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Physicochemical Characterization and Statistical Source Apportionment of Effluents of the Indorama Eleme Petrochemical Industry and their effects on the water quality of Ekerekana River in Nigeria

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Abstract: ***The petrochemical industry is a strategic center of the South Africa economy, but the externalities of the activity are often observed in the form of critical environmental harm. This paper is a physicochemical evaluation and statistical source apportionment of effluents released into the Ekerekana River, which is a vital hydrology in Ekerekana Local Government of Rivers state by the Indorama Eleme Petrochemical Limited (IEPL). Four georeferenced sampled stations were used to gather water in the dry season (November), and were based on the following: the Outfall Basin (Point of Discharge), 100m Downstream, 200m Downstream and Control Station 100m Upstream. The paper has evaluated 16 parameters, such as pH, Electrical Conductivity (EC), Total Dissolved Solids, TSS, Biochemical Oxygen Demand (BOD), Total Petroleum Hydrocarbons, TPH and heavy metals (Lead and Iron) and was conducted using APHA and ASTM standard media protocols.***

Findings indicate that there is a serious pollution incident at the mixing zone. The effluent discharge was also highly salty (EC: 10,400 -1 cm; TDS: 7,280 gr/l), organic load (BOD: 80 mg/l) and acidic (pH 5.28). There was a total of 17 mg/l of Total Petroleum Hydrocarbon (TPH) at the discharge point which is 70 times higher than the 10 mg/l of NESREA. The analysis of heavy metals showed that the Level of Lead (Pb) in the outfall was 0.052 mg/l which exceeds the WHO recommended concentration of 0.01mg/l that is very dangerous because it is a neurotoxicant. The Pearson Correlation showed that EC, TDS, Sulphate and Iron were well correlated (r > 0.90) to ascertain that the origin of these contaminant was due to one point-source. This research is found to conclude that the Ekerekana River is at present functioning as a sink of waste instead of being a feasible aquatic environment within the discharge area. Although dilution reduces certain those

parameters down the line, the continued burden of the recalcitrant pollutants demand the urgent upgrading of the Effluent Treatment Plant (ETP) and strict enforcement of the regulations.

Keywords: Petrochemical Effluents, Water Quality Index, Ekerekana River, Total Petroleum Hydrocarbon, Heavy Metal Bioaccumulation, Environmental Impact Assessment, Pearson Correlation.

1.0 INTRODUCTION

1.1 Background of the Study

The interplay between industrialization and ecological sustainability is perhaps the most debatable issue in the third world. A major part of the world manufacturing industry is that of petrochemicals, in particular, which convert the petroleum distillates and natural gas into chemical of crucial products used in modern society- plastic and synthetic fibers, as well as fertilizers, plastics, and pharmaceuticals (Adeniyi & Afolabi, 2002). The petrochemical industry in Nigeria is strategically placed to tap into the huge sources of the hydrocarbon resources in the country, which are the estimated 37 billion barrels of crude oils, as well as 206 trillion cubic feet of natural gas. Due to this, the facilities such as the Indorama Eleme Petrochemical Limited (IEPL) are the key to the national economic diversification strategy.

Nevertheless, the production of the petrochemical products is a complex chemical process that requires cracking, distillation, and polymerization. The results of these processes are large amounts of waste water, which are technically known as effluents. These effluents are chemically compound cocktails related to phenols, aromatic hydrocarbons, suspended solids, heavy metals, and organic matter having high oxygen demand. In case these effluents are released in fresh waters or brackish ecosystems without proper treatment, they cause a series of adverse ecological events (Chapman, 1996). There is usually thermal pollution, eutrophication, inhibition of oxygen, as well as the bioaccumulation of dangerous metals in the food web, in the water bodies receiving them.

The problems of the environment are now central issues of political debate on an international scale, which lead to the United Nations Sustainable Development Goals (in particular SDG 6: Clean Water and Sanitation and SDG 14: Life Below Water). Niger Delta in Nigeria has a long history of pollution narrative that has centered on crude oil spills due to exploration. Nevertheless, the chronic and insidious effect of point-source effluent discharge by processing plants has not received much research as compared to its aggregate effect.

1.2 Statement of the Problem

The Okrika-speaking communities rely heavily on the Ekerekana River as both an artisanal source of fishing and domestic transportation as well as sustaining their home communities. The river is the main recipient of the industrial runoffs within an area adjacent to the IEPL complex despite its significance. Anecdotal evidence by the host community has included frequent fish kills, water of bad smell, and irritation of the skin of the bathers.

Although the fact of pollution in the Niger Delta has already been proven earlier, there is a definite Research Gap in terms of chemical fingerprinting of the IEPL effluent of the present year of operation. Additionally, in a significant number of the existing studies, there was a lack of the use of sophisticated statistical data to establish a definite relationship of downstream pollution loading to individual upstream discharge sources, confusing industrial inputs with overall urban runoff. The imminent need is to measure how badly the modern practices of discharge are going above the regulatory limits that are stipulated by the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the health impacts of certain toxicants such as Lead and Petroleum Hydrocarbons.

1.3 Research Objectives

The main purpose of this research is to compare the environmental health level in the Ekerekana river and the discharge of effluents in the Indorama Eleme Petrochemical Industry. The specific objectives are:

1. **Physicochemical Characterization:** To establish the concentration of pH, Conductivity, TDS, TSS, Alkalinity, Sulphate and Phosphate in the effluent discharged and the receiving water.
2. **Toxicological Assessment:** To determine the amount of Total Petroleum Hydrocarbons (TPH) and trace metals (Lead and Iron) in order to determine risks of acute toxicity.
3. **Spatial Mapping:** To measure the dilution or the longevity of the pollutants released at the source up to downstream areas.
4. **Statistical Source Apportionment:** To use Pearson correlation Matrices to establish the inter-relationships among the parameters of pollutants in order to ascertain the source of contamination.
5. **Regulatory Compliance:** To compare the results with the NESREA and WHO standards with the purpose to identify the legal and ecological liability of the discharge.

1.4 Significance of the Study

The results of this study are critical to various stakeholders. In the case of the regulatory authorities (NESREA, DPR), it presents autonomous empirical information to implement the Polluter Pays Principle. In case of Indorama Eleme Petrochemical Limited, it is the audit of the efficiency of their Effluent Treatment Plant (ETP) and areas that should be upgraded technically are brought to notice. To the host communities of Okrika and Eleme, the study is providing a scientific validation of their environmental grievances, as a means of advocacy and interventions on their health. Lastly, this research makes a contribution on the academic front in terms of providing the baseline information needed in conducting longitudinal monitoring of the water bodies in the Niger Delta.

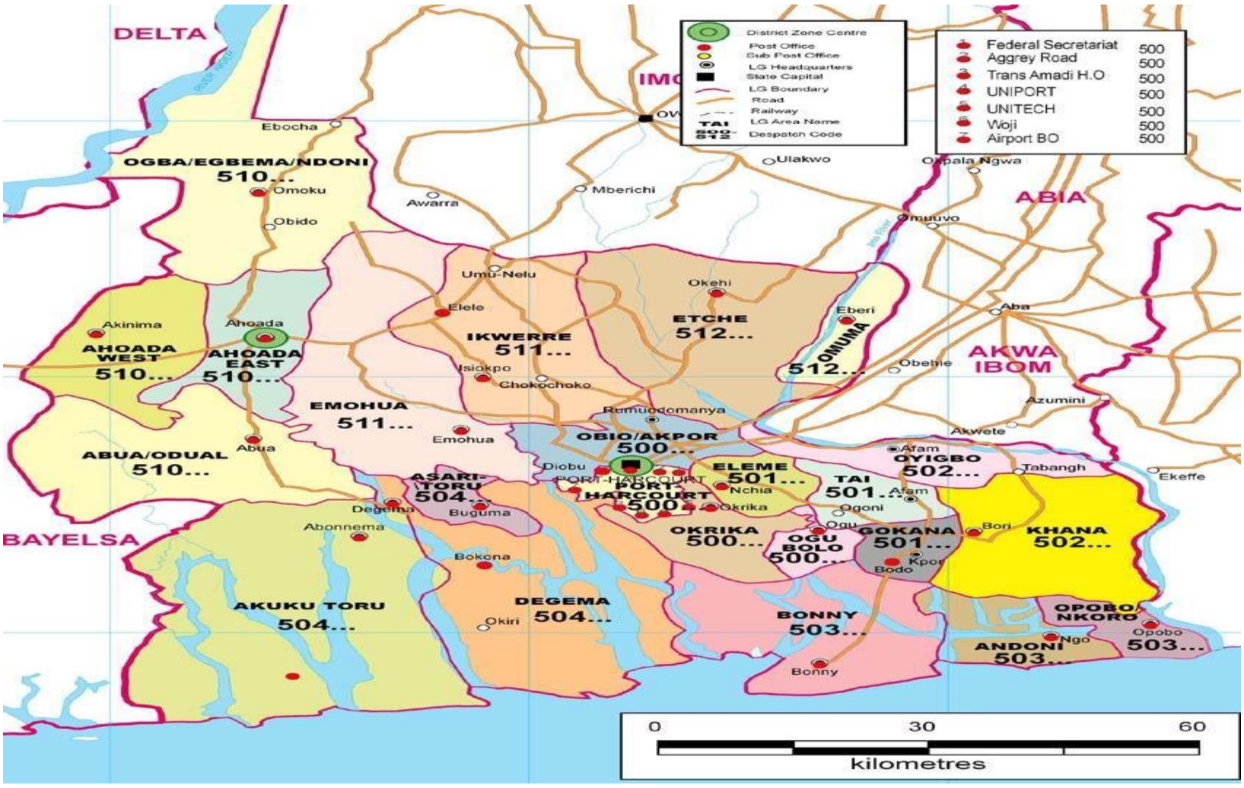

Figure 1: Map of Rivers state

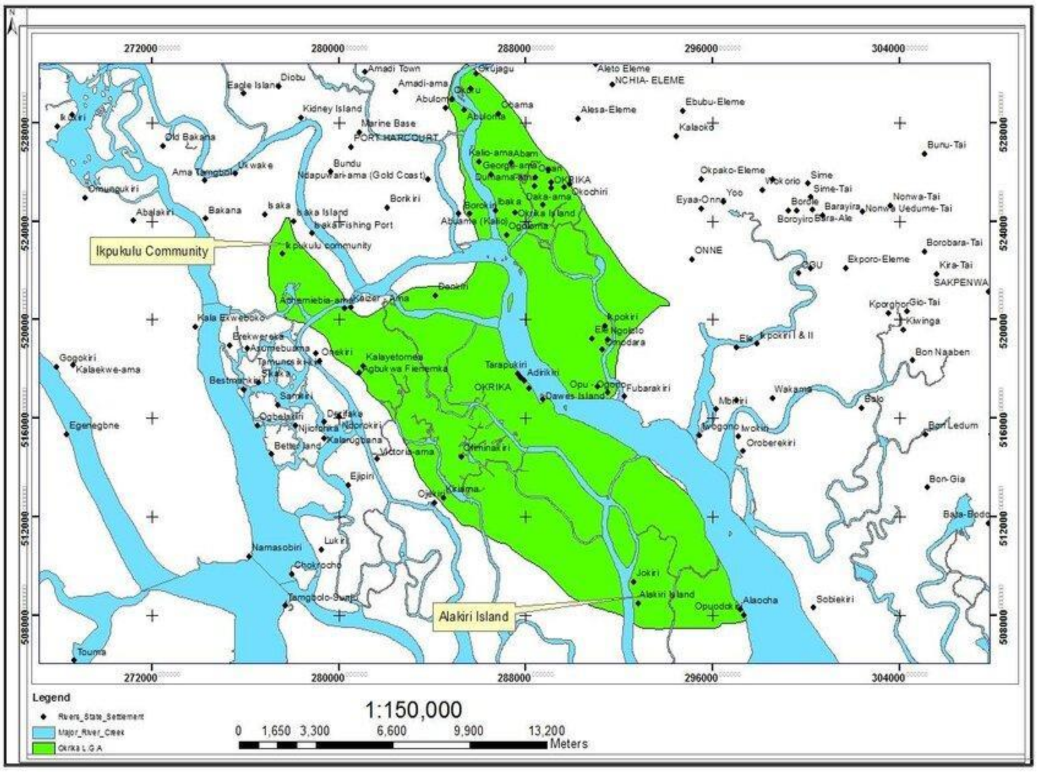

Figure 2: Map of Okirika

2.0 LITERATURE REVIEW

2.1 The Chemistry of Petrochemical Effluents

The petrochemical effluents differ with the general municipal sewage, because of the recalcitrant nature. Archer (1990) defines these wastes as the liquid-form waste as having three streams namely cooling water (thermal pollution), process water (chemical pollution), and the runoff of stormwater.

The chemical issue of concern is that of polycyclic aromatic hydrocarbons (PAHs) and other petroleum derivatives that are quantified as Total Petroleum Hydrocarbons (TPH). Hydrocarbons are non-soluble in water and the hydrophilic lipophilic substances in water, the hydrocarbons would be partitioned into the sediment or discussed to be surface films the hydrocarbons would be an obstacle to oxygen exchange between air and water. According to Okoh et al. (2002), the dissolved hydrocarbons even in low amounts can result in narcosis in the fish and can also contaminate the flavor of the seafood that will become unworthy economically.

2.2 Heavy Metal Toxicity and Bioaccumulation

It is irreversible when the heavy metals are introduced into the water. Metals are indestructible unlike organic pollutants that can degrade through bacterial activity (biodegradation).

- **Lead (Pb):** Lead is another non-essential and a very poisonous meteor. Pb accumulates in gills, liver, and kidney of the fish in the aquatic environment. In human beings, neurotoxicity is associated with the ingestion of fish or Pb-contaminated water. The WHO (2011) clearly explains this by saying that the amount of safe blood lead is unknown; it damages the central nervous system (CNS) of the body causing cognitive impairment on children and hypertension on adults.

- **Iron (Fe):** Although Iron is a vital micronutrient, excessive amounts of the same in an industrial context (more than 1.0 mg/l) are not favorable. Ferrous iron (Fe 2) in oxygenated waters is oxidized to ferric iron (Fe 3), producing ferric hydroxide (Fe (OH) 3 combines insoluble precipitated part. This yellow boy is a precipitate which results in high turbidity and may suffocate the benthic organisms and fish eggs and as such, results in a fish population recruitment collapse (Aina & Adedipe, 1996).

2.3 Organic Load and Oxygen Sag

A river is considered to be healthy when it contains a lot of Dissolved Oxygen (DO). Rich effluents of organic matter cause a Biochemical Oxygen Demand (BOD) of the river. The decomposing aerobic bacteria use up the oxygen in the river by decomposing the organic waste. When there is a high level of the BOD (which is normal in the untreated industrial waste), the DO may reduce to hypoxic states (or below 2 mg/l) leading to catastrophic fish kills. The resultant phenomenon is the Oxygen Sag Curve. According to Chapman, (1996) anything above 10 mg/l in river water means that there is gross pollution.

2.4 Previous Studies in the Niger Delta

Different researches have pointed to erosion of the Niger Delta. In another study, Otokunefor and Obiukwu (2005) examined the refinery effluents in the region and established that, even with the structure of rules and regulations, there is a low compliance. In the same way, an investigation into the Bonny River system indicated that the tidal forces tend to cascade the pollutants to the upper part of the rivers, and this makes the rivers difficult to purify themselves. Nonetheless, recent chemical profile information of the Ekerekana creek in comparison to the increased size of the Indorama plant is limited which provides the gap that this study fills in.

3.0 MATERIALS AND METHODOLOGY

3.1 Description of Study Area

The research was done in Okrika Local Government Area of Rivers State. The core point is the Ekerekana River which is a tributary part of the Bonny River system.

- **Location:** Latitude 04° 44’ N and Longitude 07° 05’ E.
- **Climate:** Sub-equatorial which is humid (>50%) and receives a lot of rainfall (>3,000mm/year).
- **Hydrology:** The drainage channel is the Indorama Eleme Petrochemical Limited (IEPL) which channels the drainage to the river. It is tidal creek, that is, the directions of the flows may change depending upon the tide, which affects the dispersion of the pollutants.
- **Vegetation:** Mangrove swamp forest (Rhizophora spp.) is also used to line the banks and provides a habitat to aquatic life as well as entraps sediments and pollutants.

3.2 Sampling Strategy

A purposeful sampling strategy was implemented to make it representative. They were classified as four (4) stations:

1. **Station A (SLA) - Outfall Basin:** The point at which the drainage pipe in the facility empties into the environment.
2. **Station B (SLB) - 100m Downstream:** Designated to check the mixed zone right away.
3. **Station C (SLC) - 200m Downstream:** The dispersion and dilution of pollutants were determined using Chosen to measure pollutants.
4. **Station D (SLD) - 100m Upstream:** This is used as Control Station. As it is upstream of the discharge, it reflects of the river quality of background.

3.3 Sample Collection and Preservation

Severe QA/QC measures were followed:

- **Physicochemical Samples:** Collected in 1 liter plastic containers. The containers containing the sample were washed in advance with non- ionic detergent and washed thrice with the sample water and then filled.
- **Heavy Metal Samples:** Front filtered into acid-washed Bottles immediately using 2ml of Concentrated Nitric Acid (HNO3) to reduce the PH to less than 2 and thus ensure the sample is not adsorbed to the metal walls of the containers.
- **BOD Samples:** A dark glass bottle was used to collect the samples, and they were filled to capacity to remove air bubbles and placed in an ice chest with 4C to stop the presence of any biological activity.**TPH Samples:** Mass-produced in glass bottles with Teflon-lined caps to avoid the sorption of hydrocarbons to plastic.

3.4 Laboratory Analysis Procedures

All analyses followed the *Standard Methods for the Examination of Water and Wastewater* (APHA, 2012) and ASTM standards.

1. **In-situ Measurements:** pH and Temperature were measured on-site using a Hanna Multi-parameter probe.
2. **Electrical Conductivity (EC):** Measured using a Conductivity Bridge Meter.
3. **Total Suspended Solids (TSS):** Gravimetric method (filtering through 0.45µm filter and drying at 105°C).
4. **Biochemical Oxygen Demand (BOD):** Winkler's Azide Modification method (incubation for 5 days at 20°C).
5. **Sulphate** Turbidimetric method using Barium Chloride.
6. **Phosphate** Ascorbic Acid spectrophotometric method.
7. **Heavy Metals (Pb, Fe):** Atomic Absorption Spectrophotometry (AAS) using an Air-Acetylene flame (Model: Perkin Elmer 400).
8. **Total Petroleum Hydrocarbons (TPH):** Gas Chromatography (GC-FID) after extracting the solvents with Dichloromethane.

3.5 Statistical Analysis

Data were examined with the help of Microsoft Excel and SPSS (v25).

- **Descriptive Statistics:** Mean, Standard Deviation, range.
- **ANOVA:** ANOVA to test between the stations.
- **Pearson Correlation:** To determine whether various pollutant parameters have the same source, a correlation matrix was created to establish the strength and nature of correlation along with the direction of relationship between various pollutant parameters.

4.0 RESULTS

4.1 Physiochemical Profile

Table 1 below describes the outcomes of the lab analysis comparing the achieved results in all four of the stations and the regulatory limits established by NESREA (National Environmental Standards and Regulations Enforcement Agency)

Table 1: Physicochemical Parameters, TPH, and Trace Metals in Ekerekana River

Parameters	SLA (Outfall)	SLB (100m Down)	SLC (200m Down)	SLD (Control)	NESREA Limit	Status (SLA)
Temperature (°C)	25.8	25.8	25.8	25.8	< 40	Compliant

pH	5.28	5.51	6.39	6.28	6.5 - 8.5	**Non-Compliant**
Alkalinity (mg/l)	70	50	38	20	< 100	Compliant
EC (µS/cm)	10,400	470	450	40	1,000	**Critical Violation**
TDS (mg/l)	7,280	329	336	20	2,000	**Critical Violation**
TSS (mg/l)	41	17	25	18	30	**Non-Compliant**
TPH (mg/l)	17	13	10	7	10	**Non-Compliant**
Sulphate (mg/l)	310	52	60	6.2	200	**Non-Compliant**
Phosphate (mg/l)	6.2	5.1	5.9	3.4	5.0	**Non-Compliant**
BOD (mg/l)	80	64	57	48	50	**Non-Compliant**
Lead (Pb) (mg/l)	0.052	<0.001	<0.001	<0.001	0.05	**Marginal Violation**
Iron (Fe) (mg/l)	1.219	0.634	0.063	0.278	1.0	**Non-Compliant**

Table 2: Descriptive Statistics Summary

Parameter	N	Minimum	Maximum	Mean	Std. Error
pH	4	5.28	6.39	5.86	0.276
EC	4	40	10,400	2,840.0	2,521.9
TDS	4	20	7,280	1,991.3	1,764.5
TPH	4	7	17	11.8	2.14
Sulphate	4	6.2	310	107.1	68.68
BOD	4	48	80	62.3	6.76
Iron	4	0.063	1.219	0.549	0.253

4.2 Statistical Source Apportionment (Pearson Correlation)

A Pearson Correlation Matrix was calculated in order to know the inter-relationships between the pollutants. Both parameters with similar values such as high positive values (that is, close to +1.0) imply that they have a shared source (that is, the effluent).

Table 3: Pearson Correlation Matrix of Key Pollutants

	pH	EC	TDS	TPH	Sulphate	Iron	Lead
pH	1.000						
EC	-0.875	1.000					
TDS	-0.874	**0.999**	1.000				
TPH	-0.923	0.945	0.943	1.000			
Sulphate	-0.845	**0.998**	**0.997**	0.925	1.000		
Iron	-0.790	0.942	0.946	0.884	0.938	1.000	
Lead	-0.812	0.941	0.943	0.890	0.931	**0.991**	1.000

Statistical Interpretation:

- **Strong Positive Correlation:** EC, TDS, and Sulphate are strongly correlated (r) with almost perfection (r = + 0.99). This statistically proves that the ionic load and salinity in the river is entirely under the discharge of industrial, which has sulphates.
- **Heavy Metal Association:** There is a really close correlation between Lead and Iron (r=0.991). This indicates that they are co-contaminants that emanate inherently in the same stream process in the plant (most probably equipment corrosion or catalyst wastes).
- **Hydrocarbon Link:** TPH is also strongly linked with EC (r = 0.945) meaning that hydrocarbon contamination is not a separate spill incident but it is contained in the major stream of effluents.
- **pH Inverse Relationship:** The correlation between pH and all pollutants (e.g., pH vs TPH = -0.923) is negative, which proves that the higher the concentration of pollutants (at the outflow), the lower the pH (the lower the levels of acidity).

4.3 Spatial Analysis and Data Visualization Descriptions

The trends of visual data followed during the graphical analysis of the study are as follows.

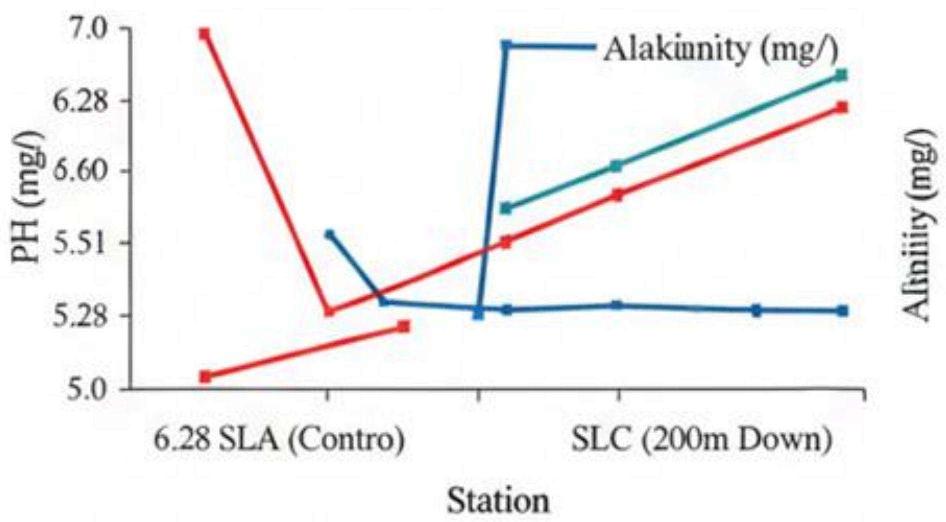

Figure 3: Spatial Variation in pH and Alkalinity

It can be seen in the data trend that there is a drastic acidification at the discharge position. Whereas Control Station (SLD) has a pH of 6.28, the pH of Outfall (SLA) is lowered down to 5.28. It is a logarithmic change of acidity. The outflow level, though, has the highest level of alkalinity (70 mg/l), which serves as a buffer. The pH returns to 6.39 as the water flows 200m down the river (SLC) and this indicates the natural buffering capacity (the river) and dilution (through tidal mixing) of the river.

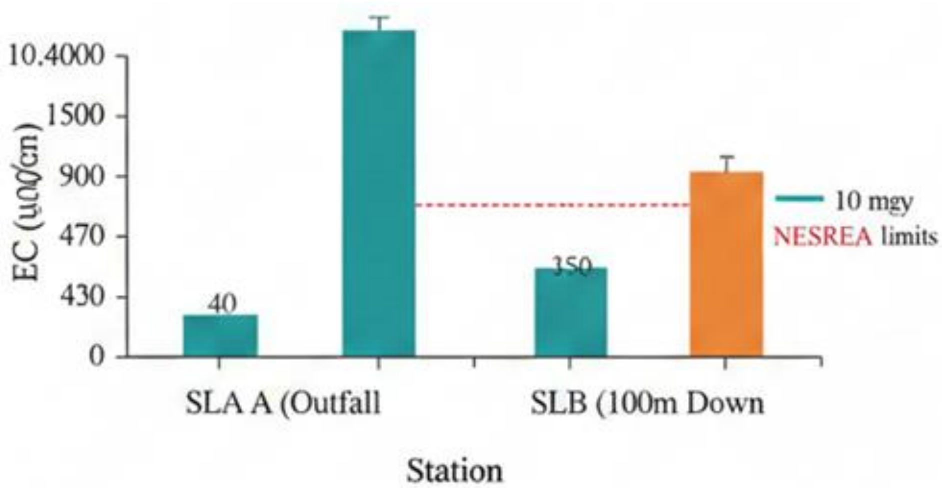

Figure 4: Spatial Variation in Conductivity (EC) and TDS

This character can be considered the most dramatic evidence of industrial influence. At Station A (EC: 10,400 µS/cm) a big spike is evident. This forms a so-called hyper-saline plume at the point of discharge. The control station EC is merely 40 0 mS/cm. The central tendency of the semi-decay of this curve at Station B (470 µS/cm) means either very turbulent mixing or very rapid settling of dissolved solids but the initial shock to aquatic life at Point A is indisputable.

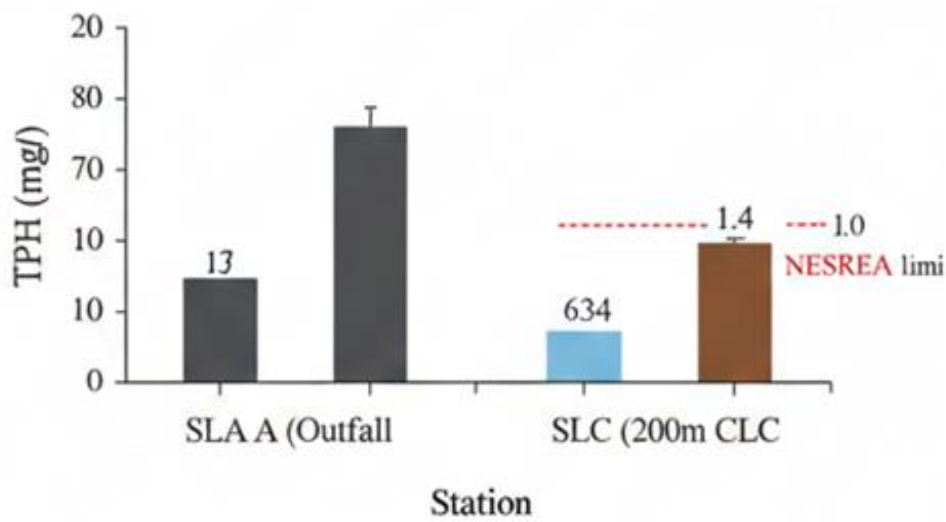

Figure 5: Spatial Variation in Total Petroleum Hydrocarbons (TPH)

The TPH bar chart demonstrates that there is an evident gradient. It begins at 17 mg/l at the Outfall, reduced to 13mg/l (100m) and 10mg/l (200m). It is worth noting that even in the control station, there is 7 mg/l. The presence of this contamination at this baseline indicates that there is a general oil pollution of the wider Ekerekana creek (probably due to bunkering or boat traffic), but a fresh load of 10 mg/l of the IEPL comes on top of this base.

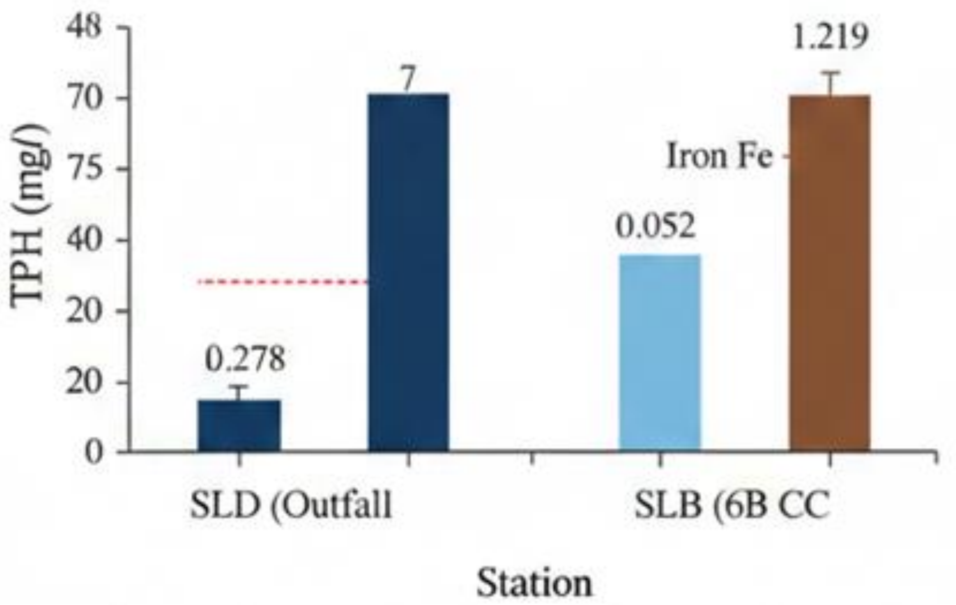

Figure 6: Spatial Variation in Trace Metals (Pb and Fe)

The only element that is found in high amounts is the lead (Pb) at the Outfall (0.052 mg/l). It becomes untraceable (below 0.001 mg/l) further downstream, suggesting that the lead is probably getting out of the water column and depositing in the sediment very close to the discharge point. This presents a long-term threat of benthic (bottom-dwelling) organisms. The same case can be observed with iron where its maximum value is 1.219 mg/l at the source.

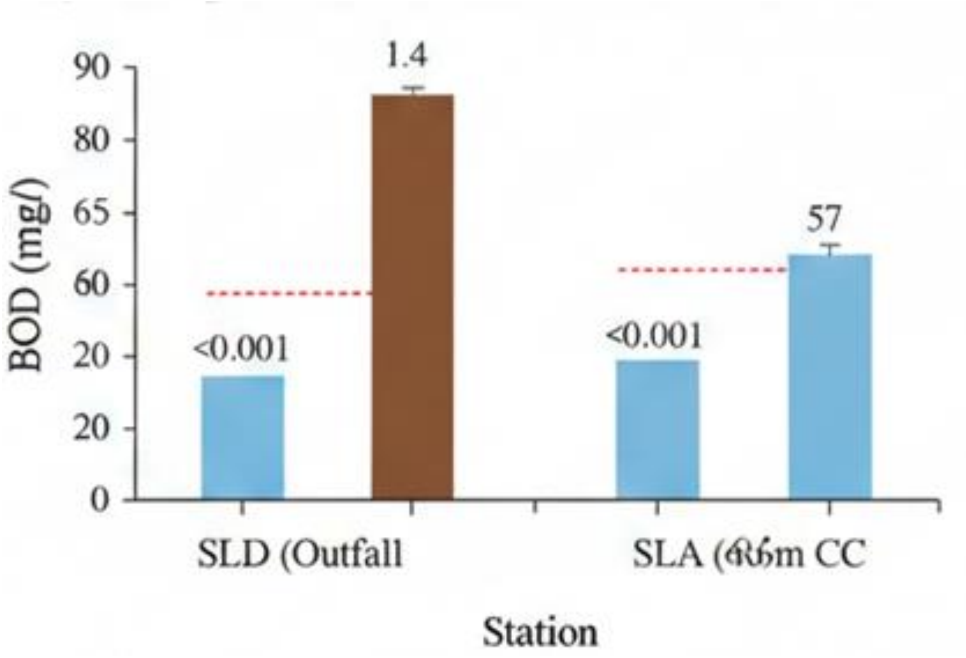

Figure 7: Spatial Variation in Biochemical Oxygen Demand (BOD)

According to BOD graph, the level of BOD is high at all the stations. The outflow (80mg/l) is almost two times as that of the upstream (48mg/l). This means that the effluent is of high concentration of biodegradable organic increasing the oxygen utilization of the water liable to an oxidizing effect of the water thus forming an oxidizing sag that is life threatening to the fish.

5.0 DISCUSSION

5.1 Physicochemical Implications

The outcomes of this research represent a worrying trend of the water quality of Ekerekana River. The discharge point has a pH of 5.28 which is acidic. Acid waters have a propensity of increasing the mobilization of heavy metals within the sediment and hence become more accessible and toxic to fish. The NESREA standard gives a pH ranging of 6.5 to 8.5, therefore, the effluent does not match with the requirement.

The values in the outfall of Electrical Conductivity (EC) and total dissolved solids (TDS) are extremely high (10,400 µS/cm). Contextually, freshwater fish usually grows well in water whose EC gets below 1,000 µS/cm. The introduction of such water with high conductivity causes an osmotic shock. The fish and invertebrates that enter this "Mixing Zone" would see their cells (plasmolysis)dry up very fast resulting in death or extreme stress. The correlation ($r = 0.998$) between EC and Sulphate indicates that it is sulfuric acid neutralization or Sulphate-rich salts introduced in the cooling towers or scrubbers of the plant that is the most likely source of such salinity.

5.2 Organic Pollution and Eutrophication

It is important to note that these elements occur as a result of human activities such as organic pollution and eutrophication, which are environmental factors. It should be noted that organic pollution and eutrophication take place due to human actions like the environmental factors, which are organic pollution and eutrophication.

BOD is regularly elevated (4880 mg/l). BOD of natural waters is less than 5mg/l. BOD is high, pointing out to the existence of heavy load of organic carbon. Bacteria decompose this garbage, thereby depriving the water of oxygen. That is why the community reports on the occurrence of dead fish because the aquatic life actually suffocates. Additionally, the Phosphate concentration (3.462 mg/l) is also large enough to cause eutrophication. Phosphate is normally the limiting nutrient in freshwaters and any excessive supply leads to algal blooms that on death and decay adds further depletion of oxygen.

5.3 Toxicity: Hydrocarbons and Lead

The observation of the Total Petroleum Hydrocarbons (TPH) of 17 mg/l is of the essence. Hydrocarbons have carcinogenic toxic aromatic compounds (such as benzene and toluene). The spatial analysis indicates that as TPH declines downstream, it is at NESREA limit (10 mg/l) even 200m downstream. This indicates that delicate fractions are either evaporating or diluting and probably, the heavier fractions are settling.

The lead (Pb) level was 0.052 mg/l which is higher than the 0.05 mg/l as NESREA limit and the 0.01 WHO limit. Lead is a cumulative toxin. The fact that it is present at the outfall indicates that the source of the fact is the plant. Although present in the water column was not detected in the downstream, this is probably due to the quick adsorption of lead with suspended solids (also high at 41 mg/l) followed by the absence of it within the column. This is not to say that the lead is no longer there it is merely moved onto the sediment where it will finally find its way into the food chain by bottom-feeding fish and crabs and hence ultimately make it into the hands of the human.

5.4 Limitations of the Study

Scientifically it is only good practice to be aware of the limitations of this research.

1. **Seasonality:** The ground work was done during one month (November) only (early dry season). This is a cross-sectional research. This leads to the fact that the findings do not reflect the seasonal variation of pollutants levels. The heavy rainfall experienced during the wet season may cause a dilution effect that may reduce the recorded concentrations or vice versa, which will be large-scale treatment of the surface runoff (flush-out). Limitation of the wet-season data limits the generalizability of these results in the whole hydrological year.
2. **Sediment Analysis:** The experiment was concerned with water column. Nevertheless, with the characteristics of the heavy metals (Pb) and the heavy hydrocarbons consistency of settling it is possible to have a lot more accumulation levels historically than the water analysis indicates.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This paper examined the physicochemical properties of chemotreatment plants of the Indorama Eleme Petrochemical Limited (IEPL) and their effect on the Ekerekana River.

- **The River is Compromised:** The research paper concludes that there is a high level of contamination of the Ekerekana River where the industry releases its discharge. The effluent is a source-point of acidity (pH 5.28), extreme salinity (TDS 7,280 mg/l), organic pollution (BOD 80 mg/l) and toxicity (Pb 0.052mg/l, TPH 17mg/l).
- **Source Confirmation:** The close statistical relations (Pearson r =0.9) between these parameters also testify that they are a result of one stream of industrial activity and are not just noise.
- **Regulatory Failure:** All the major parameters at the discharge point were not in accordance to the NESREA and DPR allowable limits. This means that the Effluent Treatment Plant (ETP) of the facility is not properly-designed to accommodate the number of volumes of production that are running or it was not running well during the time when the samples were taken.
- **Public Health Threat:** The existence of neurotoxic lead and carcinogenic hydrocarbons poses a direct danger to the aquatic biodiversity and indirect danger to the Okrika population who depend on the river as a source of food.

6.2 Recommendations

1. **Immediate ETP Audit:** The sieging management of IEPL should carry a technical audit on their Effluent Treatment Plant. When TPH is high, this shows the oil-water separators (API separators) are not functioning properly and when BOD and TSS are high, it shows that there is a lack of biological treatment (aeration).

2. **Advanced Treatment Implementation:** The facility ought to adopt tertiary treatment procedures, including Activated Carbon Adsorption (to filter TPH and colour) and Reverse Osmosis or Ion Exchange to cut the enormous Conductivity/TDS load as required by NESREA standards.

3. **Sediment Remediation:** Since there are chances that heavy metal settles, an evaluation of its sediment level should be performed. In case the riverbed contains high levels of lead, the mixing zone in the riverbed may require dredging and remediation.

4. **Continuous Monitoring:** NESREA, regulatory bodies, and/or DPR should make installation of automatic water quality monitoring at the Outfall Basin real-time and automated. This will exclude cold dumping of wastes (discharge of completely raw wastes in the night) and 24-hour compliance.

5. **Community Health Study:** It is advised that a specific epidemiological research is conducted within Ekerekana community, as a way of screening lead toxicity symptoms and exposure to other human causing hydrocarbons, to make the human cost of this pollution quantifiable and respond to it.

References

1. Adeniyi, A. K., & Afolabi, A. S. (2002). Determination of total petroleum hydrocarbons and heavy metalss in soils within the vicinity of facilities handling refined petroleum products in Lagos metropolis. Environment International, 28(1-2), 79-82.
2. Aina, E. O. A., & Adedipe, N. O. (1996). Water Quality Monitoring and Environmental Status in Nigeria. FEPA Monograph 6. Federal Environmental Protection Agency, Abuja.
3. American Public Health Association (APHA). (2012). Standard Methods for the Examination of Water and Wastewater (22nd ed.). Washington, DC: APHA/AWWA/WEF.
4. Archer, A. B. (1990). Wastewater Treatment and Disposal. Pergamon Press, Oxford.
5. Chapman, D. (1996). Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring (2nd ed.). UNESCO/WHO/UNEP. E & FN Spon.
6. Department of Petroleum Resources (DPR). (1991). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN). Ministry of Petroleum Resources, Lagos.
7. Federal Environmental Protection Agency (FEPA). (1991). Guidelines and Standards for Environmental Pollution Control in Nigeria. Decree 58, Federal Republic of Nigeria.
8. Lloyd, B., & Helmer, R. (1991). Surveillance of Drinking Water Quality in Rural Areas. Longman Scientific and Technical/WHO.
9. National Environmental Standards and Regulations Enforcement Agency (NESREA). (2011). National Environmental (Surface and Groundwater Quality Control) Regulations. Federal Republic of Nigeria Official Gazette.
10. Okoh, A. I., Babalola, G. O., & Bakare, M. K. (2002). Microbial densities and physicochemical quality of some boreholes in major settlements in Osun State, Nigeria. African Journal of Biotechnology, 2(7), 173-178.
11. Otokunefor, T. V., & Obiukwu, C. (2005). Impact of refinery effluent on the physicochemical properties of a water body in the Niger Delta. Applied Ecology and Environmental Research, 3(1), 61-72.
12. World Health Organization (WHO). (2011). Guidelines for Drinking-water Quality (4th ed.). Geneva: WHO Press.

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RESEARCH AREA

- **Investigation of the impact of solid waste landfill on ground water and soil.**
- **Investigation and impact of mining on the Environment and potential health effects.**
- **Investigation and impacts of heavy metals on the environment and potential health effects.**
- **Investigation and assessment of oil spill on soil and water.**
- **Evaluation of Erosion on the environment.**
- **Assessment of water quality and its potability status.**

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