STM JOURNALS

Journal of
Water Pollution &
Purification Research

ISSN: 2394-7306
Volume 12, Issue 1, 2025
January–April
DOI (Journal): 10.37591/JoWPPR

https://journals.stmjournals.com/jowppr

Review JoWPPR

# Evaluation of Physico-Chemical Parameters of Drilling Fluid and Its Effects on Water Quality Discharged in (Okoroagu River) in Etche LGA of Rivers State

Bright Nweke[1,*], Achinike Okogbule-Wonodi[1]

***Abstract***

*The study evaluated the surface water quality of Okoroagu River, Niger Delta of Nigeria, in order to determine the water quality index. Water samples were collected at five sampling points of the Okoroagu river. The results revealed that the Physicochemical and heavy metals parameters exceeded the NSDWQ and WHO recommended permissible limits except for TDS, pH, EC, Zinc, Chromium, Nickel and Manganese whicht were within the acceptable limit. The water quality index scores of the selected locations of Okoroagu river was observed to be very poor and unfit for drinking. According to the results obtained, the waters of Umudike (SS C), Umuochogu (SS D) and Okpala (SS E) locations were observed to be even more polluted. The study recommends consistent monitoring of the river against anthropogenic activities and to allow for dredging operation around the surface of the river by relevant agencies.*

**Keywords:** TPH, heavy metals, water quality index; drilling fluid, and surface water

## INTRODUCTION

Water is essential for life, and people's concerns about water quality vary based on their location and socio-economic status [19]. The primary cause of water contamination is human activity, which can lead to rapid and significant pollution. To meet their needs, people often extract environmental resources and release waste into the ecosystem [2]. The effects of industrial toxins and hazardous waste on aquatic life, including microorganisms, cannot be overstated. Since the industrial revolution, many production and manufacturing companies have improperly managed waste, introducing toxic substances and synthetic compounds into water bodies [3]. These pollutants can affect air, water, and soil quality, which in turn impacts human health in various ways.

Industrial waste comes in liquid, solid, and gaseous forms, altering the environment's natural composition and making it unsafe for human use [4]. Ground and surface waters can be contaminated from multiple sources, including human and animal waste, organic chemicals, pesticides, and petroleum products, which enter waterways like the Okoroagu River through seepage and discharges [7]. Heavy metals from industrial activities, such as those from mechanical garages and oil and gas facilities, are particularly harmful. The Okoroagu River is polluted with substances like petroleum products, pesticides, fertilizers, heavy metals, detergents, raw sewage, hot water from cooling plants, and harmful bacteria [10]. These heavy metals severely impact

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Received Date: November 07, 2024
Accepted Date: November 14, 2024
Published Date: January 30, 2025

**Citation:** Bright Nweke, Achinike Okogbule-Wonodi. Evaluation of Physico-Chemical Parameters of Drilling Fluid and Its Effects on Water Quality Discharged in (Okoroagu River) in Etche LGA of Rivers State. Journal of Water Pollution & Purification Research. 2025; 12(1): 32–44p.

water quality and the environment, especially when microbial processes fail to sufficiently degrade these pollutants [15].

Contaminants, including physico-chemical substances and heavy metals, accumulate in living organisms, entering the food chain and affecting the health of both animals and humans. Water pollution is one of the most pressing environmental challenges in developing countries like Nigeria. The Okoroagu River is a crucial and cost-effective water source compared to groundwater and desalination. According to Akakuru et al., maintaining water quality in streams and rivers is vital for protecting drinking water sources, supporting recreational activities, and providing a healthy environment for wildlife. Thus, evaluating and managing water quality is ecologically important [1].

Changes in the water chemistry of the Okoroagu River are largely due to human activities, including domestic, industrial, and agricultural discharges, which degrade the aquatic ecosystem [16]. The migration of people to urban areas has worsened pollution in the Okoroagu River at Igbo-Etche and other locations in Rivers State, primarily due to pollutants from domestic and industrial sources, including a nearby dredging industry and mechanical workshops.

Surface water quality is especially susceptible to pollution from untreated industrial waste, pesticides, and oil spills. The level of pollution depends on the types and quantities of discharges from various sources, including domestic, agricultural, and industrial activities, as well as seasonal runoff [13]. Due to uncontrolled human activities, many water sources no longer meet safety standards for consumption or ecological health. When the Okoroagu River becomes overloaded with waste or heat, its natural purification ability is compromised, making the water unsafe for domestic, industrial, and recreational use. Quality water should be pure and safe, serving beneficial purposes [8].

Globally, water pollution is a leading cause of death and disease, accounting for over 15,000 fatalities daily [7]. In the United States, a national report found that 45% of assessed stream miles, 47% of assessed lake acres, and 32% of assessed estuarine areas were polluted [2]. The Okoroagu Umuechem and Odagwa areas in Rivers State, Nigeria, are significant for commerce and industry. As a suburb of Port Harcourt, this area has seen rapid industrial growth, with many factories located near rivers and streams, including the Dredging Extrusion Industry, which discharges lubricants into the nearby Chokocho River [12].

In Nigeria, existing regulations meant to protect the marine environment have largely failed to prevent the indiscriminate discharge of pollutants, including chlorides, phosphates, oil, grease, nitrates, and heavy metals. Common contaminants exceeding WHO limits include lead, manganese, zinc, nickel, cadmium, chromium, and iron [9]. The extraction and processing of drilling fluids have been linked to various environmental health issues, including vector-borne diseases and respiratory problems [17].

Drilling fluids are particularly dangerous due to their toxicity and persistence in the environment. Urbanization and industrial activities have intensified pollution in estuarine and coastal areas, where contaminants accumulate in sediments and affect local wildlife. Aquatic plants and organisms can bioaccumulate these pollutants, affecting the health of the ecosystem [11].

Water is a vital resource for all living organisms, but the Okoroagu River suffers from pollution due to careless waste disposal and human activities that compromise its physico-chemical properties. Increased industrial, agricultural, and commercial chemical discharges have harmful effects on aquatic life, as these pollutants accumulate in plants, sediments, and the food chain. The natural recovery processes have proven insufficient to protect public health [17].

Some plants and algae have shown potential in removing pollutants like oil, grease, and heavy metals from contaminated water [20]. Food consumption is a significant pathway for human exposure to toxins, raising concerns about food safety and health risks. Soil and sediments are crucial links for contaminants in ecosystems. Pollution from the Okoroagu River and surrounding agricultural soils poses a serious health threat through inhalation, ingestion, and skin contact [18].

Pollution from domestic, agricultural, and industrial sources introduces various contaminants into the river, affecting its quality and use for fishing, irrigation, recreation, and overall biodiversity [5]. Although pollution has been an ongoing issue, this research aims to assess the current status of physico-chemical properties and heavy metals in the Okoroagu River in Etche Local Government Area, Rivers State.

## MATERIALS AND METHOD

### Description of the Study Area

The study area is located at Etche Local Government Area, Rivers State, in the Niger-Delta Region of Nigeri. It is between latitudes $4^0$. 98' and 4° 59'N and longitudes $7^0$. 09' and $7^0$. 51'E. The area is in the west side of Ikwerre LGAs, in the north by Imo State, and in the south by Obio-Akpor LGAs; with a rainy season from Match to October and a dry season from November to February. The region experiences a tropical climate that is frequently characterized by moderate temperatures and high humidity [20]. The stream's upper portion flows from the Imo River through Umuebulu and Igbo-Etche River. The upstream area, which is mostly freshwater, has forest vegetation made up of several palm trees and aquatic macrophytes such as Raffia palm. Most of the drilling fluids from the dredging site within Umudike and Umunkpaka discharged effluents from within and around emptied their waste to the receiving Okoroagu River. The river feels the impact of dredging activities on the mangrove at the coastal areas (Figure 1). It also serves as a receptor for the untreated or partially treated industrial and municipal wastes. It has a confluence with the Ogochia River at Umuebulu and Odufor-Nihi to form the main tributary which drains into the Imo River.

### Sample Collection

Five different points were used to collect water samples in Okoroagu River; Miri Obia, Miri Eze, Miri Atico, Miri Opipia and Miri-Ogbuahia located in Okoroagu Etche local Government of Rivers State, Niger Delta Region of Nigeria. Unused plastic containers were used to collect the water samples. The heavy metals and physicochemical parameters analyzed include (pH), Temperature, Electrical conductivity (EC), Total Dissolved Solid (TDS), Turbidity, Dissolved Oxygen (DO) and Total Petroleum Hydrocarbon (TPH), some heavy metals Iron (Fe), Lead (Pb), Cadmium (Cd), Chromium (Cr), Manganese (Mn) Nickel (Ni) and Zinc (Zn) (Table 1).

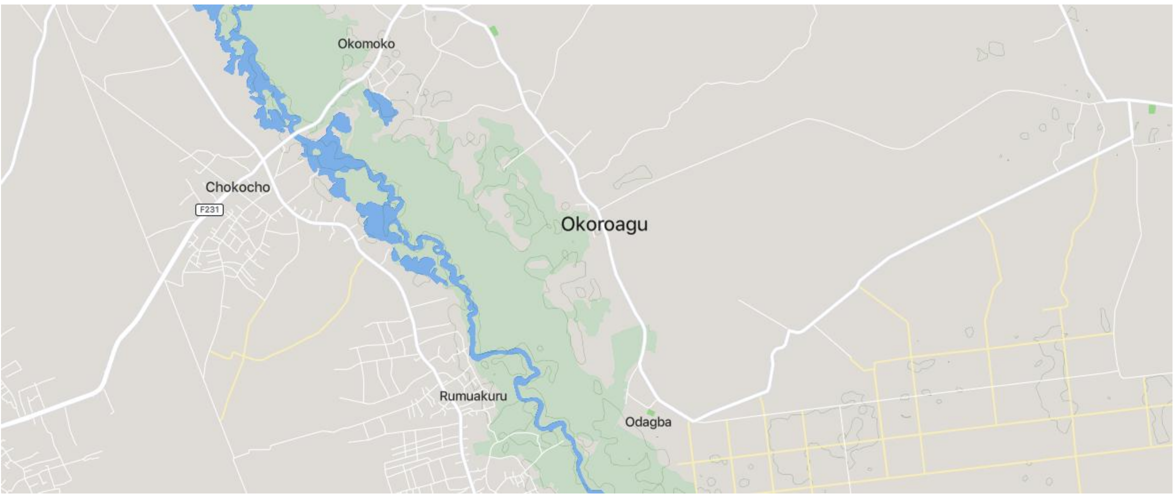


**Figure 1.** Map of Study Area: Okoroagu Etche.
*Source: Google Earth, 2024*

**Physico Chemical Characteristics of Okoroagu River**

The physicochemical parameters selected such as Electrical Conductivity, pH, Turbidity and Temperature were determined using in-situ HANNA water checker (Model HI 93414) after calibrating the instrument with Standard Hanna solution. Total Petroleum Hydrocarbon (TPH) was analyzed using Gen Tech Master G equipped with a split/split less injector in accordance with USEPA 8015 standard [21]. The dissolved oxygen (DO) was determined by the modified Azide or Winkler's method. Heavy Metals (Iron Fe, Lead Pb, Cadmium Cd, Zinc Zn, Chromium Cr, Manganese Mn and Nickel Ni using (APHA 3111-B (AAS). Heavy metals were determined using an Atomic Absorption Spectrometer (AA) as described in APHA 3111B and ASTM D3651. This involves the direct aspiration of the sample into an air/acetylene or nitrous oxide/acetylene flame generated by a hollow cathode lamp at a specific wavelength peculiar only to the metal programmed for analysis. For every metal investigated, standards and blanks were prepared and used for calibration before samples were aspirated.

**Water Quality Index Calculation**

The standards of drinking water quality recommended by the World Health Organization (WHO) was used to calculated WQI and Nigeria Standard of Drinking Water Quality (NSDWQ). The weighted Arithmetic index method as cited in a related study by Chinwendu *et al.* was adopted for the calculation of WQI in this study. Further, quality rating or sub index was calculated using the following expression [3, 4].

$$Qn = 100[Vn- Vi]/[Sn-Vi].$$

Let there be (n) water quality parameters and quality rating (qn) corresponding to nth parameter, is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible value (Tables 1-11).

- qn – Quality rating for the nth water quality parameter
- Vn – Estimated value of the nth parameter at a given water sampling station.
- Sn – Standard permissible value of the nth parameter.
- Vi – Ideal value of nth parameter in pure water (i.e., 0 for all other parameters except the parameters pH and Dissolve oxygen [7.0 and 14.6 mg/l respectively]. The unit weight was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.
- Wn = k/Sn, Where Wn – unit weight for nth parameter.
- Sn – standard permissible value for nth parameter.
- k – Proportionality constant (K=1.85445). The overall WQI was calculated with the following equation.
- WQI = $\sum$ qn Wn/$\sum$. The status of water quality according to WQI as shown in Table 2.

**Table 1.** Sample Stations, their geographic coordinates and location description.

| Sampling Station (SS) | Coordinates | Locations | Description of Locations |
|---|---|---|---|
| SS (A) | N 042.53' 35.10' | Miri Obia | Miri Obia close to Umuochogu |
| | E 071.05' 32.7' | | |
| SS (B) | N 042.52' 28.7' | Miri Eze | Miri Eze located at Umunkpaka |
| | E 071.05' 55.8' | | |
| SS (C) | N 042.52' 16.8' | Miri Aitco | Miri Atico is located at Umudike |
| | E 071.06' 10.5' | | |
| SS (D) | N 042.51' 34.00' | Miri Opipia | Miri Opipia located at Umuochogu |
| | E 071.06' 09.8' | | |
| SS (E) | N 042.50' 35.4' | Miri Ogbuahia | Miri Ogbuahia located at Okpala |
| | E 071.0' 34.6' | | |

 

**Table 2.** Description of contaminated Water Based on the WQI [4].

| Water Quality Index | Status |
|---|---|
| 0=25 | Excellent |
| 26-50 | Good |
| 51-75 | Bad |
| 76-100 | Very Bad |
| 100 Above | Unfit |

**Table 3.** Physicochemical parameters of water samples from different sampling points of Okoroagu river.

| Parameters | SS (A) | SS (B) | SS (C) | SS (D) | SS (E) | NSDWQ, 2015 | WHO, 2011 |
|---|---|---|---|---|---|---|---|
| pH | 6.36 | 6.43 | 5.88 | 7.28 | 6.45 | 6.5-8.5 | 6.5-8.5 |
| Temperature $^0$C | 28.7 | 26.8 | 29.8 | 27.4 | 25.9 | - | 25 |
| EC (µs/cm) | 146.8 | 137.5 | 354.6 | 278.9 | 227.6 | 1000 | 1000 |
| Turbidity (NTU) | 9.15 | 7.24 | 6.52 | 8.76 | 7.34 | 5 | 5 |
| TDS (mg/l) | 100.05 | 98.7 | 24.6 | 121.86 | 237.64 | 500 | 500 |
| DO (mg/l) | 6.58 | 8.32 | 9.14 | 5.78 | 0 | 5 | 2 |
| TPH (mg/l) | 8054.2 | 7564.32 | 9823.56 | 6327.0 | 5678.12 | 827 | 827 |
| Pb (mg/l) | 0.0102 | 0.0234 | 0.0141 | 0.0108 | 0.0167 | 0.01 | 0.01 |
| Fe (mg/l) | 1.62 | 0.986 | 2.11 | 3.16 | 1.532 | 0.03 | 1 |
| Cd (mg/l) | 0.004 | 0.005 | 0.004 | 0.004 | 0.005 | 0.003 | 0.003 |
| Cr (mg/l) | 0.012 | 0.145 | 1.73 | 0.043 | 0.245 | 0.05 | 0.05 |
| Ni (mg/l) | 0.83 | 2.34 | 0.534 | 0.032 | 1.57 | 0.02 | 0.07 |
| Mn (mg/l) | 0.050 | 0.141 | 0.34 | 1.18 | 1.65 | 0.2 | 1 |
| Zn (mg/l) | 0.54 | 0.084 | 3.167 | 3.214 | 0.038 | 3 | 3 |

## RESULTS AND DISCUSSION

The physicochemical parameters of Okoroagu water samples were collected at different sampling points and analyzed to ascertain the extent of contamination. Results obtained were compared with Nigerian Standard for Drinking Water Quality and World Health Organization [2015; 2011] to verify if the water is good for human use. From the results, the values of Temperature in all the sampling points were above 25°C of the standards limit by WHO and NSDWQ as shown in Table 3 below. This is because of the presence of foreign materials in the bodies of water [3, 4]. This study is in agreement with Green et al., 2023 and Chinwendu et al., 2021, that rise in temperature leads to thermal pollution and thereby resulting to loss of aquatic life [3, 4, 7].The results of different parameters are summarized in figures 2-10.

The value of pH for all the sampling points as shown in Figure 2 and Table 3, revealed that the highest sampling point is in (SS D) with 7.28. The most important operational water quality parameters is the pH according to WHO, (2011). It is of the note that the samples collected from the water surface in Okoroagu at different locations were within the acceptable limit of NSDWQ and WHO, except for SS D. Rise in temperature of water promoted the incidence of microorganisms and which may escalate the problems related to odour, colour, corrosion and taste and these will hinder the growth of aquatic organisms and their survival will be jeopardized [7]. Figure 5 as shown above revealed that the values of dissolved oxygen exceeded the NSDWQ and WHO stand ard limit of 2mg/l and 5mg/l in all the sampling points. The highest values recorded in Dissolved Oxygen could be as a result of drilling activities currently going on at Okoroagu River leading to water pollution [20]. In Figures 3 and 4 above**,** the result displayed that EC and TDS were within the permissible limit less than 1000mg/l and

 

500mg/l of NSDWQ and WHO standard from the sample locations respectively. The measure of mineral content resulting from the balance between dissolution and precipitation is the TDS [5, 6].

**Table 4.** Calculated water quality rating (Qn) of Okoroagu river from five sampling point.

| Parameters | SS (A) | SS (B) | SS (C) | SS (D) | SS (E) |
|---|---|---|---|---|---|
| pH | 42 | 38 | 74.67 | 18.67 | 36.67 |
| Temperature $^0$C | 114.8 | 107.2 | 119.2 | 109.6 | 103.6 |
| EC (µs/cm) | 14.68 | 13.75 | 35.46 | 27.89 | 22.76 |
| Turbidity (NTU) | 183 | 144.8 | 130.4 | 175.2 | 146.8 |
| TDS (mg/l) | 20.01 | 19.74 | 4.92 | 24.37 | 47.53 |
| DO (mg/l) | 63.65 | 48.84 | 43.33 | 70 | 0 |
| TPH (mg/l) | 973.91 | 914.67 | 1187.86 | 765.05 | 686.59 |
| Pb (mg/l) | 10.2 | 23.4 | 14.1 | 10.8 | 16.7 |
| Fe (mg/l) | 162 | 98.6 | 211 | 316 | 153.2 |
| Cd (mg/l) | 133.33 | 116.67 | 133.33 | 133.33 | 116.67 |
| Cr (mg/l) | 24 | 29 | 34.6 | 28.6 | 49 |
| Ni (mg/l) | 11.86 | 33.43 | 76.29 | 45.71 | 22.43 |
| Mn (mg/l) | 5 | 14.1 | 34 | 11.8 | 16.5 |
| Zn (mg/l) | 1.8 | 2.8 | 1.05 | 1.08 | 1.270 |

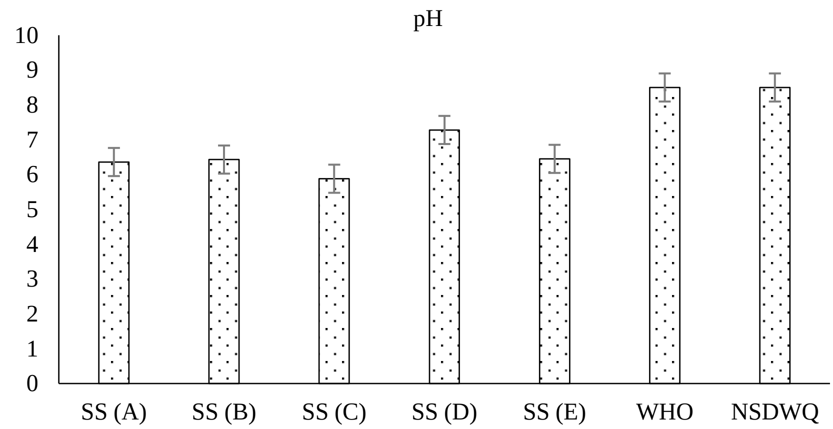


**Figure 2.** pH from sampling points.

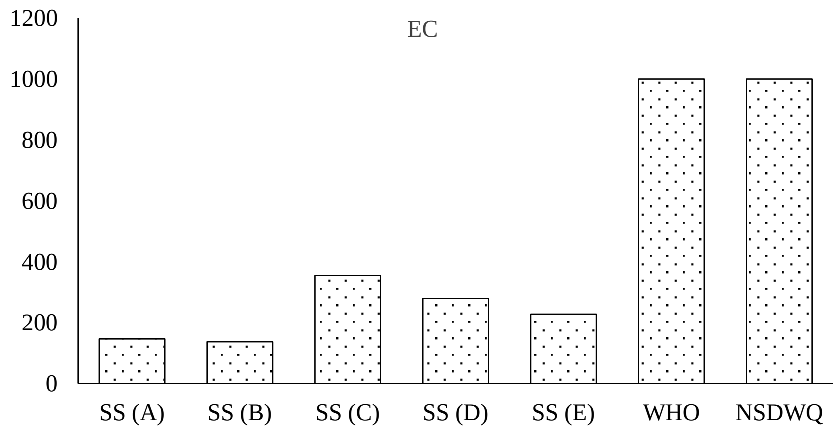


**Figure 3.** EC from sampling points.

Also, EC is the capacity of a substance to conduct electric current, this capacity depends on the presence of their total concentration mobility, ions, temperature and valence relative concentration [3, 4]. The results revealed that Okoroagu River was not considerable ionized and has lower level of ionic concentration activities. Whereas Figure 6 shown that the values recorded in TPH were all above 827mg/l permissive limit for NSDWQ and WHO which were as a result of discharged drilling fluid that have contaminated the surface of water, thereby destroying the aquatic organisms [18].

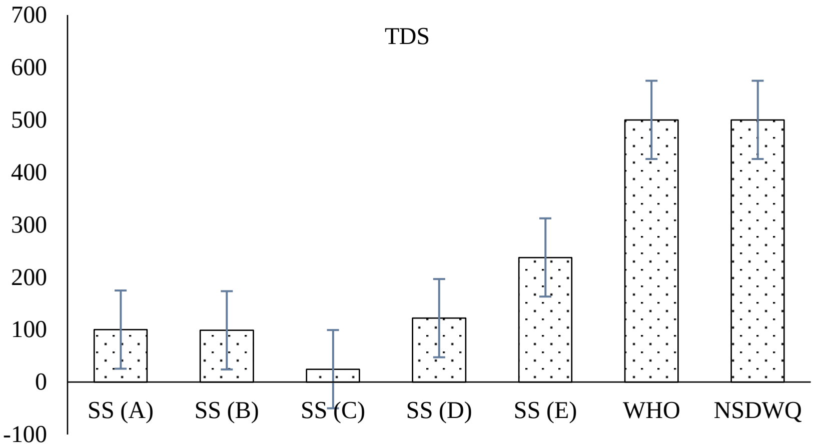


**Figure 4.** TDS from Sampling Points.

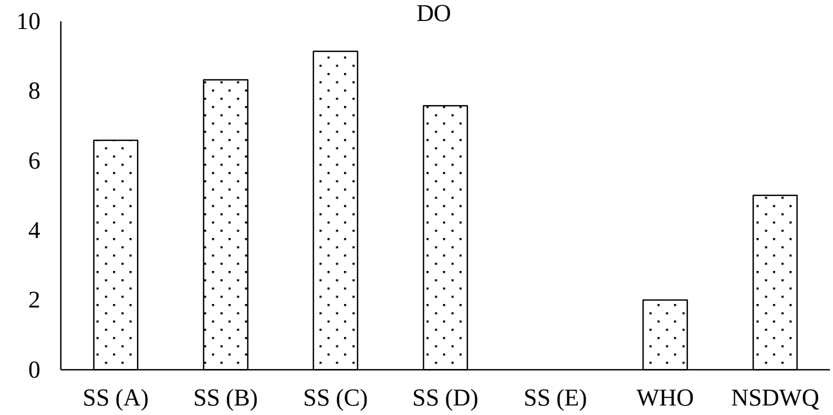


**Figure 5.** DO from sampling points.

**Table 5.** Calculated water quality rating (Qn) of Okoroagu river from five sampling points.

| Parameters | WHO, 2011 | NSDWQ, 2015 | Wn |
|---|---|---|---|
| pH | .6.5-8.5 | 6.5-8.5 | 0.218 |
| Temperature $^{0}$C | 25 | - | 0.074 |
| EC (µs/cm) | 1000 | 1000 | 0.002 |
| Turbidity (NTU) | 5 | 5 | 0.37 |
| TDS (mg/l) | 500 | 500 | 0.004 |
| DO (mg/l) | 2 | 5 | 0.927 |
| TPH (mg/l) | 827 | 827 | 0.00224 |
| Pb (mg/l) | 0..01 | 0.01 | 186.44 |
| Fe (mg/l) | 1 | 0.03 | 1.85445 |
| Cd (mg/l) | 0.003 | 0.003 | 618.15 |
| Cr (mg/l) | 0.05 | 0.05 | 37.09 |

 

| | | | |
|---|---|---|---|
| Ni (mg/l) | 0.07 | 0.02 | 26.492 |
| Mn (mg/l) | 1 | 0.2 | 1.85445 |
| Zn (mg/l) | 3 | 3 | 0.62 |

**Table 6.** Calculation of water quality index of sampling station (SS A) water quality index (WQI) = ∑WnQn/∑Wn =98.37.

| Parameters | Observed Value (Vn) | Standard Value (Vs) | Unit Weight (Wn) | Quality Rating (Qn) | WnQn |
|---|---|---|---|---|---|
| pH | 6.36 | 6.5-8.5 | 0.218 | 42 | 9.156 |
| Temperature $^0$C | 28.7 | 25 | 0.074 | 114.8 | 8.4952 |
| EC (µs/cm) | 146.8 | 1000 | 0.002 | 14.68 | 0.02936 |
| Turbidity (NTU) | 9.15 | 5 | 0.37 | 183 | 67.71 |
| TDS (mg/l) | 100.05 | 500 | 0.004 | 20.01 | 0.08004 |
| DO (mg/l) | 6.58 | 2 | 0.927 | 63.65 | 59.00355 |
| TPH (mg/l) | 8054.2 | 827 | 0.00224 | 973.91 | 2.1793184 |
| Pb (mg/l) | 0.0102 | 0.01 | 186.44 | 10.2 | 1901.688 |
| Fe (mg/l) | 0.0162 | 1 | 1.85445 | 162 | 300.4209 |
| Cd (mg/l) | 0.00835 | 0.003 | 618.15 | 133.33 | 82420 |
| Ni (mg/l) | 0.0083 | 0.07 | 26.492 | 11.86 | 314.19512 |
| Mn (mg/l) | 0.050 | 1 | 1.85445 | 5 | 9.27225 |
| Zn (mg/l) | 0.084 | 3 | 0.62 | 1.8 | 1.116 |
| Cr (mg/l) | 0.012 | 0.05 | 37.09<br>∑Wn=874.09814 | 24 | 890.16<br>∑WnQn=85983.505738 |

**Table 7.** Calculation of water quality index of sampling station (SS B) water quality index (WQI) = ∑WnQn/W∑n =90.12.

| Parameters | Observes Value (Vn) | Standard Value (Vs) | Unit Weight (Wn) | Quality Rating (Qn) | WnQn |
|---|---|---|---|---|---|
| pH | 6.43 | 6.5-8.5 | 0.218 | 38 | 8.284 |
| Temperature $^0$C | 26.8 | 25 | 0.074 | 107.2 | 7.9328 |
| EC (µs/cm) | 137.5 | 1000 | 0.002 | 13.75 | 0.0275 |
| Turbidity (mg/l) | 7.24 | 5 | 0.37 | 144.8 | 53.576 |
| TDS (mg/l) | 98.7 | 500 | 0.004 | 19.74 | 0.07896 |
| DO (mg/l) | 8.32 | 2 | 0.927 | 48.84 | 45.27468 |
| TPH (mg/l) | 7564.32 | 827 | 0.00224 | 914.67 | 2.0488608 |
| Pb (mg/l) | 0.0234 | 0.01 | 186.44 | 23.4 | 4362.696 |
| Fe (mg/l) | 0.986 | 1 | 1.85445 | 98.6 | 182.84877 |
| Cd (mg/l) | 0.004 | 0.003 | 618.15 | 116.67 | 72119.5605 |
| Cr (mg/l) | 0.145 | 0.05 | 37.09 | 29 | 1075.61 |
| Ni (mg/l) | 2.34 | 0.07 | 26.492 | 33.43 | 885.62756 |
| Mn (mg/l) | 0.141 | 1 | 1.85445 | 14.1 | 26.147745 |
| Zn (mg/l) | 0.084 | 3 | 0.62 | 2.8 | 1.736 |
| Total | | | ∑Wn=874.09814 | | ∑WnQn=78771.3993758 |

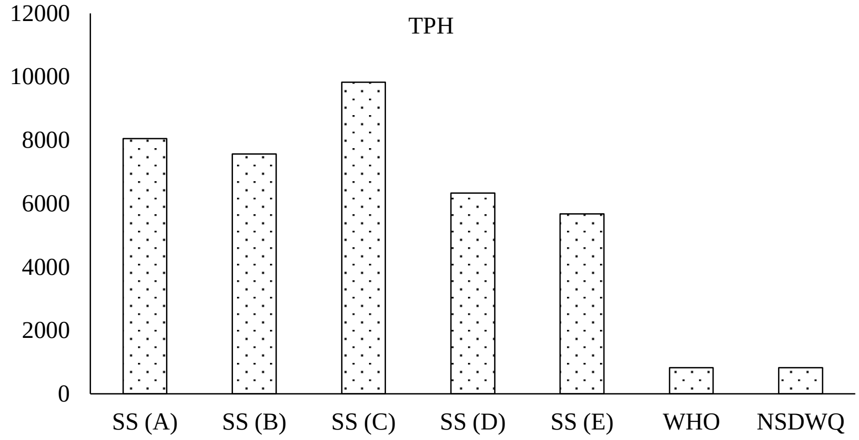


**Figure 6.** TPH from Sampling Points.

**Table 8.** Calculation of water quality index of sampling station (SS C) water quality index (WQI) =∑ WnQn/∑Wn =101.73.

| Parameters | Observed Value (Vn) | Standard Value (Vs) | Unit Weight (Wn) | Quality Rating (Qn) | WnQn |
|---|---|---|---|---|---|
| pH | 5.88 | 6.5-8.5 | 0.218 | 74.67 | 16.27806 |
| Temperature $^0$C | 29.8 | 25 | 0.074 | 119.2 | 8.8208 |
| EC (µs/cm) | 354.6 | 1000 | 0.002 | 35.46 | 0.07092 |
| Turbidity (mg/l) | 6.52 | 5 | 0.37 | 130.4 | 48.248 |
| TDS (mg/l) | 24.6 | 500 | 0.004 | 4.92 | 0.01968 |
| DO (mg/l) | 9.14 | 2 | 0.927 | 43.33 | 40.16691 |
| TPH (mg/l) | 9823.56 | 827 | 0.00224 | 1187.86 | 2.6608064 |
| Pb (mg/l) | 0.0141 | 0.01 | 186.44 | 14.1 | 2628.804 |
| Fe (mg/l) | 2.11 | 1 | 1.85445 | 211 | 391.28895 |
| Cd (mg/l) | 0.004 | 0.003 | 618.15 | 133.33 | 82417.9395 |
| Cr (mg/l) | 1.73 | 0.05 | 37.09 | 34.6 | 1283.314 |
| Ni (mg/l) | 0.534 | 0.07 | 26.492 | 76.29 | 2021.07468 |
| Mn (mg/l) | 0.34 | 1 | 1.85445 | 34 | 63.0513 |
| Zn (mg/l) | 3.167 | 3 | 0.62 | 1.05 | 0.651 |
| Total | | | ∑Wn=874.09814 | | ∑WnQn=88922.388664 |

**Table 9.** Calculation of water quality index of sampling station (SS D) water quality index (WQI) =WnQn/∑Wn =100.07.

| Parameters | Observed Value (Vn) | Standard Value (Vs) | Unit Weight (Wn) | Quality Rating (Qn) | WnQn |
|---|---|---|---|---|---|
| pH | 7.28 | 6.5-8.5 | 0.218 | 18.67 | 4.07006 |
| Temperature $^0$C | 27.4 | 25 | 0.074 | 109.6 | 8.1104 |
| EC (mg/l) | 278.9 | 1000 | 0.002 | 27.89 | 0.05578 |
| Turbidity | 8.76 | 5 | 0.37 | 175.2 | 64.842 |
| TDS (mg/l) | 121.86 | 500 | 0.004 | 24.37 | 0.09748 |
| DO (mg/l) | 5.78 | 2 | 0.927 | 70 | 64.89 |
| TPH (mg/l) | 6327 | 827 | 0.0224 | 765.05 | 16.93552 |
| Pb (mg/l) | 0.0108 | 0.01 | 186.44 | 10.8 | 2013.552 |
| Fe (mg/l) | 3.16 | 1 | 1.85445 | 316 | 586.0062 |
| Cd (mg/l) | 0.004 | 0.003 | 618.15 | 133.33 | 82417.9395 |

 

| | | | | | |
|---|---|---|---|---|---|
| Cr (mg/l) | 0.043 | 0.05 | 37.09 | 28.6 | 1060.774 |
| Ni (mg/l) | 0.032 | 0.07 | 26.492 | 45.71 | 1210.94932 |
| Mn (mg/l) | 1.88 | 1 | 1.85445 | 11,8 | 21.88251 |
| Zn (mg/l) | 3.214 | 3 | 0.62 | 1.08 | 0.6696 |
| Total | | | ∑Wn=874.09814 | | ∑WnQn=87470.75437 |

Table 3: recorded the values of turbidity which ranged from 6.52 to 9.15 NTU in all sampling points which were above the recommended limit for WHO and NSDWQ standard. This work is in agreement with the findings of Akakuru *et al*., that when turbidity is high, the aquatic penetration of sunlight will be adversely affected in the body of water [1]. Chinwendu *et al.,* (2021) also, revealed that sunlight is needed by sea weeds for photosynthetic activities. Thus, Turbidity with more than 5 NTU can encourage micro-organisms, protecting them from disinfection and can entrap heavy metals and biocides, even though it has no direct health effect. Furthermore, aquatic lives visibility is impaired at increased in turbidity levels, while declined in turbidity beyond a certain level encourages the algae growth [3, 4].

**Table 10.** Calculation of water quality index of sampling station (SS E) water quality index (WQI) =WnQn/∑Wn =89.29.

| Parameters | Observed Valued (Vn) | Standard Value (Vs) | Unit Weight (Wn) | Quality Rating (Qn) | WnQn |
|---|---|---|---|---|---|
| pH | 6.45 | 6.5-8.5 | 0.218 | 36.67 | 7.99406 |
| Temperature $^0$C | 25.9 | 25 | 0.074 | 103.6 | 7.6664 |
| EC (mg/l) | 227.6 | 1000 | 0.002 | 22.76 | 0.04552 |
| Turbidity (mg/l) | 7.34 | 5 | 0.37 | 146.8 | 54.316 |
| TDS (mg/l) | 237.64 | 500 | 0.004 | 47.53 | 0.19012 |
| DO (mg/l) | 0 | 2 | 0.927 | 0 | 0 |
| TPH (mg/l) | 5678.12 | 827 | 0.0224 | 686.59 | 15.379616 |
| Pb (mg/l) | 0.0167 | 0.01 | 186.44 | 16.7 | 3113.548 |
| Fe (mg/l) | 1.532 | 1 | 1.85445 | 153.2 | 284.10174 |
| Cd (mg/l) | 0.005 | 0.003 | 618.15 | 116.67 | 72119.5605 |
| Cr (mg/l) | 0.245 | 0.05 | 37.09 | 49 | 1817.41 |
| Ni (mg/l) | 1.57 | 0.07 | 26.492 | 22.43 | 594.21556 |
| Mn (mg/l) | 1.65 | 1 | 1.85445 | 16.5 | 30.598425 |
| Zn (mg/l) | 0.038 | 3 | 0.62 | 1.20 | 0.744 |
| Total | | | ∑Wn=874.09814 | | ∑WnQn=78045.769941 |

**Table 11.** Summary of water quality index of different sampling points of Okoroagu River.

| Sampling Point | Okoroagu | Status |
|---|---|---|
| SS (A) | 98.37 | Very Bad |
| SS (B) | 90.12 | Very Bad |
| SS (C) | 101.73 | Unfit |
| SS (D) | 100.07 | Unfit |
| SS (E) | 89.29 | Very Bad |

 

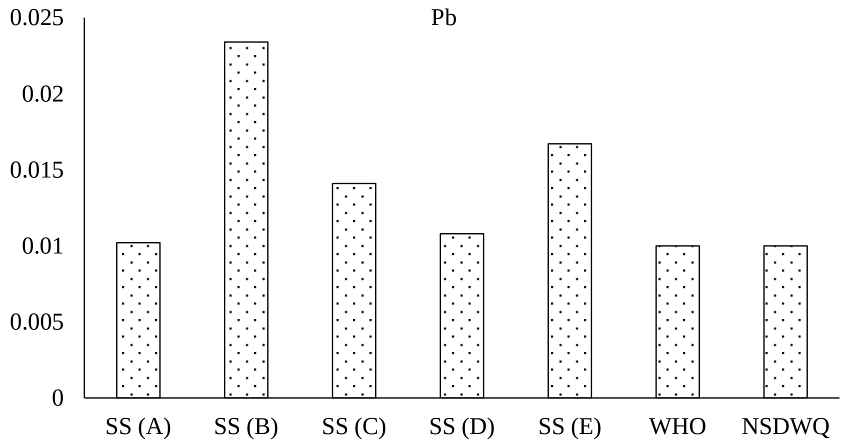


**Figure 7.** Pb from Sampling Points.

Figures 7-10 shown the values of heavy metals recorded from the sampling points, they are the most important among other heavy metals. From Figures 7-10, lead and Cadmium were all above the acceptable limit, Iron and Nickel at SS B were within the standard limit of WHO and NSDWQ but above at SS A-E. Thus, these heavy metals are very toxic and harmful in small concentration [3, 4]. They can reside inside the body tissue deforming the essential parts of the body such as mental deficiencies, cancer, brain damage and even death. High cadmium could cause agonistic and antagonistic effects on hormones and enzymes leading to several malformation such as renal damage [3, 4]. Similarly, results from Chromium show that at sampling point A and D, they are within the standard limit of WHO and NSDWQ while above at sampling location B, C and E respectively.

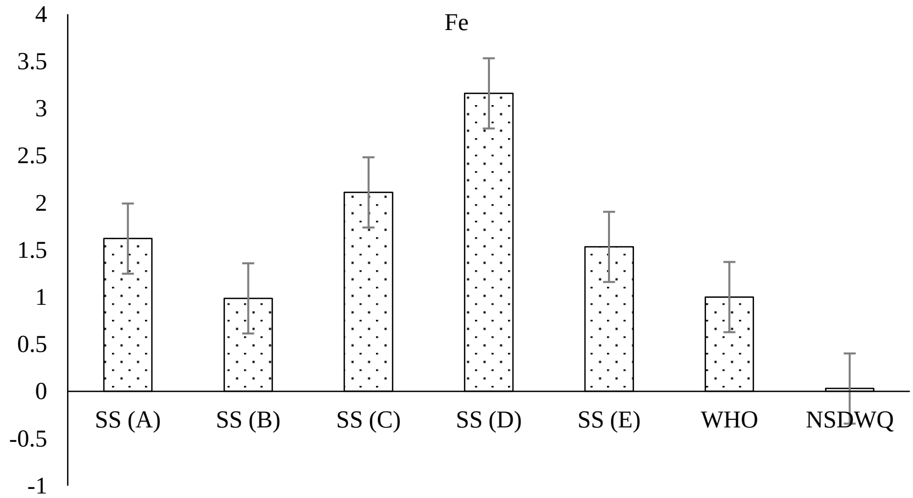


**Figure 8.** Fe from sampling points.

 

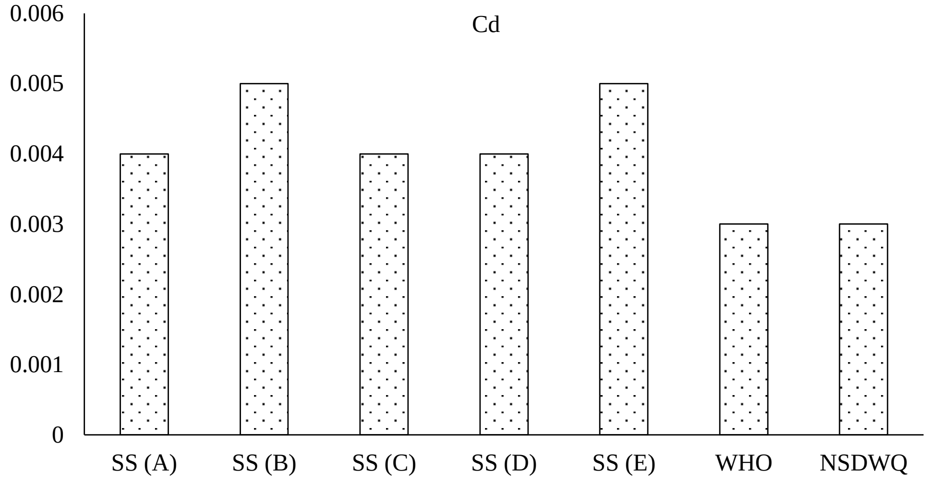


**Figure 9.** Cd from sampling points.

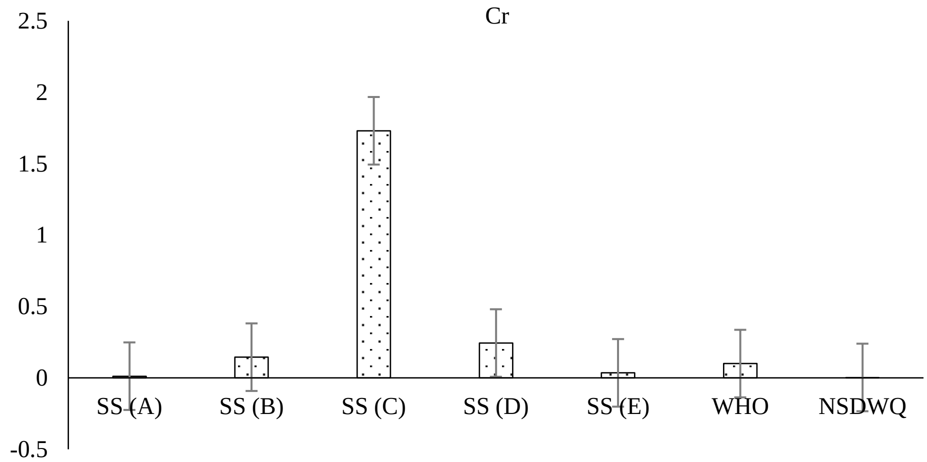


**Figure 10.** Cr from sampling points.

Also, Manganese result at sampling point A and B were below the permissible limit of WHO and NSDWQ, and above at point C, D and E. Likewise Zinc from the result shown that at sampling point A, B and E results (0.54, 0.084 and 0.038mg/l) were within the acceptable limit of WHO and NSDWQ and above the limit at point C and D (3.167 to 3.214mg/l) as against the standard limit of WHO and NSDWQ by 3mg/l [14, 22].

## CONCLUSION

The study examined the physicochemical and heavy metals properties of surface water samples of Okoroagu River in Etche local government area of Rivers State, Nigeria. There were changes in some physicochemical parameters like turbidity, temperature, dissolved oxygen, Total Petroleum Hydrocarbon, Lead, Cadmium and Iron which were above the permissible range of WHO and NSDWQ. However, Electrical Conductivity, pH, and Total Dissolved Solids were within the accepted limits. The metal concentration in Okoroagu River such as, Zinc, Chromium, and Nickel and Manganese were within the recommended acceptable limit but varies in other sampling locations.

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