**EVALUATION OF HYDROCARBONS AND HEAVY METALS IN IKO RIVER, EASTERN OBOLO L.G.A, AKWA IBOM STATE, NIGERIA**

 **ABSTRACT**

*This study evaluates hydrocarbons and heavy metals in water and sediment samples within the up and down streams of Iko River, Akwa Ibom State, Nigeria. The water and sediment samples were collected in triplicate from five designated stations of the up and down streams of the River using standard analytical procedures. The samples were analysed for hydrocarbons and heavy metals using gas chromatography with flame ionization detector (GC-FID) and atomic absorption spectroscopy respectively. Electrical conductivity (EC), salinity, temperature, PH, Total dissolved solids (TDS), and dissolved oxygen (DO) were also analyzed to ascertain the portability of the water samples. The results showed that Total petroleum hydrocarbon (TPH) in the up and downstream of the River (water samples) had a range of 3.743 to 5.518 mg/L, whereas Total hydrocarbon content (THC) in the water samples of the up and downstream had a range of 3.029 to 10.017 mg/L. Considering sediment samples, TPH in the up and downstream ranged from 479.611 to 638.391 mg/kg while THC had 724.275 to 2,574.247 mg/kg. TPH and THC values obtained were above the 50 mg/kg permissible limit of the Department of Petroleum Resources (DPR). The result obtained from the heavy metals analysis in the up and downstream of the water samples were from the ranges of 0.01 to 1.80 mg/L while heavy metals in the sediment ranged from 0.01 – 18.40 mg/kg, which is above the World Health Organisation and National Environmental Standard and Regulations Enforcement Agency (WHO/NESREA) standards (0.001 – 5.0 mg/kg). The physicochemical analysis recorded the following results within the up and downstream of the water samples; salinity (0.07 – 0.94 mg/L), TDS (0.40 – 1905 mg/L), EC (3.00 – 16.77 µS/cm), DO (2.29 – 3.44 mg/L), Temperature (30.7 oC), and PH (6.07 – 6.36), while the sediment had the following results; salinity (0.07 – 0.49 mg/kg),EC(0.66 – 1,560 µS/cm), Temperature (27.8 - 30.6 oC) and PH (6.02 – 6.28). All the results from the Analysis when compared with WHO standards were above the permissible limit indicating that the area is polluted. Hence there is need for early remediation to avoid potential health risk, encouraging healthier and cleaner environment. In addition the study has provided valuable information on the levels of heavy metals and hydrocarbons which will assist the environmentalist, public health specialist, law makers and government in their planning.*

Keywords**: Physicochemical, WHO, Downstream, Portability, Ranged, Sediment**

**1. INTRODUCTION**

The increasing human population commonly associated to areas of oil exploration activities and the consequent increase in the levels of anthropogenic pollutants have caused serious water quality deterioration problems world-wide (Oshineye,2023). Water contamination is a crucial global problem resulting from expanding industrial and agricultural activities. Many pollutants enter the aquatic environments directly or indirectly due to human activities, affecting aquatic organisms. One of the main environmental pollutants worldwide is crude oil-based hydrocarbon. (Ubong *et al*., 2023b; Ikpe *et al*., 2023).

All natural water bodies contain dissolved substances; pollutants such as hydrocarbon (THC and TPH), heavy metals, bacteria, viruses, salts and nitrates have contaminated most sources of water supplies due to unregulated activities of man which include oil spills, discharge of untreated effluents and to a large extent unregulated solid wastes disposal into water bodies and these chemical pollutants because of their hydrophobic nature tend to bind to organic particles in aquatic ecosystem where they are deposited and accumulated in three basic reservoirs: water, sediment and biota phases (Andem *et al*., 2013; Ikpe *et al*., 2023, Archibong *et al*., 2024).

Moreso, Clement *et al*., (2021) and Ikpe *et al.* (2023) reported that the behaviour of these petroleum hydrocarbons as well heavy metals upon entering the freshwater system is intimately linked with the chemical type of contaminant, the mode of entry and physical characteristics of the receiving freshwater system. Based on this, water quality monitoring is important because it forms an integral part of the physical environment and it is a subject of paramount current concern (Ikpe *et al* 2023; Ebong *et al.,* 2025). It is one of the major components that control the disease and healthy states in both animals and humans. This study is aimed at evaluating hydrocarbons (TPH and THC) and heavy metals in the up and down streams of Iko River, in Akwa Ibom state, Nigeria.

**2**. **Materials and Methods**

**2.1 Study area**

The present study was conducted in oil–rich and oil–producing host community of Iko in Eastern Obolo Local Government Area in Akwa Ibom State. The Eastern Obolo LGA is located along the coastal areas of Akwa Ibom State, which is currently the largest oil–producing state in the Nigeria’s Niger Delta region, that is, South–South geopolitical zone of Nigeria (Ebong *et al*., 2024) The Iko River estuary has semi-diurnal tides and a shallow depth ranging from 1 to 7 m at flood and ebb tide. The estuary is more than 20 km long with an average width of about 15 m. Iko River takes its course from Qua Iboe River catchments and drains directly into the Atlantic Ocean at the Bight of Bonny. It has many adjoining tributaries and part drains into Imo River estuary, which opens into the Atlantic Ocean. The people around Iko use Iko water for farmlands, drink, other domestic activities etc. The areas are under continuous cultivation throughout the year and have been supplying significant portion of a wide variety of vegetables and seafood (Udosen, 2021)



Figure 1: Map Showing Sampling Stations in Iko River (Eastern Obolo LGAs)

**2.2 SAMPLE COLLECTION AND TREATMENT**

Fresh samples of sediments and water, were collected from the Iko River in Eastern Obolo Local Government Area of Akwa Ibom State in triplicate and prepared using standard analytical method as describe by Clapcott *et al*. (2011) ; Ikpe *et al.*, 2023.

**2.2.1Water sample**

The Water samples were collected in triplicate each from the up and down stream of the Ibagwa River into a one litre amber glass bottles (for hydrocarbons analysis) and plastic bottles (for heavy metals analysis) within five stations. The sample bottles used were thoroughly pre-washed using 3M Nitric acid rinsed with deionized water to avoid contamination (AOAC, 2015; Ikpe *et al.,* 2023). The collected samples were kept in an ice-cooler before taken to the laboratory for pre-treatment and analysis (Anyanime, 2016; Akpakpan *et al*., 2024)

**2.2.2 Sediment sample collection**

The sediment samples were collected in triplicate from the up and down stream of the study site (five stations) using a clean Van Veen grab sampler. The samples were collected into a one litre amber glass bottles and polythene bags previously acid washed and rinsed using deionized water. The collected sediment samples were placed in an ice chest with ice before conveying to the laboratory and thereafter kept under refrigerator and protected from light awaiting analysis to avoid photo degradation of the samples (Clapcott *et al.,* 2011; Ubong *et al* 2023).

**2.3 DETERMINATION OF HYDROCARBONS**

**2.3.1 Preparation of Hydrocarbons (TPH and THC)**

The hydrocarbons extraction mixture was prepared using acetone and dichloromethane (1:1 v/v). Two hundred and fifty ml (250 ml) of acetone and 250 ml of dichloromethane was measured into a 1000 ml standard volumetric flask and properly mixed by swirling the mixture (Edjere *et al*., 2016; Ikpe *et al*., 2023)

**2.3.2 Determination of TPH and THC from water sample**

The total petroleum hydrocarbon (TPH) and total hydrocarbon content (THC) were determined from the water sample using gas chromatography fitted with flame ionization detector (GC-FID) as described by Merll (2025). The water samples were extracted using standard analytical methods that involved liquid-liquid extraction. Fifty (50) ml of water samples were introduce into a 250 ml seperatory funnel followed by introduction of 60 ml of extraction solvent (Dichloromethane and Acetone in the ratio of 1:1). The seperatory funnel was later swirled for about 10 minutes for extraction to occur, the process was repeated for three times to achieved complete extraction. The extracted samples were later concentrated using regulated water bath (at 500c) before purification process. One and half mL (1.5 mL) of the concentrated extract was loaded on a silica gel column. The silica gel column was prepared by loading a two grams (2g) glass wool followed by a thirty grams (30 g) chromatography silica gel, onto a chromatography column (2 cm internal diameter and 10 cm long).

Each of the bed was conditioned with 40 mL HPLC-hexane to remove any contaminant (Ikpe *et al.,* 2019 ; Ubong *et al*.,2023) The 1.5 mL concentrated extract was loaded and eluted with 30 mL HPLC hexane into a well labelled 100 mL beaker to get the aliphatic hydrocarbon components in the sample. At a point when the hexane was almost getting dried, Hexane was replaced with 30 mL of dichloromethane to elude the aromatic hydrocarbon contents into another labelled 100 mL beaker. Two gram (2 g) of anhydrous sodium sulphate was added to remove any traces of water left in the extract (for sediment extract only) The extract were re-concentrated using rotary evaporator to about 2 mL. One mL (1mL) of the extract was taken and transferred into a well labelled chromatography vial ready for gas chromatography analysis. The samples were stored at a temperature of -4oC until GC analysis (Edidiong *et al*., 2022)

**2.2.3 Determination of TPH and THC from Sediment**

In the laboratory, sediment samples were dried at ambient temperature in open containers covered lightly with clean paper and then stored in clean bottles. The samples were ground with a porcelain mortar and then passed through a series of graduated strainers to remove stones and vegetable matter. Fifty grams (50 g) of the sample was weighed into a thimble and inserted into a column in the Soxhlet apparatus for extraction at 60oC for eight (8), in order to achieve a complete extraction according to a standard analytical methods described by Schwab *et al.,* 2015 and Ikpe *et al.,* 2023. The extracted samples were later concentrated, purified before introducing into Chromatographic fial ready for GC-MS analysis using standard method.

**2.4** **SAMPL**E **PREPARATION FOR HEAVY METALS**

**2.4.1 Digestion**

**2.4.1.1 Digestion for Heavy Metals Analyses in Water**

50 ml of water sample and 10 ml of conc. Nitric acid were mixed together in a digestion flask and were heated using heating mantle in the laboratory until one third (1/3) of the sample remained. The samples were then remove and allowed to cool. Later, the samples were filtered and made up to mark of 100 ml standard volumetric flask, ready for analysis using Atomic Absorption Spectrophotometer (AAS) (AOAC, 2015; Ikpe *et al.,* 2023).

**2.4.2** **Digestion for heavy metals Analysis in sediment**

The samples were ground using three molar (3 M) nitric acid pre-washed porcelain mortar and pestle, sieved into a well labelled transparent plastic containers by passing them through a 1mm mesh, 1 g of each of the sieved sediment samples were accurately weighed into different digestion flask, well clamp to a retort stand (Oteri.,2024) . Ten mL (10 mL) of ratio 10: 1 mixture of nitric (HNO3) and perchloric (HClO4) acid were added to the sample in each of the clamped digestion flask, swirled and allowed for some minutes for any reaction to subside (Ikpe *et al*., 2020, Merll, 2025) The digestion flasks were mounted on a heating mantle, and heating began gradually until appearance of whitish dense fumes where a clear solution is obtained. The digestion flask was removed and allowed to cool. Fifty mL (50 mL) of deionized water was added to the digest filtered (using Whitman’s filter paper) and made up to mark of 100 mL standard volumetric flask with deionized water. Each of the standard volumetric flasks of the digest were corked, labelled and refrigerated ready for AAS analysis. Before the instrumental analysis (AAS) stock solutions were prepared from which serial dilutions were made for working standards. Calibration curve for each metal was plotted. The working standards were analyzed first followed by the blank before the samples (Ikpe *et al.*, 2022).The results obtained were subjected to statistical evaluation. The parameters evaluated were mean, standard deviation (SD), correlation Coefficient, and Analysis of variance (Anova)

$$C\_{m(s)}mg/kg= \frac{Cm \left(AAS\right)mg/L × V\_{mL}X 1L X 10^{3}g}{Ms \left(g\right)× 1kg × 10^{3} mL} (2.1) $$

Here; Cm – concentration of metals

 V – Volume of the digest

 1L – one litre

 Ms – metal sample used for digestion

 1k – one kilogram

**2.4.2.1 Preparation of Standards for the Buck Scientific 210 VGP Atomic Absorption**

 **Spectrophotometer**

Ten standards were prepared for use by Buck scientific 210 VGP AAS following instructions in the manufacturer’s manual (AOAC, 2015). These standards were prepared from Pb (NO3)2, CdSO4, FeCO3, Cr (NO3)3, CuSO4, Ni (Co) 4, Mn(NO3)2

**2.4.2.2** Preparation **of Pb standard from Pb (NO3)2**

To prepare lead standard, the relative molecular mass (Rmm) of the compound has to be known. The relative molecular mass of a compound is the sum of the relative atomic masses of all the atoms in one molecule of the substance (Ebong *et al*, 2024d). In this case, the relative molecular mass of Pb (NO3)2 = 331.2 g.

 From Calculation;

Relative atomic mass of Pb =207.2

Relative atomic mass of N =14x2 =28

Relative atomic mass of O = 16X3X2 =96

Therefore Relative molecular mass (RMM) = 207.2+28+96 = 331.2 g of 207.2 g of lead contains 331.2 g of Pb (NO3)2

Then 1 g of lead will contain 1x331.2 /

 207.2x331.2 (2.2)

 = 1.5985 g Pb (NO3)2

Therefore 1.5985 g Pb (NO3)2 was accurately weighed and dissolved in 1 dm3 with deionized water. This solution now contains 1000 mg of Pb in 1 litre i.e 1000 ppm stock.

From here 2,4,6,8 and 10 ppm could be prepared (i.e working standard). To prepare 2ppm

Apply dilution principle; C1V1 = C2V2 (2.3)

 1000 x V = 2 X 100 mL

 V = 200/1000 = 0.2 mL

Therefore 0.2mL of stock was diluted to 100 ml with deionized water to give 2 ppm solution of Pb. Other standards were prepared using the same procedure. Each of the standards prepared were aspirated into AAS flame and the absorbance recorded. The sample concentration was determined by the above formula given in equation 2.1.

**2.5**  **Determination of Physico-Chemical Parameters**

This is the study of the relationship between the physical and chemical properties of a substance or system. It involves examining how a substance(s) composition and structure affects its chemical characteristics and vice versa (Ukpong *et al*., 2017, Ebong *et al*., 2024a).

**2.5.1 Determination of Temperature**

Temperature which is the quantifiable way to describe the warmth or coldness of a substance. It was determined in both samples on site (in-situ) by dipping the thermometer in the samples for few seconds and reading recorded. The results are expressed in degree Celsius (Ubong *et al*., 2023; Ebong *et al*., 2024b)

**2.5.2 Determination of pH**

The pH analysis was done using Jenway digital pH meter based on the difference in activity of hydrogen ion in and out of the electrode. The pH meter was calibrated with buffer solution of pH 4.0, 7.0 and 9.0 respectively. Ten grams (10 g) of ground fresh samples were placed in a 100 mL beaker separately. Fifty mL (50mL) of deionised water was added to it and stirred in a beaker, allowed to stand for 30 minutes for equilibration with occasional stirring. The electrode of the pH meter was inserted into the partly settled mixture and the pH was read on the meter. The electrode was rinsed with deionized water and dried with soft tissue paper after each reading to avoid cross contamination (Oteri, 2025; Ebong *et a*l., 2024)

**2.5.3 Determination of Electrical Conductivity (EC) and Total Dissolved Solids (TDS)**

This was determined according to AOAC, 2015 standard methods, using the Hack conductivity/TDS digital meter. The instrument was turned on, the electrode rinsed with deionized water and wiped with a clean tissue paper. The probe was then immersed in the sample to be determined. Readings were taken after few minutes’ stabilization of the meter. The probe was rinsed and clean carefully after each successful reading. The electrical conductivity was reported in µS/cm while TDS was in mg/L (Ubong *et al.,* 2023; Edet *et al*., 2017)

**2.5.4 Determination of Salinity**

Salinity which is the total concentration of all dissolved salt in the water, it was determined in both the water and the sediment samples. These electrolyte form ionic particles as they dissolved each with positive and negative charge. In this study, 10 g of the sediment sample was weighed for the test of salinity and 50 ml of distilled water was also measured and poured into a 100 ml beaker container. The sample was allowed to stand for 30 minutes for proper equilibration (Ikpe *et al*., 2020; Anyanime *et al*., 2017)

After 30 minutes, the samples were taken for the test using the conductivity meter according to standard methods described by Ikpe *et al. (*2023) and Ebong *et al*. (2024b)

**2.5.5 Determination of Dissolved Oxygen (DO)**

The Dissolved Oxygen was determined using Jenway DO meter electronic device. The meter was calibrated according to the manufacturer’s instructions. The determination was done by immersing the probe into the water samples according standard methods by AOAC, 2015; Ebong *et al*., 2024c. The readings were in mg/L.

**2.6 Statistical Analysis**

Statistical package for social sciences (SPSS) was employed for statistical evaluation of data obtained.

**2.6.1 Mean**

This is the average of the numbers, a calculated “central” value of a set numbers.

**2.6.2 Standard Error**

These are the standard errors of the coefficients. They can be used to construct the lower and upper bounds for the coefficient. An example is coefficient $\pm $ standard error, which provides an indication where the value may fall if another sample data set is used.

The standard error is also used to test whether the parameter is significantly different from 0. If a coefficient is significantly different from 0, then it has impact on the dependent variable.

**2.6.3 P-value:** The P-value indicates whether the independent variable has statistically significant predictive capability. It essentially shows the probability of the coefficient being attributed to random variation. The lower the probability the more significant the impact of the coefficient (Mbong, 2015).

**2.6.4 Correlation Coefficient**

A correlation coefficient is a statistical measure of some type of correlation, meaning a statistical relationship between two variables (Taylor, 1997). The variables may be two columns of a given data set of observations, called a sample, or two components of a multivariate random variable with a known allocation.

Several types of correlation coefficient exist, each with their own definition and own range of usability and characteristics. They all assure values in the range from – 1 to + 1, where $\pm $1 indicates the strongest possible agreement and 0 strongest disagreements (Taylor, 1997). As tools of analysis, correlation coefficient presents certain problems, including the propensity of some types to be distorted by outliers and the possibility of incorrectly being used to interfere a casual relationship between the variables.

**2.6.5 Anova**

Analysis of Variance (ANOVA) is a collection of statistical models and their estimation procedures (such as the “variation” among the and between groups) used to analyze the differences among group mean in a sample.

In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether the population means of several groups are equal, and therefore generalizes the t-test to more than two groups. ANOVA is useful for comparing (testing) three or more group means for statistical significance (Bailey, 2008).

**3. RESULTS AND DISCUSSION**

The results of the analysis carried out on water body and sediment of the up and downstream of Iko River within five stations are presented as follows;

**3.1 Physicochemical parameters**

**3.1.1 Variation in pH**

The results of the physico-chemical analysis (pH) for the up and downstream are indicated in Table 1 – 4. The negative logarithm of hydrogen ion concentration (pH) of water in the upstream of Iko River had the ranged of 4.31 to 7.17 with a mean value of 6.36 while the downstream with a ranged of 3.60 to 7.26 with a mean value of 6.07. Considering the sediment samples; upstream had a ranged from 5.55 to 6.68 with a mean value of 6.28 while downstream felled from 5.58 to 6.45 with a mean of 6.02, which all the mean were below the world health organisation (WHO) standard of 6.5 – 8.5 for drinking water. On the whole Sediment downstream had the highest acidity (low pH of 6.02).This could be linked to the fact that sediment remains the pollutant sink (Ademoroti 1996; Okuo *et al*., 2016)

 It was observed that the water samples were more acidic (low pH) at the downstream than the upstream. This might be attributed to the untreated waste flowing from the upstream (in proximity to the operating oil company) to downstream over time. The industrial activities of the company such as gas flaring releases carbon dioxide which reacts with atmospheric precipitation to form carbonic acid (CO2 + H2O ------ > H2CO3) into the River (Alloway and Ayres, 2018). Also according to Imoisi *et al*., 2020 the deviation from natural pH level of 7.0 may be attributed to presence of dissolved carbonates and bicarbonates which affect the pH of most surface water. However the values obtained in the study corroborates with a similar study within the Niger Delta region undertaken by Ubong *et al*., 2023. This implies that waste discharged by the operating oil company and other anthropogenic activities could have possibly influence the high acidity of the samples in the River. Therefore water with a pH not in line with the WHO recommended standard may be unsafe to drink and carry potential health risks, as well as corrosion to industrial tools (Eddy *et al*.,2006;Isichei *et al.,* 2015).

**3.1.2 Variation in Temperature**

Temperature which is the degree of hotness or coldness of a body is a critical water quality parameter, which is directly influenced by the quantity of dissolved oxygen available to marine organisms. For surface water, the temperature varies between 4 – 23oC with variations strongly influenced by climate and latitude (Umanah, 2010; Enyeribe *et al.,* 2020).

Increase in temperature is known to have a number of effects on water quality (Wilson *et al*., 1992; Ikponmwen *et al.,* 2021), amongst these are fast assimilation of waste and faster depletion of dissolved oxygen.

Temperature of the water samples (Table 1-4) in the upstream ranged from 30.2 to 31.5 oC, while in the downstream it had 30.7 oC. The upstream sediment exhibited a temperature of 27.8 to 28.4 oC while downstream had 29.7 to 30.6 oC. All the values from water samples were above the WHO desirable level of 29.4 oC which could be attributed to direct solar radiation on the river surface during the period of sampling(dry season) (Isichei *et al*., 2015). The results were higher than similar studies by Ikpe *et al*., 2023, who had a Temperature of 27.0 to 27.1 oC

**3.1.3 Variation in Electrical Conductivity (EC)**

This refers to the ability to conduct an electrical current, which is primarily determined by the concentration of dissolved ions (salts) in water. The presence of dissolved substances in water increases its conductivity.

The electrical conductivity of water samples (Table 1-4) in upstream exhibited the ranged from 3.00 to 16.77 µS/cm while downstream had 3.25 to 3.69 µS/cm. These values are very low when compared with the WHO standard limit of 400 µS/cm; it indicates very low levels of dissolves solids or ions in water. The implication is that the water has very low concentrations of dissolved substances as such the water might lack essential minerals (FAO/WHO, 2011; Clement *et al*., 2021; Nwaichi *et al*., 2022). The water might be suitable for specific industrial or laboratory uses requiring low ions. Moreso, the water with very low EC might taste flat or bland. It can also be corrosive to pipes (Usoro *et al*.,2017;Isichei *et al*., 2015) .The sediment upstream had a ranged of 0.66 to 9.29 µS/cm while sediment downstream had 2.00 to 1560 µS/cm. The highest value obtained from sediment could have been as a result dissolved ions in the sediment over time (bioaccumulation) because sediment remains the pollutant sink (Ebong *et al*., 2024)

3.1.4 Variation in Salinity

Salinity refers to the concentration of dissolved salts (such as sodium chloride, magnesium, and calcium) in water. It’s usually measured in part per thousand or milligrams per litre (mg/L).

The salinity level recorded in the water sample upstream is from the ranged of 0.20 to 0.94 mg/L while water downstream exhibited 0.09 – 0.19 mg/L. The sediment upstream had 0.30 to 0.49 mg/L while the downstream sediment showed a result of 0.07 to 0.19 mg/L. The overall values from water and sediment samples were below the WHO maximum allowable level of 250 mg/L of salinity in water. The low level of salinity could be attributed to geological formation while the presence of it especially in the sediment could be as result of atmospheric deposition, industrial and human activities over time (Ikpe *et al*., 2023). It should be on note that high salinity above he WHO limit could lead to decrease in plant growth and water quality, it kills plants, leaving bare soil prone to erosion (Olubokola *et al*., 2015; Ubong *et al*., 2023)

**3.1.5 Dissolved Oxygen (DO)**

This is the amount of oxygen dissolved in water, essential for aquatic life. It’s a critical water quality parameter. However, oxygen levels are essential for good water quality. The dissolved oxygen in the water upstream varies from 2.29 to 3.44 mg/L while the downstream had 2.93 to 3.22 mg/L with a mean of 2.7 mg/L. These low DO indicates pollution or stagnation which might affect water quality and aquatic life (Ntuen *et al*., 2024; Ebong *et al*., 2024; Waribo *et al*., 2025). The obtained results revealed that the values were below the WHO standards of 4.0 to 8.0 mg/L.

**3.1.6 Total Dissolved Solids (TDS)**

These measures the combined content of all inorganic and organic substances dissolved in water. This includes minerals (calcium, magnesium, potassium, and sodium), salts, metals and other inorganic compounds. The water sample from the upstream had TDS of 0.40 to 1905 mg/L with a mean of 389.17 mg/L while the downstream showed a ranged from 1629 to 1847 mg/L with a mean value of 1733.4 mg/L. The mean value from the up and downstream was above the WHO desirable level of 200 mg/L and maximum allowable limit of 500 mg/L. This is an indication of water quality issues (Ubong *et al*., 2023). The high TDS above the WHO maximum allowable level can cause scaling in pipes, may exhibits metallic taste or health risk if contaminants like lead or nitrates are present (Nwabueze ,2011; ERUN,2025).

Table 1: Descriptive statistics showing physicochemical parameters of water (Upstream)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameters(WHO)**   | **Stations****1** | **2** | **3** | **4** | **5** |
| TDS (mg/L) 500 | 2.43±0.02 | 2.24±0.00 | 5.78±0.06 | 0.40±0.00 | 1905±0.97 |
| EC(µs/cm) not>400 | 4.09±0.05 | 4.50±0.02 | 11.56±0.64 | 16.77±0.11 | 3.00±0.75 |
| Salinity (mg/L)250 | 0.25±1.03 | 0.23±0.00 | 0.63±0.62 | 0.94±0.41 | 0.20±0.00 |
| DO(mg/L) 4.0-8.0 | 2.46±0.01 | 2.39±0.11 | 2.29±0.08 | 3.11±0.85 | 3.44±0.03 |
| Temp. (0C) 29.4 | 31.5±0.06 | 31.5±0.13 | 31.4±0.04 | 31.4±0.33 | 30.2±0.95 |
| pH 6.5-8.5 | 4.31±0.01 | 6.55±0.02 | 6.61±0.71 | 7.15±0.54 | 7.17±0.03 |

Table 2: Descriptive statistics showing Physiochemical parameters of water (Downstream)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameters(WHO)** | **Stations****1** | **2** | **3** | **4** | **5** |
| TDS (mg/L)500 | 1743±0.22 | 1689±0.07 | 1629±0.28 | 1759±0.27 | 1847±0.00 |
| EC(µS/cm)not>400 | 3.48±0.61 | 3.39±0.06 | 3.25±0.00 | 3.51±0.47 | 3.69±0,13 |
| Salinity (mg/L) | 0.09±0.50 | 0.17±0.08 | 0.17±0.33 | 0.10±0.01 | 0.19±0.43 |
| DO (mg/L) | 3.20±0.11 | 3.22±0.01 | 3.02±0.36 | 3.02±0.03 | 2.93±0.17 |
| Temp. (0C) 29.4 | 30.7±0.09 | 30.7±0.00 | 30.7±0.11 | 30.7±0.08 | 30.7±0.18 |
| pH 6.5 – 8.5 | 7.26±0.64 | 7.10±0.91 | 3.60±0.10 | 5.97±0.07 | 6.40±0.16 |

Table 3: Descriptive statistics showing Physiochemical parameters of sediment (Upstream)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameters(WHO)** | **Stations****1** | **2** | **3** | **4** | **5** |
| EC (µs/cm) | 7.52±0.02 | 7.14±0.00 | 9.29±0.024 | 7.21±0,07 | 0.66±0.44 |
| Salinity (mg/L) | 0.40±0.03 | 0.30±0.96 | 0.49±0.02 | 0.30±0.06 | 0.46±0.75 |
| Temperature (0C) | 28.4±0.11 | 28.1±0.21 | 28.2±0.01 | 27.8±0.04 | 28.0±0.55 |
| pH | 5.55±0.00 | 6.13±0.54 | 6.54±0.09 | 6.47±0.00 | 6.68±0.03 |

Table 4 Descriptive statistics showing Physiochemical parameters of sediment (Downstream)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameters(WHO)** | **Stations****1** | **2** | **3** | **4** | **5** |
| EC (µs/cm) | 1393±0.37 | 3.70±0.06 | 2.00±0.07 | 2.14±0.05 | 1560±0.07 |
| Salinity (mg/L) | 0.07±0.14 | 0.19±0.08 | 0.10±0.04 | 0.11±0.78 | 0.08±0,62 |
| Temperature (0C) | 30.4±0.12 | 30.2±0.02 | 29.7±0.02 | 30.2±0.05 | 30.6±0.12 |
| pH | 5.58±0.03 | 6.25±0.13 | 6.45±0.11 | 5.85±0.33 | 5.99±0.81 |

**3.2 Concentration of Heavy Metals in Water and Sediment of the Up and Downstream**

**3.2.1 Heavy metals in Water Samples**

The Table 5 showed the descriptive statistics of levels of Heavy metals in water sample of the up and downstream of Iko River. Meanwhile levels of Cd, Pb, Ni, Fe, Cu, Cr and Mn were detected in the up and downstream water sample of Iko River. However Cd, Fe, Cu and Mn were observed to be higher in the upstream than the downstream water sample this may be attributed to its closeness to the waste discharge unit of the operating oil company(sterling global), Pb were observed to have the same values (0.01 mg/L) in up and downstream. Ni in the downstream was higher in the upstream than downstream water sample and also above the WHO standard of 0.02 mg/L. The relative higher concentration of Ni may be due to its presence in waste of diverse form, particularly existing in soluble form (Quatara and Sangara, 2021, Anwuli *et al*., 2024) Such concentration may not go well even in lower concentration; it can cause allergic reactions apart from being carcinogenic (Lentech, 2011). Mn exhibited a concentration of 0.23 mg//L in upstream higher than downstream (0.19 mg/L) and WHO (2011) (0.05mg/L) and NESREA (2011) (0.5mg/L) standards.

**Table 5: Descriptive Statistics showing levels of Heavy metals in Water Sample of Iko River**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Heavy metals(mg/l)  | WHO(mg/L) | NESREA(mg/L) Standards  | UpstreamMean ± S.E | Downstream Mean ± S.E |
| Cd | **0.01** | **less than 1.0** | **0.02 ± 0.01** | **0.01 ± 0.00** |
|  Pb  | **0.03** | **0.0** | **0.01 ± 0.21** | **0.01 ± 0.14** |
| Ni  | **0.02** | - | **0.11 ± 0.32** | **0.14 ± 0.11** |
| Fe | **0.1 -1.0**  | **2.0** | **1.80 ± 0.07** | **1.71 ± 0.10** |
| Cu  | **0.05**  | **< 1.0** | **0.04 ± 0.09** | **0.03 ± 1.00** |
| Cr | **0.05-0.50**  | **< 1.0** | **0.23 ± 0.11**  | **0.21 ± 0.09** |
| Mn | **0.05** | **0.5** | **0.23 ± 0.16** | **0.19 ± 0.10** |

**S.E = standard error**

**3.2.2 Concentration of Heavy metals in Sediment**

Table 6 indicates the presence of the heavy metals in the following sequence, for upstream water samples; Fe, > Mn > Cr > Ni > Cu > Pb > Cd whereas the downstream had Fe > Cr > Mn > Ni > Cu > Cd > Pb. The investigation revealed slight increase in the sediment than water sample which corroborates a similar study in the Niger Delta region by Ikpe *et al.,* 2023; Ubong *et al*., 2023. Comparing the values (Table 6) all the heavy metals in the upstream sediment there were above the WHO standards while the downstream sediment had the highest Fe content of 18.40 mg/kg which could be attributed to accumulation over time, from the activities of human, operating oil company and run-off during wet season. Asides, Ademoroti (1996); Andem *et al*. (2013) reported that natural soil contains significant concentration of iron (Fe). Eddy *et al*. (2006) asserted that pollution of environment by iron cannot be overwhelmingly linked to waste materials alone but other ordinary sources of iron must be considered. Chromium (Cr) in the downstream sediment was higher than the upstream with a value of 0.35 mg/kg above the WHO (0.05 – 0.5 mg/kg) and within the NESREA standard of < 1.0 mg/kg. According to Alloway and Ayres, 2018 chromium can be used in preparation of various types of chrome steel and alloys, example of such chrome steal are stainless steel, chrome steel, chrome vanadium steel, chrome-nickel steel etc. Consequently most of these steel are being used by the operating oil company in constructing their platform and for oil exploration/exploitation activities, which might introduce Cr into the water body and sediment. Finally, chronic exposure to Cr, Pb, Cd and other heavy metals may lead to congenital or can cause other chronic conditions (USEPA, 2006; FMenv, 2006). It should be noted that the hexavalent chromium (Cr (VI) is toxic, carcinogenic and mobile in environment (Ikpe *et al*., 2023). Also Chromium can accumulate in organisms and biomagnifies in food chains.

**Table 6: Descriptive statistics showing levels Heavy metal in Sediment Sample of Iko River**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Heavy metals(mg/kg)  | WHO(mg/kg)  | NESREA(mg/kg) Standards  | Upstream  Mean ± S.E | DownstreamMean ± S.E |
| Cd | **0.01** | **less than 1.0** | **0.02 ± 0.03** | **0.01 ± 0.14** |
| Pb  | **0.03** | **0.0** | **0.02 ± 1.07** | **0.01 ± 0.00** |
| Ni  | **0.02** | - | **0.13 ± 0.18** | **0.09 ± 0.11** |
| Fe | **0.1 -1.0**  | **2.0** | **2.04 ± 0.01** | **18.40 ± 0.09** |
| Cu | **0.05**  | **< 1.0** | **0.07 ± 1.04** | **0.03 ± 0.17** |
| Cr | **0.05-0.50**  | **< 1.0** | **0.25 ± 0.01**  | **0.35 ± 0.04** |
| Mn | **0.05** | **0.5** | **0.27 ± 0.13** | **0.11 ± 0.15** |

**S.E = standard error**

**3.3 Concentration of Hydrocarbons in Water and Sediment of the Up and Downstream**

**3.3.1 Concentration of hydrocarbon in water**

Table 7 show various concentrations of total petroleum hydrocarbon (TPH) and total hydrocarbon content (THC) in water samples of five different stations of the up and downstream of Iko River.

The investigations revealed that TPH in the upstream of water sample had a value ranged of 1.624 to 3.743 mg/L while THC had 2.34 to 4.057 mg/L. Considering downstream water sample, TPH recorded a ranged of 3.748 to 5.518 mg/L. On the whole THC had a higher value in the water sample than TPH. This could be linked to the fact that THC entails the entire hydrocarbons in the stations which could be attributed to oil spillage from the oil facility of the operating oil company as well as other anthropogenic activities which may introduce gasoline, alkanes water soluble aromatics (BTEX, substituted, benzene) and water insoluble polyaromatics as reported by Edjere *et al*.(2016). The least concentrations of TPH and THC were recorded in station one (1) (water sample) upstream of the River. This may be due to less human activities, and the direction of flow of the water body from less polluted area (Okona-Mensa, 2005). Also the assertion of Jack *et al*., (2022) ; that hydrocarbons takes longer time to go under to the River bed by gravity than to spread by tidal waves can attributes to high values of TPH and THC in the water samples. However the values obtained from all the stations were above the Department of Petroleum Resources (DPR, 2002) regulatory limit of 0.6 mg/L.

**Table 7: Descriptive Statistics showing Total Hydrocarbons in Water Sample of** Iko **River**

|  |
| --- |
| Site UPSTREAM DOWNSTREAM TPH (mg/l) THC (mg/l) TPH (mg/l) THC (mg/l)  Mean ± S.E Mean ± S.E Mean ± S.E Mean ± S.E  |
| 1 | **1.624 ± 0.04**  | **2.343 ± 0.62**  |  | **4.156 ± 0.13** | **8.857 ± 19.30** |
| 2 | **2.832 ± 0.17**  | **3 .543 ± 0.26** |  | **4.849 ± 0.18**  | **8 .971 ± 11.02** |
| 3 | **2.073 ± 0.99** | **3.029 ± 0.31** |  | **3.991 ± 0.11**  | **8.457 ± 14.01** |
| 4 | **3.061 ± 1.01** | **3.486 ± 0.26** |  | **3.748 ± 0.33** | **10.17 ± 8.11** |
| 5 | **3 .743 ± 2.02**  | **4.057 ± 0.54** |  | **5.518 ± 0.02**  | **8.914 ± 0.31** |

**S.E = standard error**

**3.3.2 Concentration of hydrocarbons in Sediment**

Table 8 indicate the levels of TPH and THC in the up and downstream Sediment sample of Iko River. The upstream sediment sample revealed the TPH (ranged) values of 479.611 to 638.391 mg/kg while THC had 2,265.680 to 2,572.819 mg/kg. Meanwhile, for sediment downstream TPH had a result that ranged from 499.101 to 593.620 mg/kg while THC exhibited a range of 724.273 to 1044.270 mg/kg. These results corroborate a similar study of higher hydrocarbons in sediment by Ikpe *et al.* (2023), and can also be supported by assertion of Ademoroti (1996) which regards sediment as the pollutant sink. From this study, sediment exhibited higher values when compared with the water samples. Meanwhile TPH and THC compounds have been reported by Ebong *et al*. (2025) to be of detrimental effect to human, by affecting central nervous system, headaches and dizziness at high concentrations, effect on the blood, lungs, skin and eyes.

**Table 8: Descriptive Statistics showing Total Hydrocarbons in Sediment Sample of** Iko **River**

|  |
| --- |
| Site UPSTREAM DOWNSTREAM TPH (mg/l) THC (mg/l) TPH (mg/l) THC (mg/l)  Mean ± S.E Mean ± S.E Mean ± S.E Mean ± S.E  |
| 1 | **607.771 ± 1.22**  | **2, 574.247 ± 0.42** |  | **507.461 ± 0.17** | **859.987 ± 16.34** |
| 2 |  **638.391 ± 3.01**  | **2,498 .534 ±19.32**  |  | **593.620 ± 0.29**  | **724 .275 ± 0.73** |
| 3 | **479.611 ± 1.46** | **2,265.680 ± 11.02** |  | **518.331 ± 1.04**  | **1,044.270 ± 0.89** |
| 4  | **619.819 ± 1.22** | **2,572.819 ± 13.51** |  | **499.101 ± 1.61** | **827.130 ± 0.18** |
| 5 | **633 .091 ± 1.02**  | **2,425.678 ± 0.37** |  | **486.781 ± 1.56**  | **857.130 ± 0.41** |
|  |  |  |  |  |  |

**S.E = standard error**

**3.4 Comparative Statistical Analysis OF Heavy Metals, TPH, and THC between UP and Downstream using Analysis of variance (ANOVA) and Pearson Product Moment Correlation**

**3.4.1** **Analysis of Variance of the Difference in** **Heavy metals in Water Sample of Iko River between Upstream and Downstream**

 The result in Table 9 shows that the F-value of .946 for the difference in heavy metals in water sample of Iko River between upstream and downstream is not significant. This is because the p-value of .350 is greater than .05 at 1 and 12 degrees of freedom. Therefore, the amount of heavy metal in water sample of Iko River between the upstream and downstream does not differ significantly. This could be attributed to the flow of the river. Enhancing spread of the contaminant (Mbong, 2015**)**

**Table 9: Analysis of Variance of the Difference in** **Heavy metals in Water Sample of Iko River between Upstream and Downstream**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sources of Variance** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Between Groups | .202 | 1 | .202 | .946 | .350 |
| Within Groups | 2.557 | 12 | .213 |  |  |
| Total | 2.758 | 13 |  |  |  |

**3.4.2** **Pearson Product Moment Correlation of the Relationship of** **Heavy metals Between Upstream and Downstream in Water Sample of Iko River**

The result in Table 10 shows the relationship of heavy metals in the upstream and downstream water sample of Iko River. As shown in the table, an r-value of .435 was obtained for relationship, indicating a moderate relationship in the presence of heavy metal in the upstream and downstream water sample of Iko River. It implies that not all the metals have the same sources of enrichment (its moderate) (Mbong, 2015**)**

**Table 10: Pearson Product Moment Correlation of the Relationship of** **Heavy metals Between Upstream and Downstream in Water Sample of Iko River**

|  |  |  |
| --- | --- | --- |
| **Correlation**  | **Upstream** | **Downstream** |
| Upstream |  | 1 |  |
| Downstream |  | .435 | 1 |

**3.4.3** **Analysis of Variance of the Difference in** **Heavy metal in Sediment Sample of Iko River between Upstream and Downstream**

The result in Table 11 shows that the F-value of .775 for the difference in heavy metals in sediment sample of Iko River between upstream and downstream is not significant. This is because the p-value of .396 is greater than .05 at 1 and 12 degrees of freedom. Therefore, the amounts of heavy metal in sediment sample of Iko River between the upstream and downstream do not differ significantly. This is an indication that the sediment had been contaminated over time within the same level.

**Table 11: Analysis of Variance of the Difference in** **Heavy metal in Sediment Sample of Iko River between Upstream and Downstream**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sources of Variance** | **Sum of Squares** | **Df** | **Mean Square** | **F** | **Sig.** |
| Between Groups | 18.746 | 1 | 18.746 | .775 | .396 |
| Within Groups | 290.332 | 12 | 24.194 |  |  |
| Total | 309.078 | 13 |  |  |  |

**3.4.4** **Pearson Product Moment Correlation of the Relationship of** **Heavy metal in Sediment Sample of Iko River between Upstream and Downstream**

The result in Table 12 shows the relationship of heavy metals in the upstream and downstream sediment sample of Iko River. As shown in the table, an r-value of .992 was obtained for relationship, indicating a very high relationship in the presence of heavy metal in the upstream and downstream sediment sample of Iko River. There is likelihood of having the same sources of enrichment (Mbong, 2015**)**

**Table 12: Pearson Product Moment Correlation of the Relationship of** **Heavy metal in Sediment Sample of Iko River between Upstream and Downstream**

|  |  |  |
| --- | --- | --- |
| **Correlation** | **Upstream** | **Downstream** |
| Upstream |  | 1 |  |
| Downstream |  | .992\*\* | 1 |
| \*\*. Correlation is significant at the 0.01 level (2-tailed). |

**3.4.5** **Analysis of Variance of the Difference** **in** **Hydrocarbons (TPH) in Water Sample of** Iko **River between Upstream and Downstream**

The result in Table 13 shows that the F-value of 13.095 for the difference in hydrocarbons (TPH) in water sample of Iko River between upstream and downstream is significant. This is because the p-value of .007 is less than .05 at 1 and 12 degrees of freedom. Therefore, the presence of hydrocarbons (TPH) in the upstream and downstream water sample of Iko Rivers differ significantly. This could be attributed to proximity to crude oil contaminant (oil spillage) from the operating oil company (Mbong, 2015**)**

**Table 13: Analysis of Variance of the Difference** **in** **Hydrocarbons (TPH) in Water Sample of** Iko **River between Upstream and Downstream**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sources of Variance** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Between Groups | 7.973 | 1 | 7.973 | 13.095 | .007 |
| Within Groups | 4.871 | 8 | .609 |  |  |
| Total | 12.843 | 9 |  |  |  |

**3.4.6** **Pearson Product Moment Correlation of the Relationship of** **Hydrocarbons (TPH) in Water Sample of** Iko **River between Upstream and Downstream**

The result in Table 14 shows the relationship of hydrocarbons (TPH) in the upstream and downstream water sample of Iko River. As shown in the table, an r-value of .630 was obtained for relationship, indicating a high relationship in the presence of hydrocarbons (TPH) in the upstream and downstream water sample of Iko River. This implies having the same sources of enrichment (Ikpe *et al*., 2023**)**

**Table 14: Pearson Product Moment Correlation of the Relationship of** **Hydrocarbons (TPH) in Water Sample of** Iko **River between Upstream and Downstream**

|  |  |  |
| --- | --- | --- |
| Correlation | Upstream | Downstream |
| Upstream |  | 1 |  |
| Downstream |  | .630 | 1 |

**3.4.7 Analysis of Variance of the Difference** **in** **Hydrocarbons (THC) in Water Sample of** Iko **River between Upstream and Downstream**

 The result in Table 15 shows that the F-value of 201.358 for the difference in hydrocarbons (THC) in sediment sample of Iko River between upstream and downstream is significant. This is because the p-value of .000 is less than .05 at 1 and 8 degrees of freedom. Therefore, the amount of hydrocarbons (THC) in sediment sample of Iko River between the upstream and downstream differs significantly. This could be attributed to proximity to THC contaminant sources, especially from the downstream where there is an increase in human activities that can increase THC (Mbong, 2015**)**

**Table 15: Analysis of Variance of the Difference** **in** **Hydrocarbons (THC) in Water Sample of** Iko **River between Upstream and Downstream**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sources of Variance** | **Sum of Squares** | **Df** | **Mean Square** | **F** | **Sig.** |
| Between Groups | 83.585 | 1 | 83.585 | 201.358 | .000 |
| Within Groups | 3.321 | 8 | .415 |  |  |
| Total | 86.905 | 9 |  |  |  |

**3.4.8** Pearson **Product Moment Correlation of the Relationship of** **Hydrocarbons (THC) in Water Sample of** Iko **River between Upstream and Downstream**

The result in Table 16 shows the relationship of hydrocarbons (THC) in the upstream and downstream water sample of Iko River. As shown in the table, an r-value of .261 was obtained for relationship, indicating a low relationship in the presence of hydrocarbons (THC) in the upstream and downstream water sample of Iko River It implies that they do not have much related sources of enrichment (Mbong, 2015**)**

**Table 16: Pearson Product Moment Correlation of the Relationship of** **Hydrocarbons (THC) in Water Sample of** Iko **River Between Upstream and Downstream**

|  |  |  |
| --- | --- | --- |
| **Correlation** | **Upstream** | **Downstream** |
| Upstream |  | 1 |  |
| Downstream |  | .261 | 1 |

. **3.4.9 Analysis of Variance of the Difference** **in** **Hydrocarbons (TPH) in Sediment Sample of** Iko **River between Upstream and Downstream**

 The result in Table 17 shows that the F-value of 4.545 for the difference in hydrocarbons (TPH) in sediment sample of Iko River between upstream and downstream is not significant. This is because the p-value of .066 is greater than .05 at 1 and 8 degrees of freedom. Therefore, the amount of hydrocarbons in sediment sample of Iko River between the upstream and downstream does not differ significantly. This could be attributed to accumulation of contaminant overtime because according to Ademoroti (1996) sediment remains pollutant sink.

**Table 17: Analysis of Variance of the Difference** **in** **Hydrocarbons (TPH) in Sediment Sample of** Iko **River between Upstream and Downstream**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sources of Variance** | **Sum of Squares** | **Df** | **Mean Square** | **F** | **Sig.** |
| Between Groups | 13941.935 | 1 | 13941.935 | 4.545 | .066 |
| Within Groups | 24539.274 | 8 | 3067.409 |  |  |
| Total | 38481.209 | 9 |  |  |  |

**3.4.10 Pearson Product Moment Correlation of the Relationship of** **Hydrocarbons (TPH) in Sediment Sample of** Iko **River between Upstream and Downstream**

The result in Table 18 shows the relationship of hydrocarbons (TPH) in the upstream and downstream sediment sample of Iko River. As shown in the table, an r-value of .129 was obtained for relationship, indicating a low relationship in the presence of hydrocarbons (TPH) in the upstream and downstream sediment sample of Iko River. There is likelihood of sharing very small sources of enrichment. (Mbong, 2015**)**

**Table 18: Pearson Product Moment Correlation of the Relationship of** **Hydrocarbons (TPH) in Sediment Sample of** Iko **River between Upstream and Downstream**

|  |  |  |
| --- | --- | --- |
| **Correlation** | **Upstream** | **Downstream** |
| Upstream |  | 1 |  |
| Downstream |  | .129 | 1 |

**3.4.11 Analysis of Variance of the Difference** **in** **Hydrocarbons (THC) in Sediment Sample of Iko River between Upstream and Downstream**

 The result in Table 19 shows that the F-value of 431.529 for the difference in hydrocarbons (THC) in sediment sample of Iko River between upstream and downstream is significant. This is because the p-value of .000 is greater than .05 at 1 and 8 degrees of freedom. Therefore, the amount of hydrocarbons (THC) in sediment sample of Iko River between the upstream and downstream differs significantly. It could be attributed to proximity to contaminant sources, which can lead to a significant increase (Mbong, 2015, Ikpe *et al*., 2023**)**

**Table 19: Analysis of Variance of the Difference** **in** **Hydrocarbons (THC) in Sediment Sample of Iko River between Upstream and Downstream**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sources of Variance** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Between Groups | 6438724.000 | 1 | 6438724.000 | 431.539 | .000 |
| Within Groups | 119363.112 | 8 | 14920.389 |  |  |
| Total | 6558087.111 | 9 |  |  |  |

**3.4.12 Pearson Product Moment Correlation of the Relationship of** **Hydrocarbons (THC) in Sediment Sample of** Iko **River between Upstream and Downstream**

 The result in Table 20 shows the relationship of hydrocarbons (THC) in the upstream and downstream sediment sample of Iko River. As shown in the table, an r-value of -.754 was obtained for relationship, indicating a high negative relationship in the presence of hydrocarbons (THC) in the upstream and downstream sediment sample of Iko River. This implies that they do not have same sources of enrichment (Mbong, 2015**)**

**Table 20: Pearson Product Moment Correlation of the Relationship of** **Hydrocarbons (THC) in Sediment Sample of** Iko **River between Upstream and Downstream**

|  |  |  |
| --- | --- | --- |
| **Correlation** | **Upstream** | **Downstream** |
| Upstream |  | 1 |  |
| Downstream |  | -.754 | 1 |

**4.0 Conclusion and Recommendation**

**4.1 Conclusion;** This research was carried out to assess the levels of heavy metals, TPH and THC in the up and downstream of the sediment and water body of Iko River and its environs. Also heavy metals and hydrocarbons were statistically compared using ANOVAs and Pearson product moment correlation coefficient to compare the significant differences and the relationship respectively**.** The result has helped in ascertaining the quality of water and seafood’s for human consumption and aquaculture. Moreso, it has created an awareness which has provided information on the distribution assessment of TPH, THC and Heavy metals, as well as the effect of petroleum exploitation and other human activities on marine environment (biota). This study has provided valuable information for health workers officials, environmentalist and government for their planning and policy making

**4.2; Recommendations**

**i. Further research should be conducted on** Modelling the levels of heavy metals and hydrocarbons between the up and downstream biota and water body of Iko River during dry and wet season.

ii. The government must ensure that the Environmental impact assessment (EIA) and post EIA of the operating oil companies in Iko town , Eastern Obolo L.G.A and its environment are fully implemented in order to ameliorate the pollution level in the area thereby safeguarding the health of the inhabitants.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, manuscript.

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