**Water Quality Assessment of Nkesa River, Rivers State, Nigeria**

**ABSTRACT**

The study assessed the water quality parameters of the Nkesa River in comparison with National and International standards. In most urban-rural communities in developing countries especially Sub-Saharan Africa, surface waters (rivers, streams, and lakes among others) have been the most available sources of water used for domestic purposes. The water from these sources is contaminated with domestic, agricultural, and industrial wastes and is likely to cause water-related diseases. The study was carried out at Nkesa River, located in Ogba Egbema Ndoni Local Government Area in Rivers State in the Niger Delta region of Nigeria, and lies between latitude 5⁰27’32.5" N and longitude 6⁰42'38.1" E. The samples were collected at the three different sampling points with 35cl plastic containers. There was a linear correlation among temperature, conductivity, and Dissolved oxygen and this correlation revealed that, due to anthropogenic activities, the water quality deteriorated increasingly as the water travelled from Site 1 to Site 3. The physicochemical parameters – pH, water temperatures, conductivity, Total Dissolved Solid, Total Suspended Solid, Hardness and Alkalinity were within the limits recommended by USEPA (2010) for the survival of aquatic organisms, as well as WHO (2004) for drinking purposes. However, the values of Dissolved Oxygen, Chemical Oxygen Demand and Biochemical Oxygen Demand, fell outside these limits. It is therefore recommended that, an urgent need to properly manage wastes in the cities and monitor anthropogenic (human) activities is germane, to ensure minimized effects on these parameters of Nkesa River. Sensitization should be carried out to educate the people on the dangers of ingestion. The need for constant monitoring of the levels of contamination to assess the impact of the heavy metals cannot be underestimated. Further study on the concentrations of hydrocarbons should be carried out in consideration of oil spillage in the area. This is necessary since the river serves as a source of drinking water, irrigation and fisheries for the local inhabitants.

**KEYWORDS:**  **Water quality, oil spillage, wastewater discharges, water pollution**

**INTRODUCTION**

“Ensuring the sustainable use of water resources can only meet the anticipated goals by collecting monitoring data. Original monitoring studies are crucial for effective water resource management. These studies provide essential information about the water source, including its physical, chemical, and biological conditions, which is necessary for assessing the resource” (Kaur and Naseer, 2023). Water is a vital commodity (NBS, 2012) and its sources include rivers, streams, lakes, wells, boreholes, springs etc. Rivers are among the oldest water bodies in the world (Higler, 2012). “Water quality is determined by its physical, chemical, and biological properties, affecting its utility for various reasons. Potable water, often known as drinking water, should be safe for human consumption and pose no major health risks over time” (Aruf et al., 2024; Ucheana et al., 2024). “In most urban-rural communities in developing countries especially Sub-Saharan Africa, surface waters (rivers, streams, and lakes among others) have been the most available sources of water used for domestic purposes. The water from these sources is contaminated with domestic, agricultural, and industrial wastes and is likely to cause water-related diseases” (Ojekunle, 2000; Ayeni *et al*., 2009).

 “The river basin has been a major source of water supply for many purposes and provides fertile lands, which support the development of highly populated residential areas due to its favourable conditions” (Mouri *et al*., 2011). “Human settlements and industries have long been concentrated along rivers, estuaries, and coastal zones owing to the predominance of water-borne trade. A river’s water quality is the composite of several interrelated compounds, which are subjected to local and temporal variations and also affected by the volume of water flow” (Mandal *et al*., 2010). “Rivers constitute the main inland water body for domestic, industrial, and agricultural activities and often carry large municipal sewage, industrial wastewater discharges, and seasonal runoff from an agricultural field” (Singh *et al*., 2004; Pradhan *et al*., 2009; Hu *et al*., 2011). “The river waters have been contaminated as a result of the discharges of wastewater containing degradable organics, nutrients, domestic effluent, and agricultural waste” (Dimitrovska *et al*., 2012). River water pollution can be linked to the type of wastewater produced by urban, industrial, and agricultural activities that flow into surface and subsurface waters (Vittori *et al*., 2010).
 “The increase in human population and economic activities has grown in scale; the demands for large-scale suppliers of fresh water from various competing end users have increased tremendously. The decline in the quality and quantity of surface water resources can be attributed to water pollution and the improper management of the resource” (Mustapha and Nabegu 2011). “Many regions around the world are simultaneously impacted by urbanization processes and industrial and agricultural activities, and many cities in developing countries have been developed without adequate and proper planning. This has led to indiscriminate actions, including dumping of wastes into the water and washing and bathing in open surface water bodies” (Cukrov *et al*., 2012). “The deteriorating water quality affects man, animal, and plant life with far-reaching consequences. From the environmental, economic, and/or social point of view, it is important to identify these sources and their contribution to the total contamination of an area” (Tobiszewski *et al*., 2010).

“The health of a river depends on the quality of its water, which is influenced by the presence of pollutants. The quality of water is generally assessed by a range of parameters, which express the physical, chemical and biological composition of water” (Meybeck and Helmer 1992). This research deals with some specific water quality parameters of the Nkesa River, which include: Temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electrical Conductivity (EC) and the concentration of Lead, Chromium, Ammonia, Nitrogen and Phosphate phosphorus

**MATERIALS AND METHODS**

 **DESCRIPTION OF STUDY AREA**

 Nkesa River is located in Ogba Egbema Ndoni Local Government Area in Rivers State in the Niger Delta region of Nigeria, and lies between latitude 5⁰27’32.5" N and longitude 6⁰42'38.1" E. It is a tidal-dominated River, with possible freshwater input. The source of Nkesa River is the Orashi River (its source is the rocks of Ezeama community of Dikenafai, Imo State which is 183m above mean sea level) which flows through communities like Urualla, Ozubulu, Oguta, Opuoma, Mmahu, Abacheke, Omoku, Mgbede, and Epie before emptying into the Atlantic Ocean Alchetron, (2018). The anthropogenic activities taking place within the region are agriculture (farming, palm oil production) and offloading of petroleum products (bunkering).

 **SAMPLE COLLECTION**

The samples were collected at the three different sampling points (Mgbede, Okwuzi and Aggah) with 35cl plastic containers.

**SAMPLE ANALYSIS**
“The physicochemical properties of the water samples were determined according to standard methods. Twelve important parameters were selected for physicochemical water quality analysis: temperature, color, turbidity, total dissolved solids (TDS), total suspended solids (TSS), pH, electrical conductivity (EC), total alkalinity (TA), total hardness (TH), dissolved oxygen (DO) concentration, BOD5, and COD. The temperature, pH, and EC of the water samples were instrumentally measured in situ with a mercury thermometer and a glass electrode pH and EC meter, respectively” (APHA, 2005). “Water depth was observed using a meter scale, and TH of water was determined through titration with an EDTA conjoining Eriochrome Black T indicator” (APHA, 2005). “TA was measured as CaCO3 through titration with a bromocresol green-methyl red indicator” (APHA, 2005). Turbidity, color, and DO concentration were determined with a turbidity meter, with the standard method of APHA (2005), and with a DO meter with a luminescent DO probe, respectively. TSS were obtained gravimetrically by filtration and thereafter dried in an oven (Radojevic and Bashkin, 1999). “TDS concentration was rapidly measured with a TDS meter. BOD5 was determined through the five-day dilution method” (Klein and Gibbs, 1979). “COD was determined with a United States Environmental Protection Agency (USEPA) micro-digestion reactor and the colorimetric method” (Jirka and Carter, 1975).

 **Determination of Water Hardness**

**Determination of Total Hardness**

 Hardness is measured using the standard analytical method of APHA. (American Public Health Association, 1998).

The total hardness of the water sample was calculated.

Total hardness (mg/CaC03) = Volume of Titrate x 1000

 Volume of samples (cm3)

 **Determination of Electrical Conductivity**

 Analysis was carried out according to APHA 2510 B guideline Model DDS-307 (APHA; 1998)

 **Determination of total dissolved solids**

 The total dissolved solid was determined using APHA 2510 A TDS 139 tester (APHA; 1998)

 **Determination of total solids:**

“Total solids are the term applied to the material residue left in the vessel after evaporation of the water sample and its subsequent drying in an oven at a temperature of 103-105oC. Total solids include Total Suspended Solids and Total Dissolved Solids” (APHA; 1998).

 **Determination of total Suspended Solids**

The total suspended solid was determined by subtracting the result of total dissolved solids from total solid.

Total solids (TS) – Total dissolved solids (TDS) = Total Suspended solids (TSS) (APHA; 1998)

 **Biological Oxygen Demand Determination**

The general equation for the determination of a BOD value is:

BOD (mg/l) = D1 –D5

Where D1 = initial DO of the sample, D2 = final DO of the sample after 5 days, and P = decimal volumetric fraction of sample used.

If 100 ml of samples, are diluted to 300ml, then P= 0.33.

**Chemical Oxygen Demand Determination**

This wasaccording to themethod described by APHA 1998

**Dissolved Oxygen in Water Determination**

1cm3 concentrated sulphuric acid was added with the trip of the pipette below the level of solution and again the stopper was replaced. It was mixed well by rotation until the precipitation was completely dissolved. 100cm3 of the solution was Pipetted into a 250cm3 conical flask and immediately titrated against standard sodium thiosulphate (0.0125 mol/ dm3) using freshly prepared starch solution as the indicator (add when the solution becomes pale yellow). The titration was carried out in duplicate.

 **Total Alkalinity**

Two drops of the mixed indicator were added into the sample (solution) in which phenolphthalein alkalinity was determined. It was titrated with 0.02m standard HCl until, at pH 4.6, the colour changed pink for a mixed indicator or a change from yellow colour to orange for methyl orange indicator. The conversion obtained in this step corresponds to equation:

 HCO3- + H+ =H2CO3= H2O +CO2

Total alkalinity as Mg/l CaCO3= VT × M ×100, 000mL of the sample.

OH- + CO32- + HCO3- + 4H+ = 3H2O + 2CO2

**STATISTICAL ANALYSIS**

The data was subjected to one-way ANOVA analysis using SPSS for the various parameters. Further test such as Duncan’s multiple range tests were carried out to ascertain whether there is a significant difference among the parameters.

**RESULTS AND DISCUSSION**

**Table 1: Physicochemical parameters of water samples collected from Nkesa River**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameters** | **Mgbede** | **Okwuzi** | **Aggah** | **WHO/EPA MCL (2004/2010)** |  |
|  |  |  |  |  |  |
| **pH** | 6.65±0.1a | 6.75±0.07b | 7.02±0.03c | 6.5-8.5 |  |
| **TDS mg/l** | 904.00±1.00a | 822.00±2.65b | 801.33±4.16c | 1000 | 500 |
| **Conductivity us/cm** | 242.00±3.46a | 295.33±5.51b | 255.67±5.86c | 1000 |  |
| **DO mg/l day** | 22.50 ±0.52a | 18.66±0.31b | 17.45±0.68c | 18 |  |
| **COD mg/l** | 108.32±0.35a | 132.28±1.52b | 119.54±1.10c | 23.7 |  |
| **TSS mg/l** | 5.81±0.03a | 6.44±0.06b | 8.17±0.17 | 1700 |  |
| **Temperature oC** | 22.18±0.25a | 20.24±0.11b | 20.94±0.55c | 25-50 |  |
| **Turbidity NTU** | 6.67±0.40a | 6.63±0.15a | 7.30±0.10b | 5 |  |
| **Hardness mg/l** | 48.33±0.58a | 33.67±3.21b | 48.33±1.15a | 100 | 100 |
| **Alkalinity mg/l** | 45.67±2.08a | 47.67±3.21a | 65.67±6.66b |  | 200 |
| **BOD mg/l** | 653.93±19.74a | 587.67±17.96b | 566.27±27.08b | 11.6 |  |

**Note:** Results are means ± standard deviation of means of the samples.

Means that share superscripts are not significantly different (that is p>0.05)

The summary of physicochemical parameters obtained from the three Sites of Nkesa River as shown in the table above, shows the values being placed alongside WHO (2004) and USEPA (2010) standard values for guide.
PH ranged from 6.65±0.1 to 7.04±0.03. The highest value (7.04±0.03) was recorded in Aggah and the lowest value (6.65±0.1) was recorded in Mgbede of the study area. The results obtained for Total Dissolved Solids (TDS) ranged between 801.33±4.16 to 904.00±1.00 having Mgbede with the highest value (904.00±1.00 mg/l) and Aggah with the lowest value (801.33±4.16 mg/l). Conductivity fluctuated between 242.00±3.46usm/cm to 295.33±5.51usm/cm. The highest value (295.33±5.51usm/cm) was recorded in Okwuzi and the lowest value (242.00±3.46usm/cm) was recorded in Mgbede. The Dissolved Oxygen level decreased down the River, ranging from the lowest (17.45±0.68 mg/l ) in Aggah to the highest (22.50±0.52mg/l) in Mgbede. The lowest value of Chemical Oxygen Demand (COD) was observed in Mgbede (108.32±0.35 mg/l) whereas the highest value was observed in Okwuzi (132.28±1.52mg/l)

 From the result, the Total Suspended Solids (TSS) increased down the River, the lowest value was observed in Mgbede (5.81±0.03mg/l) and the highest value was observed in Aggah (8.17±0.17mg/l). There was a fluctuation in the Temperature of the River, with Mgbede, having the highest value (22.18±0.25⁰C) and similar values between Okwuzi (20.24±0.11⁰C) and Aggah (20.94±0.55⁰c). A turbidity value of 7.30±0.10 NTU was the highest recorded in Aggah with similar values at Mgbede (6.67±0.40 NTU) and site 2 (6.63±0.15 NTU). The highest value of hardness was observed in Mgbede (48.33±0.58 mg/l) and Aggah (48.33±1.15 mg/l) while the lowest value was observed in Okwuzi (33.67±3.21 mg/l). Alkalinity increased down the River, the highest value was observed in Aggah (65.67±6.66 mg/l) and the lowest in Mgbede (45.67±2.08 mg/l). The Biological Oxygen Demand (BOD) decreased down the River, Mgbede (653.93±19.74 mg/l) with the highest value and Aggah (566.27±27.08 mg/l) with the lowest value.

“The quality of a given water body is controlled by its physical, chemical and biological factors, all of which interact with one another to influence its productivity” (Akponine and Ugwumba, 2014). “Results obtained from Nkesa River showed that the physicochemical parameters of the water body are only stressed minimally. The pH range obtained from this study conferred slight acidity levels on Nkesa River. However, this range was within the range reported for rivers flowing through areas with thick vegetation” (Uwadiae *et al*., 2009; Akponine and Ugwumba, 2014).

 “Thus, the pH range obtained in this study is within the acceptable level of 6.0 to 8.5 for culturing tropical fish species and, for the recommended levels for drinking water” (WHO, 2004; USEPA, 2010). Environmental Protection Agency (EPA) recommended pH 6.5- 8.0 for drinking and recommended pH 6.5- 8.0 for drinking and 6.0-9.0 for aquatic life. High pH levels of water force the dissolved ammonia to its toxic and unionized form which gravely affects aquatic organisms (USEPA, 2008). “The water surface temperature is the most significant parameter which controls the in-born physical qualities of water. Total Dissolved Solids (TDS) are the inorganic matter and small amounts of organic matter, which are present as a solution in water. Table 1 shows TDS values for all 3 River samples. The standard or allowable value of the TDS set by NDWQS is 1000 mg/L” (MHM, 2004). The values found from the River samples are all within the maximum limit of 1000 mg/L. The highest TDS values of 904.00±1.00mg/L and the lowest TDS values of 801.33±416 mg/L correspond to samples from Site 1 and Site 3 respectively. “Electrical conductivity is the normalized measure of the water’s ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride” (SIT, 2008). The sources of conductivity may be an abundance of dissolved salts due to poor irrigation, minerals from rainwater run-offs, or other discharges. Generally, the conductivity levels measured in this study were far below the maximum contamination levels (MCL) of WHO (2004). The generally low conductivity levels indicated low dissolved salts in the study Sites. Higher conductivity values of 295.33±5.51 and 255.67±5.86 µS/cm were observed for Sites 2 and 3, respectively. “This could be a result of dissolved solutes from decaying organic materials deposited at these sites forming surface run-offs. Conductivity levels below 50 µS cm-1 are regarded as low; those between 50 µS cm-1 to 600 µS cm-1 are medium, while those above 600 µS cm-1 are high conductivity levels” (Umeham and Elekwa, 2005). Dissolved Oxygen (DO) in water affects the oxidation-reduction state of many of the chemical compounds such as nitrate and ammonia, sulphate and sulphite, ferrous and ferric ions. DO levels of in this study were not similar to 1.20 to 9.40 reported by Edokpayi and Osimen (2001) in Ibiekuma River in Ekpoma; Akponine and Ugwumba (2014) in Ibuya River in Old national park, Sepeteri. The results showed that the dissolved oxygen recorded was above the permissible limits of the standard drinking water for WHO (2004) and NESREA (2011). “The amount of dissolved oxygen in water has been reported as not constant but fluctuates, depending on temperature, depth, wind and amount of biological activities such as degradation” (Ibrahim *et al*., 2009).

 Chemical Oxygen Demand (COD) concentration obtained from Nkesa River was above the maximum permissible limit (23.7mg/L) by the World Health Organisation (WHO) for River and drinking water. The concentrations of COD in all the sampling Sites are lower than the WHO values of 200 mg/L for the discharge of wastewater into the stream. “High COD concentrations observed in the water might be due to the use of chemicals. Suspended solids may kill fish and other aquatic fauna by causing abrasive injuries by clogging the gills and respiratory passages, blanketing the stream bottom, destroying the spawning beds, and screening out light necessary for the photosynthetic activity of aquatic plants. From the results of this study, the levels of Total Suspended Solids (TSS) in the entire Sites were below the WHO guidelines of 50 mg/L for the protection of fisheries and aquatic life” (Chapman,1993). “The water temperature is the most significant parameter which controls the in-born physical qualities of water. The temperature of Nkesa River was within the maximum permissible limit (MPL). The highest temperature was at Site 1 while the lowest was recorded in Sites 2 and 3. This is because of the shallowness of the sites and the volume of water in contact with air. The mean air and surface water temperatures obtained are typical of African tropical rivers” (Masese *et al*., 2009). A higher level of Turbidity is associated with disease-causing bacteria, suspended materials due to soil run-off etc (USEPA, 2017). The Turbidity recorded in all the Sites is above the recommended level for 5 NTU as set by WHO and NDWQS for drinking water (WHO, 2017; MHM, 2004)

“The Total Hardness (TH) of water is defined as the sum of calcium and magnesium concentrations, both expressed as milligrams of calcium carbonate equivalent per litre” (Karim and Panda, 2014). In the present study, the Total Hardness of Nkesa River was found to be low (Table 1). Egemen (2011) classified water bodies based on total hardness into six categories; soft (hardness less than 50CaCO3 mg/L), moderately soft (from 50-100 CaCO3 mg/L), slightly hard (from 100-150 CaCO3 mg/L), moderately hard (from 150-250 CaCO3 mg /L), hard (from 250-350 CaCO3 mg/L) and very hard (from >350 CaCO3 mg/L). According to those limits, Nkesa River could be classified as moderately soft.

“Alkalinity is a measure of the ability of water to neutralize acids and it mainly occurs due to the presence of carbonates and bicarbonates in the water. The measured values of total alkalinity in all the Sites were within the permissible limit of WHO (120 mg/L) for drinking water” (WHO, 2008). Also, the total alkalinity of all the Sites was within the permissible limit of ESA 200 mg/L (ESA, 2013). The Biological Oxygen Demand (BOD) in all three sites of Nkesa River were within the permissible limit of WHO (8 mg/L) for drinking water (WHO, 2008). According to Stevens Institute of Technology (SIT), (2008), BOD classification of 1-2 mg/L as very good, with less organic matter present; 3-5 mg/L as moderately clean; 6-9 mg/L as poor, somewhat polluted (indicates organic matter is present and bacteria are decomposing this waste); etc, the water samples were moderately clean and safe for drinking. The level of BOD recorded in this study revealed that Nkesa River was heavily poor. The higher value of BOD in Site It may be due to a higher rate of decomposition of organic matter at higher temperatures. This also corroborated with Umeham (1992), who observed that “organic matter from increased weed decomposition within lake water and domestic sewage increased the biological oxygen demand”. The present values were within acceptable limits prescribed by the World Health Organization, (WHO, 2004).

**CONCLUSION**

There was a linear correlation among temperature, conductivity, DO, and this correlation revealed that, due to anthropogenic activities, the water quality deteriorated increasingly in all the sampled areas. The physicochemical parameters – pH, water temperatures, conductivity, TDS, TSS, Hardness and Alkalinity were within the limits recommended by USEPA (2010) for survival of aquatic organisms, as well as WHO (2004) for drinking purposes. However, the values of DO, COD and BOD fell outside these limits.

The result of the research is valuable in informing the populace of the health risks associated with contaminated water bodies.

There is therefore an urgent need to properly manage wastes in the cities and monitor anthropogenic activities to ensure minimized effects on these parameters of Nkesa River and any of such water bodies. Sensitization should be carried out to educate the people on the dangers of direct ingestion. Further study on the concentrations of hydrocarbons should be carried out in consideration of oil spillage in the area . This is necessary since the river serves as a source of drinking water, irrigation and fisheries for the local inhabitants.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**REFERENCES**

Akponine, J.A and Ugwumba, O.A (2014). Physico-Chemical Parameters and Heavy Metal Content of Ibuya River, Old Oyo National Park, Sepeteri, Oyo State, Nigeria. The *Zoologists* **12**: 54-63.

Alchetron (2018). Alley ER. Water Quality Control Handbook. Vol. 2. New York: Mcgrawhill; 2007. Https://Alchetron.Com/Orashi-River Accessed 6thjanuary, 2020

APHA. (2005). Standard Methods for the Examination of Water and Wastewater. 21st ed. Washington, DC: American Public Health Association.

Aruf, M., Muhammad, A., Sulaiman, M., Usman, H.M., Panda, S.L. and Idris, I.M.. (2024). Water Quality Assessment and Health Implications: A Study of Kano Metropolis, Nigeria. *Journal of Science and Technology.* **9**(6):33-52.

Ayeni A. O., Soneye A. S. O., And Balogun I. I., (2009), The Arab World *Geographer* **12:**(1-2): 95-104

Chapman, D. (1993). Assessment Of Injury To Fish Populations: Clark Fork River NPL Sites, Montana. In: Lipton J., Editor. Aquatic Resources Injury Assessment Report. Helena, MT, USA: Montana Natural Resource Damage Assessment Program;[Google Scholar]

Cukrov, N., Tepic, N., Omanović, D., Logen, S., Bura-Nakić, S. and Vojvodic, E. (2012) Qualitative Interpretation Of Physico-Chemical And Isotopic Parameters In The Krka River (Croatia) Assessed By Multivariate Statistical Analysis. *Int J Environ Anal Chem* **92**(10):1187–1199

Dimitrovska, O., Markoski, B., Toshevska, B.A., Milevski, I. and Gorin, S. (2012) Surface Water Pollution Of Major Rivers In The Republic Of Macedonia. *Procedia. Environ. Sci*. **14**:32–40. Doi:10.1016/J.Proenv.2012.03.004

Edokpayi, C.A. and Osimen, E.C. (2001). Hydrobiological Studies On Ibiekuma River At Ekpoma, Southern Nigeria, After Impoundment: The Fauna Characteristics. *African Journal Of Science And Technology* **2**(1): 72–81.

Egemen, O., (2011). Water Quality. Ege University Fisheries Faculty Publication No. 14, Izmir, Turkey, Pp: 1-150.

Ethiopia Standard Agency (E.S.A.) (2013). Compulsory Ethiopian Standard: Drinking Water Specifications, Ethiopia Standard Agency, Addis Ababa, Ethiopia,

Higler, L. (2012), Fresh Surface Water: Biology And Biodiversity Of River Systems, Encyclopedia Of Life Support Systems (EOLSS), ALTERRA, Wageningen, The Netherlands

Hu, J., Qiao, Y., Zhou, L. and Li, S. (2011) Spatiotemporal Distributions Of Nutrients In The Downstream From Gezhouba Dam In Yangtze River, China. *Environ. Sci. Pollut. Res.* **19**:2849–2859. Doi:10.1007/ S11356-012-0791-6

Ibrahim, B.U., Auta, J.and Balogun, J.K. (2009). An Assessment Of The Physicochemical Parameters Of Kontagora Reservoir, Niger State, Nigeria. *Bayero Journal Of Pure And Applied Sciences* **2**(1): 64 – 69.

Karim, A.A. and Panda, R.B. (2014). Assessment Of Water Quality Of Subarnarekha River In Balasore Region, Odisha, India. Curr. *World Environ.* **9**: 437-446.

Kaur, S. and Naseer, S. (2023). Water Quality Assessment of Sahastradhara Stream, Dehradun, Uttarakhand, India. *Asian J. Env. Ecol.* [Internet]. 2023 Jul. 26 [cited 2025 Feb. 20];**22**(1):29-3. Available from: https://journalajee.com/index.php/AJEE/article/view/473

Mandal, P., Upadhyay, R. and Hasan, A.(2010) Seasonal And Spatial Variation Of Yamuna River Water Quality In Delhi, India. *Environ. Monit. Assess.* **170**(1):661–670

Meybeck, M. and Helmer, R. (1992). An Introduction To Water Quality. In Chapman D(Ed.), Water Quality Assessment. UNESO/WHO/UNEP. P. 21.

Ministry Of Health Malaysia, (2004). NDWQS: National Drinking Water Quality Standard, Engineering Of Services Division, Ministry Of Health Malaysia, 2nd Edition,.

Mouri, G., Takizawa, S. and Oki, T. (2011) Spatial and Temporal Variation In Nutrient Parameters In Stream Water In A Rural–Urban Catchment, Shikoku, Japan: Effects Of Land Cover And Human Impact. *J. Environ Manage* **92**(7):1837–1848

Mustapha, A, and Nabegu, A.B. (2011) Surface Water Pollution Source Identification Using Principal Component Analysis And Factor Analysis In Getsi River, Kano, Nigeria. *Austr J Basic Appl Sci* **5**:1507–1512

National Bureau Of Statistics (NBS), (2012), Water Supply Statistics, (Www.Nigerianstat.Gov.Ng) PDF Downloaded 20th August, 2012

NESREA (2011). National Environmental (Surface And Groundwater Quality) Regulations. *National Environmental Standards And Regulations Enforcement Agency*.

Nikulina, A., and Dullo, W.C. (2009) Eutrophication And Heavy Metal Pollution In The Flensburg Fjord: A Reassessment After 30 Years*. Marine Pollution Bulletin*, **58**, 905-915.Https://Doi.Org/10.1016/J.Marpolbul.2009.01.017

Ojekunle, I. A. (2000), Transport And Urban Environmental Quality In Nigeria In Contemporary To AD 2000, Frankad Publishers, Lagos

Pradhan, U.K, Shirodkar, P.V. and Sahu, B.K (2009) Physico-Chemical Characteristics Of The Coastal Water Off Devi Estuary, Orissa And Evaluation Of Its Seasonal Changes Using Chemometric Techniques. *Curr Sci* **96**(9):1203–1209

Singh, K.P., Malik, A., Mohan, D., And Sinha, S. (2004) Multivariate Statistical Techniques For The Evaluation Of Spatial And Temporal Variations In Water Quality Of Gomti River (India)—A Case Study. *Water Res* **38**:3980–3992

SIT (2008). Stevens Institute Of Technology: Centre For Innovation In Engineering And Science Education, Article On Water Quality, 46-48.

Tobiszewski, M., Tsakovski, S., Simeonov, V. and Namiesnik, J. (2010) Surface Water Quality Assessment By The Use Of Combination Of Multivariate Statistical Classification And Expert Information. *Chemosphere* **80** (7):740–746

Ucheana, I.A., Ihedioha, J.N., Abugu, H.O. and Ekere, N.R. (2024). Water Quality Assessment of Various Drinking Water Sources in some Urban Centres in Enugu, Nigeria: Estimating the Human Health and Ecological Risk. *Environmental Earth Sciences*. **83**(10):325.

Umeham, S.N (1992). Some Aspects Of Physico Chemical Limnology Of Lake Chad (Southern Sector). *Journal Of Aquatic Sciences* **2**: 21-32.

USEPA (2010). Lists Of Contaminants And Their Maximum Contaminant Levels (Mcls). URL:Http://Water.Epa.Gov/Drink/Contaminants/Index.Cfm#List. Accessed On 13/2/2016.

USEPA (United States Envoirmental Protection Agency) (2008). Handbook For Developing Watershed Plans To Restore And Protect Our Waters. Reference No: EPA 841- B-08-002. [Cited 2014 Feb 18]. Available From: Http:// Www.Epa.Gov/Owow/Nps/ Watershed\_Handbook.

United States Environmental Protection Agency (2017). EPA Web Snapshot

Uwadiae, R.E., Edokpayi, C.A., Adegbite, O. and Abimbola, O. (2009). Impact Of Sediment Characteristics On The Macrobenthic Invertebrates Community Of A Perturbed Tropical Lagoon. *Eco. Env. And Con* **15** (3): 441-448.

Vittori, A.L., Trivisano, C., Gessa, C., Gherardi, M., Simoni, A. and Vianello G (2010) Quality Of Municipal Wastewater Compared To Surface Waters Of The River And Crtificial Canal Network In Different Areas Of The Eastern Po Valley (Italy). *Water Qual Expo Health* **2**(1):1–13

World Health Organization(WHO) (2004). Guidelines For Drinking Water Quality. V-I Recommendations World Health Organization, Geneva, Swizerland, 145-220.

World Health Organization, (2008) Guidelines For Drinking Water Quality, World Health Organization, Geneva, Switzerland,