INVESTIGATION OF NORMAL HYDROCARBON CONTENTS ON SOIL AT SELECTED INDUSTRIAL DISCHARGE POINTS IN RIVERS STATE

IZIONWORU, VINCENT ONUEGBU; UKPAKA, CHUKWUEMEKA PETER AND EEMELE VICTOR

ABSTRACT

This study determined the composition of Polycyclic Aromatic Hydrocarbon (PAH) in soil polluted with industrial effluent in four Local Government areas of Rivers State Nigeria. The Extraction of samples was carried out using di-chloromethane as the extracting solvent. The concentration units of the 16 PAHs namely: benz(a) anthracene, benz(e) acenaphthylene, benzo(e) pyrene, benzo(a) pyrene, benzo(ghi) perylene, dibenz(ah) anthracene, naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, triphenylene, and indeno(1,2,3-cd) pyrene varied at each site. The data analysis was carried out using the Gas Chromatography-Mass Spectrometer (GC-MS) to determine the impact of these industrial discharges on soil and the effluent receiving river bodies at four selected sites: Ekerikana (S₁), Ebocha (S₂), Slaughter (S₃) and RSUST (S₄) in order to compare the differences in the level of soil contamination. The 16 PAHs concentration units of Ekerikana varied from 2.32ppm-0.00ppm, Ebocha varied from 1.84ppm-0.00ppm, Slaughter varied from 6.81ppm-0.00ppm and RSUST result varied from 4.48ppm-0.00ppm respectively. The result shows the concentration units of the PAHs ranging from the highest polycyclic compound to the lowest at different sites, with the PAHs concentration in the industrial port area being very high with a value of 6.81ppm phenanthrene compared to the uncontaminated soil with little traces of PAHs 0.03ppm phenanthrene.

Key words: Hydrocarbon Contents, Soil, Industrial discharge point, Contamination

1. INTRODUCTION

Humans and animals had enjoyed an environment free of pollution before the industrial revolution of the 19th century. Living things at the time enjoyed clean water, air and humans farmed on soil that was free of industrial contaminants. Sadly, the industrial revolution that was perfected in the 20th century as it were, gradually caused air, water and soil to become polluted by the activities of man (Sadatipour et al., 2004). The increased production of industrial goods and services resulting from increase in demand for such goods and services coupled with rising sophistication in technology have led to tremendous increase in waste and other by-products. As shown by research (Kanu and Achi, 2011), the immediate environment—the ecosystem suffers when waste resulting from production of goods and services interact with the immediate environment. The result is a compounding of pollution challenges.

In a more strict sense the indiscriminate discharge of untreated industrial and domestic wastes into the water-ways, spewing of thousands of tons of particulates and airborne gases into the
atmosphere, the throw-away attitude toward solid wastes, and the use of newly developed chemicals without considering potential consequences have resulted in major environmental disasters. For instance the formation of smog in the Los Angeles area since the late 1940's and the pollution of large areas of the Mediterranean Sea has stood out as specific references (Kanu and Achi, 2011).

The awareness of the threat of pollution has made some highly industrialized countries to device and adopts certain fundamental measures for the prevention of environmental pollution (Osibanjo et al., 2011).

Like other industrial processes refining of crude oil into petroleum products for energy requires large volume of water that in the course of the process get contaminated. Under this condition such water present contaminants challenge to the immediate environment if not treated (Basheer et al., 2011). Contaminants at low level if discharged into the environment will interact with the physical environment leading to partial or outright pollution of the environment. At worse the aesthetics will be negatively impacted. (Kanu and Achi, 2011).

One of such water contaminant is Total Petroleum Hydrocarbons (TPH) which comprise of a diverse mixture of hydrocarbons that occur at petrochemical sites and storage areas, waste disposal pits, refineries and oil spill sites. They are considered persistent hazardous pollutants, and include compounds that can bioconcentrate and bioaccumulate in food chains, are acutely toxic and some such as benzene and benzo[a]pyrene are recognized mutagens and carcinogens. TPHs are divided into two categories – Gasoline and Diesel range organics. Diesel range organics (DRO) includes longer chain alkanes (C10–C40) and hydrophobic chemicals such as polycyclic aromatic hydrocarbons (PAH). Individual contaminants behave differently. While some contaminants are highly mobile in the environment, others such as PAHs tend to bind strongly to soil particles near the source or remain entrapped within an organic phase (K.Kamath et al., 2007). Examples of PAH's and their physical –chemical properties are as seen in Table 1, Haritash and Kaushik (2009).

Table 1: Physical–chemical properties of Polycyclic Aromatic Hydrocarbons (PAHs).

<table>
<thead>
<tr>
<th>S.N o</th>
<th>Name</th>
<th>M.F</th>
<th>B.Pt (°C)</th>
<th>M.Pt.(°C)</th>
<th>V.P. (Pa at 25 °C)</th>
<th>Aqueous solubility (mg/l)</th>
<th>IARCc group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Benzo[k]fluoranthene</td>
<td>C_{20}H_{12}</td>
<td>480</td>
<td>215.7</td>
<td>5.5 × 10^{-8}</td>
<td>.</td>
<td>2B</td>
</tr>
<tr>
<td>2</td>
<td>Anthracene</td>
<td>C_{14}H_{10}</td>
<td>342</td>
<td>216.4</td>
<td>1 × 10^{-3}</td>
<td>0.015</td>
<td>3</td>
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</tbody>
</table>
The presence of petroleum hydrocarbon in water and sediments has been a major source of concern, especially as it affects the colonies of macro-invertebrate (Fish etc). Emoyan et al., in 2008 had reported that marine and aquatic environments are subjected to various degrees of pollution. While in a 1998 report, Ekweozor et al. showed that hydrocarbon pollution affects the distribution of mullet species. Nwabueze and Agbogidi, (2010) reported that heavy metals, phenolic substances and polycyclic aromatic hydrocarbons are considered to be the most toxic and carcinogenic component of crude oil and its related compound. Pierre reported as far back as 1980 that some water soluble fractions, particularly aromatic compounds are toxic to aquatic animals and plants. They are acutely lethal in concentrations of a few parts per million (ppm) and chronically lethal in sub-lethal concentrations in parts per billion (ppb), although plants and animals vary widely in their sensitivity the water-soluble fractions they are generally endangered. Wake in 2005 reported that some of the different components of the refinery effluent such as pH, temperature, total dissolved solid, total suspended solids, turbidity, biological oxygen demand, phenol, ammonia, sulphides, nitrates and phosphate, phenol, total hydrocarbon concentration, heavy metals and faecal coliform can have varying effects and toxicities. Clearly then the effect of industry effluent once it is discharged into the environment depends on the conditions and hydrodynamics of the receiving water. One common component of such discharged water is the Total Dissolved Solid (TDS) which is a measurement of inorganic salts, organic matter and other dissolved materials in water impact on water suitability. Phylis et al. (2007) found a significant and negative correlation between concentrations of chlorophyll-a (an estimate of primary production) and concentrations of Na\(^{+}\), Mg\(^{2+}\), SO\(_4^{2-}\), HCO\(_3^{-}\)and CO\(_3^{2-}\) and also reported substantial changes in marsh communities. Salinity and aquatic biodiversity are inversely related in lake water (Phylis et al., 2007). Changes in the ionic composition of water can exclude some species while promoting population growth of others (Phylis et al., 2007). Suspended solids which refers to the mass (mg) or concentration (mg) of inorganic and organic matter, which is held in the water column of a stream, river, lake or reservoir by turbulence are typically comprised of fine particulate matter with a diameter of less

<table>
<thead>
<tr>
<th>3</th>
<th>Benzo[b]fluoranthene</th>
<th>C(<em>{20})H(</em>{12})</th>
<th>481</th>
<th>168.3</th>
<th>6.7 \times 10^{-5}</th>
<th>–</th>
<th>2B</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Benzo(c)pyrene</td>
<td>C(<em>{20})H(</em>{12})</td>
<td>493</td>
<td>178.7</td>
<td>4 \times 10^{-7}</td>
<td>–</td>
<td>3</td>
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<tr>
<td>5</td>
<td>Fluoranthene</td>
<td>C(<em>{16})H(</em>{10})</td>
<td>375</td>
<td>108.8</td>
<td>1.2 \times 10^{-3}</td>
<td>0.25</td>
<td>3</td>
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<tr>
<td>6</td>
<td>Naphthalene</td>
<td>C(<em>{10})H(</em>{8})</td>
<td>218</td>
<td>80.2</td>
<td>11</td>
<td>30</td>
<td>n.e.</td>
</tr>
<tr>
<td>7</td>
<td>Phenanthrene</td>
<td>C(<em>{14})H(</em>{10})</td>
<td>340</td>
<td>100.5</td>
<td>2 \times 10^{-2}</td>
<td>1–2</td>
<td>3</td>
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<tr>
<td>8</td>
<td>Benzo[ghi]perylene</td>
<td>C(<em>{22})H(</em>{12})</td>
<td>500</td>
<td>277</td>
<td>6 \times 10^{-8}</td>
<td>–</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Pyrene</td>
<td>C(<em>{16})H(</em>{10})</td>
<td>150.4</td>
<td>393</td>
<td>6.0 \times 10^{-4}</td>
<td>0.12–0.18</td>
<td>3</td>
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</tbody>
</table>
than 62 mm (Bilotta and Brazier, 2008), though for the majority of cohesive solids, research has demonstrated that transport frequently occurs in the form of larger aggregated flocks (Bilotta and Brazier, 2008). Food Science and Technology, (2012) defined Biological Oxygen Demand (BOD) another water contaminant inducer in terms of the amount of oxygen that would necessarily be consumed if all the organic materials in 1L of water were oxidized by bacteria and protozoa. BOD is the most commonly used parameter for determining the oxygen demand on the receiving water of a municipal or industrial discharge. On the other hand Chemical Oxygen Demand at high COD levels decreases the amount of dissolved oxygen available for aquatic organisms (Kanu and Achi, 2011).

The oil in the industry effluent can affect marine organisms in a number of different ways. Etkin reported in 1997 that marine mammals, seabirds (especially penguins) and sea turtles are all particularly vulnerable to oil on surface waters as they spend considerable amounts of time on the surface feeding, breathing and resting. Otokunefor and Obiukwu (2005) concluded that hydrocarbons are the most significant cause of toxicity in sediment sample obtained from around The North Sea oil platform contaminated by large piles of oil-based drill cuttings and polar organic compounds. Again, Fecal coliform bacteria commonly found in the feaces of humans and other animals, and their presence is used as an indicator of biological contamination of water sources. The presence of feacal pollutants in water contributes to the growth of algae and weeds, which can lower oxygen levels and block water flow. Parasitic worms and bacterial pathogens like Salmonella are also commonly found in water that tests positive for high levels of feacal coliform bacteria (Emily et al., 2013). It can be seen that if the toxicity of the effluent is reduced or the effluent is stopped completely, the area of impact is able to recover. Species that have been found to re-colonise most successfully included the amphipods Pontoporeiaaffinis and Corophiumvolutator, the Oligochaete Tubifexco status, the polychaetes Polydoraredekiant and the bivalve Cerastodermaedule (Dean, 2008).

This research investigated the hydrocarbon contents on soil at selected industrial discharge points in the Niger delta of Rivers State, Nigeria with the goal of examining the extent of soil contamination by petroleum hydrocarbons from industries at industrial discharge point and to define the highest detectable and quantifiable hydrocarbon compound present in a particular site and its effect.

2. MATERIALS AND METHODS

The analysis of the test samples were carried out using four (4) samples collected from Ekerekana as site 1(S1), Ebochasite 2(S2), Slaughter site 3(S3) and Rivers State University of Science and Technology as a standard uncontaminated soil as site 4(S4). The samples were collected in amber coloured glass containers baked at 450°C since plastic containers can contaminate sample by absorbing some analytes and container failure is also possible.
Predetermined sample sizes were collected using the depth integrated grab sampling method.

The Gas chromatography- Mass Spectrometer Detector (GC-MS), was used to determine the Polycyclic Aromatic Hydrocarbon (PAH) content of discharge water effluent and its effect on the soil. Samples were Soxhlet extracted with dichloromethane and determined by GC-MS detector. The samples were homogenized by stirring together and then 10 grams of each sample was weighed out using a weighing balance. The readings are as seen in Table 2. Then 30ml of dichloromethane was poured into the weighed sample and stirred with a stirrer. The samples were covered with foil till dawn. The samples were sieved with a filter paper and anhydrous sodium sulphate then the filtrate were covered with a foil to avoid evaporation of dichloromethane. Anhydrous sodium sulfate was poured in filter paper in order to stop the water from penetrating through the filter paper in the oil extracted.

**Table 2: Weight of each sample and the sample sites**

<table>
<thead>
<tr>
<th>Sample site</th>
<th>Weight (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ekerekana</td>
<td>10.0497 mg kg⁻¹</td>
</tr>
<tr>
<td>Slaughter</td>
<td>10.3782 mg kg⁻¹</td>
</tr>
<tr>
<td>Ebocha</td>
<td>10.4769 mg kg⁻¹</td>
</tr>
<tr>
<td>UST</td>
<td>10.1734 mg kg⁻¹</td>
</tr>
</tbody>
</table>

**3.2 Results and Discussion of Results**

The results of the sample analysis are as seen in Table 3 and the graphs of figures 1 to 4. We find the different PAH's identified in the samples and the amount in parts per million. Each of these is classified either as - possibly carcinogenic to human (2A) or not classifiable as to its carcinogenicity to humans (3) following the classification of International Agency for Research on Cancer (IARC) on Table 1, Haritash and Kaushik (2009)

**3.2.1 Benzo(a) Pyrene: C₂₀H₁₂**

The concentration unit of benzo(a) pyrene in all the sampled sites as shown in Table 3 varied from 0.06ppm to 0.00ppm. Ebocha site recorded the highest with concentration of 0.06ppm followed by Slaughter, Ekerekana and then UST with concentration units of 0.05ppm, 0.01ppm and 0.00ppm respectively. The concentration units were above permissible limit except Ekerekana and UST, the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg⁻¹).

189
3.2.2 Benz(a) Anthracene: C_{18}H_{14}

The concentration units of benz(a) anthracene in all the sampled sites as shown in Table 3 varied from 0.24ppm to 0.01ppm. Slaughter site recorded the highest with concentration unit of 0.24ppm followed by Ebocha, Ekerekana and then UST with concentration units of 0.91ppm, 0.16ppm and 0.01ppm respectively. The concentration units were above permissible limit except for samples from UST which is the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01mg kg\(^{-1}\)).

3.2.3 Benz(e) Acephenanthrylene: C_{20}H_{12}

The concentration units of benz(e) acephenanthrylene in all the sampled sites as shown in Table 2-9 varied from 1.84ppm to 0.00ppm. Ebocha site recorded the highest with concentration unit of 1.84ppm followed by Slaughter, Ekerekana, and UST with concentration units of 0.24ppm, while Ekerekana and UST sites have same concentration units of 0.00ppm respectively. The concentration units were above permissible limit except Ekerekana and UST, the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).

3.2.4 Benzo(e) Pyrene : C_{26}H_{12}

The concentration units of benzo(e) pyrene in all sampled sites as shown in Table 3 varied from 1.80ppm to 0.00ppm. Ebocha site recorded the highest with concentration units of 1.80ppm followed by Slaughter, Ekerekana and UST with concentration units of 0.27ppm, 0.01ppm and 0.00ppm respectively. The concentration units were above permissible limit except for samples from UST which is the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).

3.2.5 Benzo(ghi) Perylene: C_{22}H_{12}

The concentration units of benzo(ghi) perylene in the sampled sites as shown in Table 3 varied from 0.00ppm to 0.00ppm. These shows no traces of benzo(ghi) perylene was found. The concentration units were below permissible limit as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).

3.2.6 Dibenz(ah) Anthracene: C_{22}H_{14}

The concentration units of dibenz(ah) anthracene in all the sampled sites as shown in Table 3 varied from 0.00ppm to 0.00ppm. The concentration units were below permissible limit as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).
3.2.7 Naphthalene: $C_{10}H_8$

The concentration units of naphthalene in all the sampled sites as shown in Table 3 varied from 1.26ppm to 0.00ppm. Ebocha site recorded the highest with concentration unit of 1.26ppm followed by Ekerekana, Slaughter and UST with concentration units of 0.34ppm, 0.13ppm and 0.00ppm respectively. The concentration units were above permissible limit except for samples from UST which is the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg$^{-1}$).

3.2.8 Acenaphthylene: $C_{12}H_8$

The concentration units of acenaphthylene in all the sampled sites as shown in Table 3 varied from 0.47ppm to 0.06ppm. UST site recorded the highest with concentration unit of 0.47ppm followed by Ebocha, Slaughter and Ekerekana with concentration units of 0.32ppm, 0.12ppm, and 0.06ppm respectively. The concentration units were above permissible limit as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg$^{-1}$).

3.2.9 Acenaphthene: $C_{12}H_{10}$

The concentration units of acenaphthene in all the sampled sites as shown in Table 3 vary from 4.48ppm to 0.10ppm. UST site recorded the highest with concentration unit of 4.48ppm followed by Ebocha, Slaughter and Ekerekana with concentration units of 1.21ppm, 0.56ppm and 0.10ppm respectively. The concentration units were above permissible limit as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg$^{-1}$).

3.2.10 Flourene: $C_{13}H_{10}$

The concentration unit of flourene in all the sampled sites as shown in Table 3 varied from 0.62ppm to 0.19ppm. Ebocha site recorded the highest with concentration unit of 0.62ppm followed by Ekerekana, Slaughter and UST with concentration units of 0.29ppm, 0.24ppm and 0.19ppm respectively. The concentration units were above permissible limit as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg$^{-1}$).

3.2.11 Phenanthrene: $C_{14}H_{10}$

The concentration unit of phenanthrene in the entire sampled site as shown in Table 3 varied from 6.81ppm to 0.03ppm. Slaughter site recorded the highest with concentration unit of 6.81ppm followed by Ekerekana, Ebocha and UST with concentration units of 2.32ppm, 1.57ppm, and 0.03ppm respectively. The concentration units were above permissible limit as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg$^{-1}$).

191
3.2.12 Anthracene: \( C_{14}H_{10} \)

The concentration unit of anthracene in the entire sites sampled as shown in Tables 3 varies from 6.62ppm to 0.09ppm. Slaughter site recorded the highest with concentration unit of 6.62ppm followed by Ekerekana, UST and Ebocha with concentration units of 2.26ppm, 0.17ppm, and 0.09ppm respectively. The concentration units were above permissible limit as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).

3.2.13 Fluoranthene: \( C_{16}H_{10} \)

The concentration unit of flouranthene in the entire sampled site as shown in Tables 3 varies from 4.50ppm to 0.00ppm. Slaughter site recorded the highest with concentration unit of 4.50ppm followed by Ekerekana, Ebocha and UST with concentration units of 0.03ppm, 0.02ppm, and 0.00ppm respectively. The concentration units were above permissible limit except UST site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).

3.2.14 Pyrene: \( C_{16}H_{10} \)

The concentration unit of pyrene in the entire sampled site as shown in Tables 3 varies from 4.25ppm to 0.00ppm. Slaughter site recorded the highest with concentration unit of 4.25ppm followed by Ekerekana, Ebocha and UST with concentration units of 0.14ppm, 0.02ppm, and 0.00ppm respectively. The concentration units were above permissible limit except for samples from UST which is the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).

3.2.15 Triphenylene: \( C_{18}H_{12} \)

The concentration unit of triphenylene in the entire sampled site as shown in Table 3 varies from 0.94ppm to 0.00ppm. Ebocha site recorded the highest with concentration unit of 0.94ppm followed by Slaughter with concentration unit of 0.25ppm while Ekerekana and UST with concentration units 0.00ppm respectively. The concentration units were above permissible limit except for Ekerekana and UST, the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg\(^{-1}\)).

3.2.16 Indeno(1,2,3-cd) Pyrene: \( C_{22}H_{12} \)

The concentration unit of Indeno(1,2,3-cd) pyrene in all the sampled site as shown in Tables 3 varies from 0.04ppm to 0.00ppm. Slaughter site recorded the highest with concentration unit of 0.04ppm while Ekerekana, Ebocha and UST all have concentration units of 0.00ppm respectively. The concentration units is above permissible limit except Ekerekana, Ebocha and...
UST, the standard soil site as specified by chemtest standard method reporting limits for PAH and TPH at (0.1/0.01 mg kg⁻¹)

**Conclusion**

The industrial effluent was composed of some polycyclic aromatic hydrocarbons such as; Benzo(a) pyrene, Benz(a) anthracene, benz(e) acephenanthrylene, benzo(e) pyrene, benzo(ghi) perylene, dibenz(ah) anthracene, naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, triphenylene and indeno(1,2,3-cd) pyrene.

The untreated effluent from the industrial areas were above the permissible limit, which is a major cause of worry and the treatment plant was not efficient enough to remove pollutants to acceptable limits which led to high concentrations of PAHs in the soil.

**5.2 Recommendations**

Pollution of soil by petroleum-hydrocarbons is widespread in land areas sediments and swampland. The decision to clean up individual sites has to be done based on detailed site by site assessment which must include consultation with community and regulators. This research further underscores the need for both environmental improvement and prevention of further oil contaminations on soil. Consistent review of fitness of treatment assets where they exist should be given due attention through a fully developed and monitored Asset integrity management plan with risk levels identified and monitored for sustainability. A communication loop that includes inhabitants of impacted environment needs to be implemented for efficient community engagement and ownership. Local initiated towards bioremediation should be encouraged.

<table>
<thead>
<tr>
<th>S/N</th>
<th>COMPOUNDS</th>
<th>CONC. (PPM) EKERERKANA</th>
<th>CONC. (PPM) EBOCHA</th>
<th>CONC. (PPM) SLAUGHTER</th>
<th>CONC. (PPM) UST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Benz(a) Anthracene</td>
<td>0.16</td>
<td>0.91</td>
<td>0.24</td>
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<tr>
<td>2.</td>
<td>Benz(e) Acephenanthrylene</td>
<td>0.00</td>
<td>1.84</td>
<td>0.24</td>
<td>0.00</td>
</tr>
<tr>
<td>3.</td>
<td>Benz(e) pyrene</td>
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<td>0.27</td>
<td>0.00</td>
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<td>4.</td>
<td>Benzo(a) pyrene</td>
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<td>0.06</td>
<td>0.05</td>
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<tr>
<td>5.</td>
<td>Benzo(ghi) perylene</td>
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<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>6.</td>
<td>Dibenz(a,h) Anthracene</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>7.</td>
<td>Naphthalene</td>
<td>0.34</td>
<td>1.26</td>
<td>0.00</td>
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<td>8.</td>
<td>Acenaphthylene</td>
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<td>0.47</td>
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<td>9.</td>
<td>Acenaphthene</td>
<td>0.10</td>
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<td>4.48</td>
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<td>10.</td>
<td>Fluorine</td>
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<td>0.62</td>
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<td>11.</td>
<td>Phenanthrene</td>
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<td>6.81</td>
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<td>Value 2</td>
<td>Value 3</td>
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<tr>
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<td>Anthracene</td>
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<td>Fluoranthene</td>
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<tr>
<td>14</td>
<td>Pyrene</td>
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<td>0.02</td>
<td>4.25</td>
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<tr>
<td>15</td>
<td>Triphenylene</td>
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<td>0.94</td>
<td>0.25</td>
<td>0.00</td>
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<td>16</td>
<td>Indeno(1,2,3,cd) pyrene</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 1: Graph Showing the Concentration Level of PAHs at Ekerekana Site
Figure 2: Graph Showing the Concentration Level of PAHs at Ebocha Site

Figure 3: Graph Showing the Concentration Level of PAHs at Slaughter Site


Food Science and Technology (2012). Effects of Biological Oxygen Demand on the water quality. www.fst.bod.com


