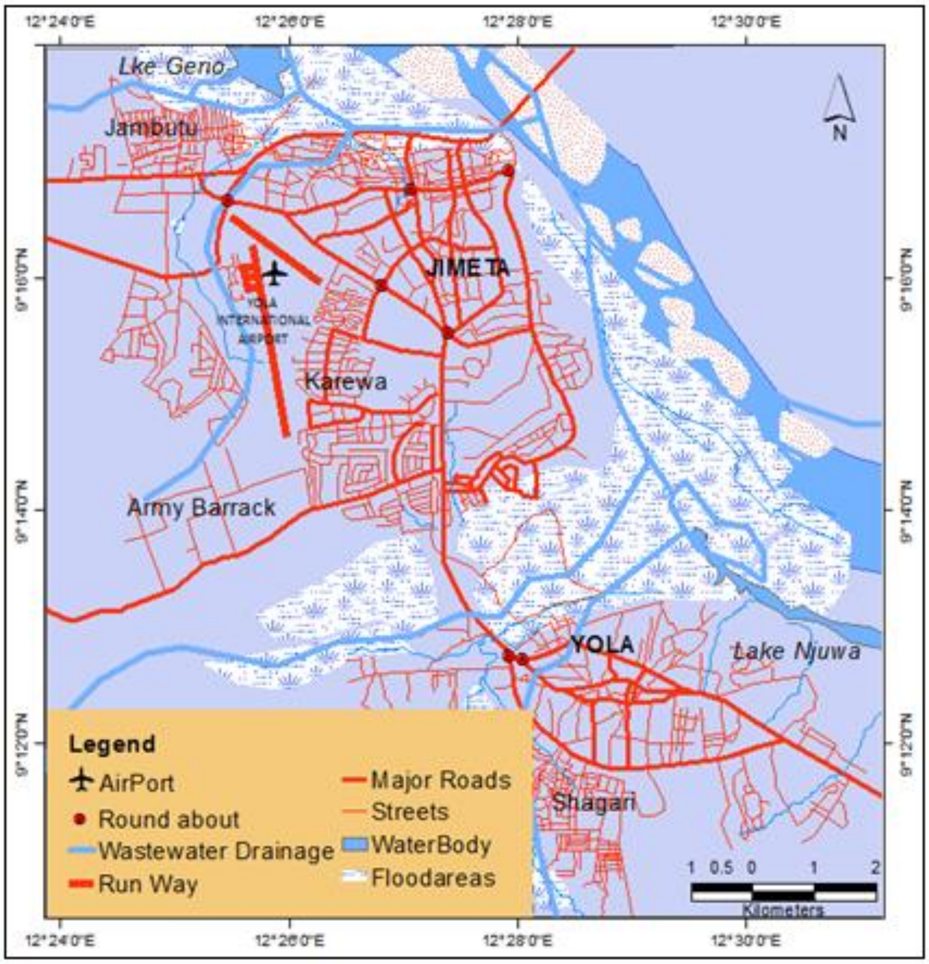

Figure 1: Jimeta and Yola metropolitan area. Lake Gerio (top left) and Lake Njuwa (bottom right) are shown.

METHODOLOGY

Water quality assessment requires various input data including point and non-point pollution sources, quantities, locations, concentrations, wastewater, water temperatures, drainage network, and surface water inflows. The flow of wastewater into the lakes mainly feeds through domestic, industrial and stormwater runoff routes (Fig. 2 b). There are no precise data available on the total volume of wastewater produced from different sources. The daily volume of domestic wastewater is hereby generated based on an estimated 75 litres of average daily consumption per capita (UNEP, 2001).

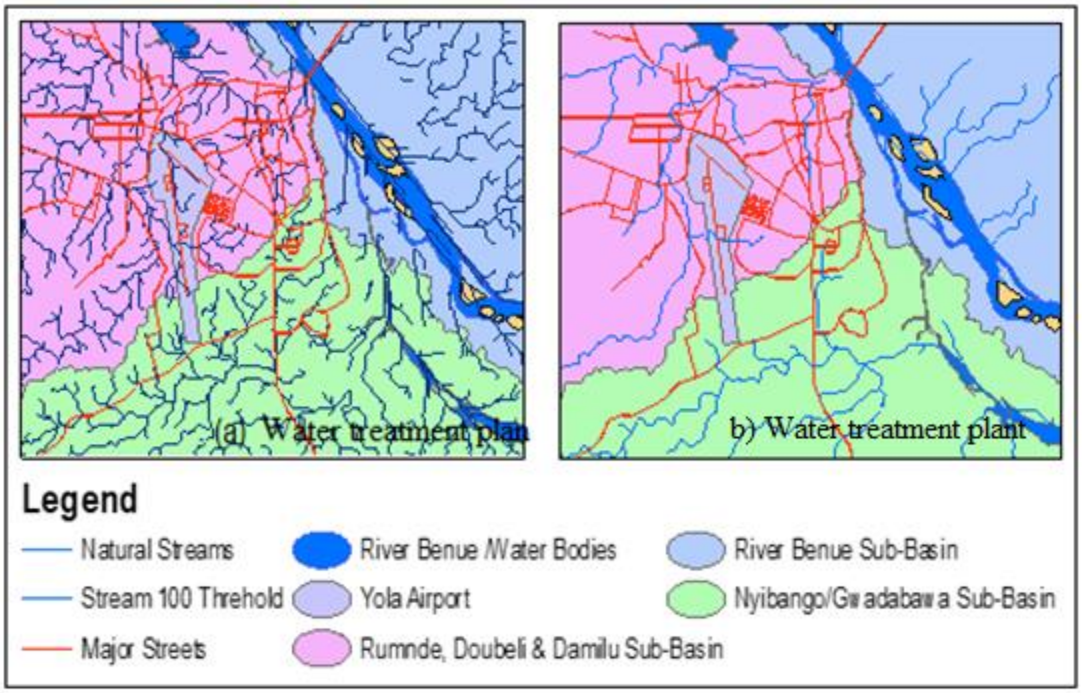

Figure 2: The sub-basins and locations of stream flow and water quality treatment plants stations within the study area.

This study, Compares the quantity of water contaminants through water analysis at Microbiology Laboratory, Modibbo Adama University of Technology, Yola, physical observation and interviews for qualitative data that support the empirical analysis. Therefore, thirty respondents were interviewed in order to conform with Dixon & Leach (1977) set standard for sampling in a qualitative research. There are many lakes in Adamawa state and within the study area, but these two lakes were selected because they are the base levels where the urban wastewater flowing into and some rainfall runoffs from agricultural lands and urban fields of Jimeta and Yola metropolis. The lakes are providing a suitable environment for the microorganisms to develop and form colonies. Materials that were used included: lake water samples, autoclave machine, hydrion papers. Others, includes thermometers to measure temperatures, and remotely sensed Advanced Space borne Thermal Emission and Reflection Radiometer Digital Elevation Model (ASTER DEM). The 30-meter spatial resolution DEM was used to delineate some of the wastewater drainage networks for analysis. Precautions that were taken for this procedure to prevent introduction of ferine contaminants included autoclaving and sterilizing all equipment prior to usage.

The pH Test of the water was carried out separately in order to assess the level of acidity or alkalinity of the water. Some physical properties that were observed and analysed include colour, suspended particles in water, odour and water clarity assessment. This was carried out through measurement and observation. The entire study area was divided into sub-basins with consideration for the influent locations of major tributaries terminating at their base levels that is the lakes.

RESULTS AND DISCUSSION

The results of microbial analysis particularly the coliforms and pH shows that both lakes contained coliforms (Table 1). This is likely the major cause of waterborne diseases among the domestic users such as typhoid and cholera in the metropolitan areas. The pH of Lake Gerio was observed to be 6.5, it is less acidic than that of Lake Njuwa with pH 6.0 it is more acidic than that of Lake Gerio. The pH value can sensitively indicate variations in water quality and is affected by dissolved substances (WHO, 2008). The pH is a measure of the concentration of hydrogen ions in the water or simply referred to a measure of acidity and alkalinity of the water. Naturally occurring fresh waters have a pH range between 6.5 and 8.5. Surface water pH can be relatively higher in low discharge waters. However, lower-pH water (approximately pH 7 or less) is more likely to be corrosive (WHO, 2017). The presence of coliforms and the level of pH in the lakes signifies danger attributed to the inappropriate wastewater disposal and unsustainable utilisation of the lakes by the nearby settlements.

Table 1. Colifom test results of water samples from the lakes

Water Sample	Coliform Count	pH Value
Lake Gerio	103	6.5
Lake Njuwa	124	6.0

Microbial analysis was conducted of the two lakes which show the presence of bacteria such as *escherichia coli,* which is considered as the most common cause of urinary tract infections. Also, *salmonella* which causes food poisoning was also found in the water. There was also an occurrence of heavy metals in their abnormal quantities in Lake Gerio. The value of metals recorded in this work is below the maximum permissible limit set out by the World Health Organization. Some physical elements of the lakes as observed showed that the water temperature of the lakes was 26.6^{o}C for Lake Gerio and 17.9^{o}C for Lake Njuwa. The implication is that temperature affects surface water quality as it controls oxygen levels, which influences rate of chemical and biological reactions for aquatic organisms (Mohsin & Sahib, 2013).

Lake Gerio has lesser acidity and consequently higher salinity due to higher values of temperature and pH when compared to what is obtained at Lake Njuwa (Table 2). High Total Suspended Solids levels in surface water absorb heat from sunlight, which increases water temperature and decreases levels of dissolved oxygen (Iqbal *et al*., 2010). As a results the water bodies are losing the ability to support aquatic life (Cavanagh *et al*., 2014).

Table 2. Physicochemical properties of the water in the lakes

Parameters	Sample Sites	
	Lake Gerio	Lake Njuwa
Temperature (°C)	26.6 (pH =6.5)	17.9 (pH= 6.0)
Transparency (cm)	30.6	30.5
Conductivity	23.65	10.7
Free CO_2 (g)	500.6	942

No significant difference in terms of water transparency or cloudiness of the lakes. The water is generally cloudy with short range (30.5 cm) top-bottom visibility. Turbidity and transparency of water is determined by the concentration and nature of Total Suspended Solids (TSS) (Matta, 2014). TSS and turbidity differs with time based on biological activity in the water system and type of sediments carried by surface run-off. Conductivity (EC) of an electrolyte solution is directly linked to Total Dissolved Solid (T.D.S.).

High quality deionized water has a conductivity of 5.57µS/cm at 25 ^{o}C. Typical drinking water is in the range of 5 - 50 µS/cm. Lake Gero record higher T.D.S value of 23.65µS/cm and 10.7µS/cm for Lake Njuwa; i.e. the higher the salt content, the higher the EC will be which also produce unwanted taste in water (Anhwange *et al*, 2012; Mohsin & Sahib, 2013; Stone *et al*., 2013). Free Carbon (ii) oxide were 500.6 for Lake Gerio and 942 for Lake Njuwa. This measure the amount of dissolved gas which is acidic in nature. Surface waters normally contain less than 10 parts per million (ppm) free carbon dioxide, while some ground waters may easily exceed that concentration as exist in the two lakes primarily due to natural and human factors within the lakes' basins. Furthermore, the result of the observation substantiates the facts obtained from the laboratory assessment of the water quality.

The Socio-economic activities are dominated by low income earners. The activities at Lake Gerio are light compared to Lake Njuwa; probably as a result of distance decay factor. These activities range from rainfed and irrigated agriculture; for growing rice, maize and vegetables, to fishing, grazing, swimming, washing of wares, vehicles, and general laundry services are among the major observable events happening almost every time of the day. Subsequently, liquid waste flows from urban drainages and rainfall runoff help these emergent contaminant gets their way into the lakes (Fig. 2).

The major industrial effluents are from Kofare industrial layout with Adama Plast and Faro Water and other spotted small-scale industrial works such as dying of cloths, soap and other detergent making outfits in the urban centres of Jimeta and Yola. Automobiles maintenance garage are also part of the industrial activities in the study areas that generates contaminants that flow into the lakes. Consequently, the presence of these chemical compounds from industrial effluents like nitrates, potassium, and phosphorus in excess quantities pollutes the water directly or indirectly. Observable also are the heaps of refuse dumps within the basin areas of the lakes. All these contribute to both point and non-point source of pollutants. The result of the interviews on the effect of the contaminants revealed very low awareness on the dangers associated with the lake waters.

The interactions with some of the users showed a serious concern on lack of environmental education. The people there drink the water from both lakes without knowing the consequences. Greater percentage of the respondents agree that no any form of water treatment carried out before consumption. It is clear that the people around the lakes are vulnerable to diseases. Therefore, there is need for further research by community health workers or experts in medical geography to investigate the nature of ailments suffered by the nearby community particularly the direct users of the waters from the two lakes. The lakes contain water all year round, but the volume depends on season and climatic condition. Similarly, the effects of reduction in depth of water levels due to siltation was also confirmed by the respondents who attributed same to the rate of activities which determines the level of the sediment generation.

Among the heavy metals, there are trace elements, or elements required for proper growth, development and functioning of living organisms (e.g. Copper, Zinc, Chromium, and Iron) and those which are unnecessary for them (e.g. Cadmium, Lead, and Mercury). However, their common feature is that beyond a certain limit or threshold, they are toxic and are very dangerous for plants, animals and humans (Bruemmer *et al*, 1986). Toxic heavy metals found in the lakes are largely due to lack of proper or controlled utilisation of the lake's basins. Though it does not exceed the lakes carrying capacities, but there is significant amount of contamination (see table 3). The excess or absence of these metals in the body destabilise the body system resulting to different kind of disorders or sicknesses in humans.

Iron (Fe) is found in all human organs and tissues and is used for the synthesis of haemoglobin and myoglobin muscle and lack of sufficient iron in the body may lead to anaemia. The presence of Iron (Fe) in both lakes is as a result of some contaminants, but the results of the empirical test showed low contents of Fe in the two lakes (see table 3) and indication of good drinking water quality, when compared with maximum permissible limit given by World Health Organisation.

Table 3. Concentration of heavy metals at Lake Gerio and Lake Njuwa,

Heavy Metals	Concentration (µg/l)		WHO (2017) limits for heavy metals in drinking water
	Lake Gerio	Lake Njuwa	
Iron (Fe)	0.065	0.054	0.027 – 0.39 µg/l
Zinc (Zn)	0.067	0.063	0.01 – 1.47 (mg/l)
Manganese (Mn)	0.023	0.022	0.1 mg/l
Cupper (Cu)	0.005	0.002	<0.005 – 30 mg/l
Cobalt (Cb)	0.004	0.005	1.00 – 2.00 mg/l
Cadmium (Cd)	0.027	0.024	0.005 – 0.04 µg/l
Lead (Pd)	0.0007	0.006	Below Detection Level (BDL) – 0.114 µg/l

Zinc (Zn), on the other hand was found to be 0.067 and 0.063 for Lakes Njuwa and Gerio respectively. Zinc in the body plays an important role in a variety of enzymes and hormones. Symptoms of zinc poisoning are; damage to the lining of the nasal cavity - throat and lower respiratory tract and necrotic changes in the walls of the stomach. Copper (Cu), Manganese (Mn). Cobalt (Cb), Lead (Pb), Cadmium (Cd), are present in permissible and accepted quantity when compared to the standard of the World Health Organization (WHO, 2017). It is obvious that all the heavy metals have their metabolic functions in human body. Whenever it exceeds the body carrying capacity it results to complex reactions of the body system, their absence also results to other forms of complications.

CONCLUSION

The water from both lakes are not bad nor excellent in terms of quality. However, this study revealed that none is safe for drinking untreated. Comparatively, Lake Njuwa has more coliforms and heavy metals than Lake Gerio. The *Escherichia coli (E. Coli)* was observed in both lakes which shows faecal contamination of the water. The high contents of particulate matter in Lake Njuwa is attributed to the high rate of unsustainable utilisation and waste disposal. All the heavy metals in the lakes were present in permissible quantities given by World Health Organisation, with maximum allowable limit of 3.0 mg/L. It is assumed that the harmful substances flows downstream throughout the years, but it is expected to go through some purification processes through air, water and earth which might break down some chemical composition to less harmful forms. This could explain the reason why the respondents claimed to have been consuming the water without any negative effect. Similarly, the metals that are far below normal requirement in the lakes are readily available in food died. Generally, the physiochemical and qualitative analysis shows that, Lake Njuwa has a pH value of 6.0 this is more acidic, and having higher contamination than that of Lake Gerio having a pH of 6.5 it is close to 7.0 that is neutral pH value. The contents of heavy metals and the level of contaminants in the lakes needs further empirical research in order to quantify the waste generation, its chemical composition and interactions with other metals at the upper course before reaching the lakes.

References

Al-Anzi, B., Abusam, A., & Shahalam, A. (2012). Assessment of Wastewater Reuse in Kuwait and Its Impact on Amounts of Pollutants Discharged into the Sea. *Journal of Environmental Protection*, *03*(08), 935–939. https://doi.org/10.4236/jep.2012.328108

Alausa, S. K., & Akinyemi, L. P. (2015). Heavy metal contaminants in the water from Oil-Sand-Rich River Imeri , Ogun State Southwestern Nigeria. *SAGEEP*, 28–38. https://doi.org/10.4133/SAGEEP.28-038

Anhwange, B. A., Agbaji, E. B., & Gimba, E. . (2012). Impact Assessment of Human Activities and Seasonal Variation on River Benue , within Makurdi Metropolis. *International Journal of Science and Technology*, *2*(5), 248254. Retrieved from https://www.researchgate.net/publication/233854579%0AImpact

Aradhna, G., Rai, D. K., Pandey, R. S., & Sharma, B. (2008). *Analysis of some heavy metals in the riverine water , sediments and fish from river Ganges at Allahabad*. (September 2016). https://doi.org/10.1007/s10661-008-0547-4

Barde, M. M., Tukur, A. L., & Muhammadu, A. M. (2019). Detection and Mapping of Flood Prone Areas of Jimeta, Adamawa State, Nigeria. *ATBU, Journal of Science, Technology & Education (JOSTE)*, *7*(2), 2019.

Bruemmer, G. W., Gerth, J., & Herms, U. (1986). Heavy metal species, mobility and availability in soils. *Zeitschrift Für Pflanzenernährung Und Bodenkunde*, *149*(4), 382–398. https://doi.org/10.1002/jpln.19861490404

Cavanagh, J.-A. E., Hogsden, K. L., & Harding, J. S. (2014). *Effects of suspended sediment on freshwater fish*. Retrieved from http://www.landcareresearch.co.nz/

Chimwanza, B., Mumba, P. P., Moyo, B. H. Z., & Kadewa, W. (2006). The impact of farming on river banks on water quality of the rivers. *International Journal of Environmental Science and Technology* ·, *2*(4), 353–358. https://doi.org/10.1007/BF03325896

Choubey, B. V. V. K. (2012). Surface water quality evaluation and modeling of Ghataprabha River ,Karnataka, India. *Environ Monit Assess*, *183*(3), 1371–1378. https://doi.org/10.1007/s10661-011-2047-1

Dixon, C., & Leach, B. (1977). Sampling Methods for Geographical Research. *Geography*.

Dunca, A. M. (2018). Water pollution and water quality assessment of major transboundary rivers from Banat (Romania). *Journal of Chemistry*, *2018*. https://doi.org/10.1155/2018/9073763

Ehichioya, I., Okodugha, D. A., & Oboh, A. A. (2018). Impacts of Solid Waste Disposal on Water Quality of Ugboha River - Esan Impacts of Solid Waste Disposal on Water Quality of Ugboha River -. *Advances in Multidisciplinary and Scientific Research; A Multidisciplinary and Interdisciplinary Journal*, *4*(4). https://doi.org/10.22624/AIMS/V4N4P5

Goulding, L. B. and K. W. T. (2002). Effects of atmospheric deposition, soil pH and acidification on heavy metal contents in soils and vegetation of semi-natural ecosystems at Rothamsted

Experimental Station, UK. *Plant and Soil*, *103*(3), 239–248. https://doi.org/10.1023/A:1015731530498

Hoff, M. A. (2013). *Control of Agricultural Nonpoint Source Pollution in Kranji Catchment, Singapore*.

Iqbal, J., Waseem Mumtaz, M., Mukhtar, H., Iqbal, T., Mahmood, S., & Razaq, A. (2010). Particle size distribution analysis and physico-chemical characterization of Chenab river water at Marala headworks. *Pakistan Journal of Botany*, *42*(2), 1153–1161.

Ismail, A. H., & Abed, G. A. (2013). BOD and DO modeling for Tigris River at Baghdad city portion using QUAL2K model . *Journal of Kerbala University*, *11*(3), 257–273. Retrieved from http://www.ecy.wa.gov/

Melillo, J. M., Terese, (T.C.) Richmond, Gary, W. Y., & Eds. (2014). Climate Change Impacts in the United States: The Third National Climate Assessment. (USGCRP). In and G. W. Y. Melillo, Jerry M., Terese (T.C.) Richmond (Ed.), *U.S. Global Change Research Program*. https://doi.org/10.7930/J0Z31WJ2

Mishra, B. K., Regmi, R. K., Masago, Y., Fukushi, K., Kumar, P., & Saraswat, C. (2017). Assessment of Bagmati river pollution in Kathmandu Valley: Scenario-based modeling and analysis for sustainable urban development. *Sustainability of Water Quality and Ecology*, *9–10*, 67–77. https://doi.org/10.1016/j.swaqe.2017.06.001

Mohsin, M., & Sahib, D. N. (2013). *Assessment of Drinking Water Quality and its Impact on Residents Health in Bahawalpur City*. *3*(15), 114–128.

Mumba, P., Phiri, O., Moyo, B. H. Z., & Kadewa, W. (2005). Assessment of the Impact of Industrial Effluents on Water Quality of Receiving Rivers in Urban Areas of Malawi. *International Journal of Environmental Science and Technology*. Vol 2, pp237–244.

National Bureau of statistics (NBS, 2009),

Oginni, F. A. (2013). Variations in the Water Quality of an Urban River in Nigeria. *Computational Water, Energy, and Environmental Engineering*, *2*(April), 81–91. https://doi.org/10.4236/cweee.2013.22B014

Oguntoke, O., Aboderin, O. J., & Bankole, A. M. (2009). Association of water-borne diseases morbidity pattern and water quality in parts of Ibadan City , Nigeria. *Tanzania Journal of Health Research*, *11*(4), 189–195.

Pal, A., Gin, K. Y., Lin, A. Y., & Reinhard, M. (2010). Impacts of emerging organic contaminants on freshwater resources : Review of recent occurrences , sources , fate and effects. *The Science of the Total Environment*, *408*(24), 6062–6069. https://doi.org/10.1016/j.scitotenv.2010.09.026

Petrovi, M., Gonzalez, S., & Barceló, D. (2003). *Analysis and removal of emerging contaminants in wastewater and drinking water*.

Sodhi, N. S., & Ehrlich, P. R. (Eds.). (2010). *Conservation Biology for all* (First Edit). Retrieved from https://moodle.ufsc.br/pluginfile.php/822765/mod_resource/content/1/Conservation Biology for All %282010%29 by Navjot S. Sodhi Paul Ralph Ehrlich.pdf

Stone, N., Shelton, J. L., Haggard, B. E., & Thomforde, H. K. (2013). Interpretation of Water Analysis Reports for Fish Culture. In *Southern Regional Aquaculture Center (SRAC)*. Retrieved from https://docplayer.net/64443657-Interpretation-of-water-analysis-reports-for-fish-culture.html

Taiwo, A. M., Olujimi, O. O., Bamgbose, O., & Arowolo, T. A. (2012). Surface Water Quality Monitoring in Nigeria: Situational Analysis and Future Management Strategy. *Water Quality Monitoring and Assessment*. https://doi.org/10.5772/33720

Tukur, A. L., & Barde, M. M. (2014). The Geography of Politics: A Case for the Political Redistricting of Adamawa State, Nigeria. *IOSR Journal Of Humanities And Social Science*, *19*(1), 12–24. https://doi.org/10.9790/0837-19121224.

UNEP (2001). *Nepal: State of the Environment Report, 2001*. Retrieved from http://www.sacep.org/pdf/Reports-Technical/2001-State-of-Environment-Report-Nepal.pdf

WHO (2008). *Guidelines for Drinking-water Quality. Third Edition Incorporating the First and Second Addenda. Volume 1 Recommendations Geneva 2008 WHO Library Cataloguing-in-Publication Data*. Geneva.

WHO. (2017). Guidelines for Drinking-water Quality. Incorporating the First Addendum. WHO Publications.4th Edition 2017.