

## Distribution pattern of total hydrocarbon categories in Orashi River, engenni, Rivers state, Nigeria

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### Abstract

The concentration of the different categories of total petroleum hydrocarbons in surface water and sediments of Orashi River were determined for the period of four months. The samples were collected at four different locations along the river. Standard methods were used for the extraction of the samples. The samples were analyzed using Gas Chromatography-Flame Ionization Detector (GC-FID). The results obtained for the surface water showed that, gasoline range organics (GRO) ranged between not detected to  $0.846\pm 0.061$ mg/L, diesel range organics (DRO),  $7.625\pm 2.0524$  to  $11.962\pm 3.293$ mg/L and lube oil range,  $0.25\pm 0.0104$  to  $1.668\pm 0.051$ mg/L in the stations and in the months, GRO, not detected to  $0.732\pm 0.092$ mg/L, DRO,  $5.399\pm 1.126$  to  $14.808\pm 2.91$ mg/L and lube oil range, not detected to  $1.346\pm 0.155$ mg/L. In the sediments, GRO, was within  $1.0795\pm 0.512$  to  $8.6913\pm 2.413$ mg/Kg, DRO,  $17.575\pm 4.7044$  to  $42.9514\pm 5.5566$ mg/Kg and lube oil range,  $1.343\pm 0.0714$  to  $4.6995\pm 0.547$ mg/Kg and in the months, GRO, not detected to  $11.9523\pm 4.461$ mg/Kg, DRO,  $22.0206\pm 4.499$  to  $39.4842\pm 13.496$ mg/Kg and lube oil range,  $0.206\pm 0.104$  to  $9.8841\pm 3.305$ mg/Kg. The average percentage concentration of the different categories in the surface water were, GRO, 3.09, DRO, 90.91 and lube oil range, 6.00 in the stations and in the months GRO 2.99, DRO 92.96, and lube oil range, 4.05. In the sediments, GRO, 13.79, DRO, 75.99 and lube oil range, 10.22 in the stations, and in the months, GRO, 12.13, DRO, 79.65 and lube oil range, 8.22. The findings showed that the river is contaminated with total petroleum hydrocarbons and therefore urgent remediation is needed to clean-up the river.

**Keywords:** Orashi River, pollution, total petroleum hydrocarbons, contamination, sediment, anthropogenic

### Introduction

The pollution of rivers, lakes, creeks and other water bodies is on the increase due to the inability of man to check his lifestyle. This unchecked pattern of life exhibited by humans have resulted in the contamination and pollution of our waters and rendering them unfit for human consumption. Water which is very plentiful and an abundant resource in the Niger Delta Region of Nigeria is now scarce as a result of man's inability to maintain certain guidelines and standards to lead a progressive life. This style of life has rendered the water of the region (groundwater and surface water) of the region not good enough for use in our homes, agricultural and industrial usage (Edori and Kpee, 2019) [17, 18]. This has grossly affected the social, economic and cultural life of the people that live within this region, and has polluted the ecological system and led to degradation of the environment (Achi, 2003; Okoye and Okunrobo, (2014) [41]. Presently the greatest source of pollution in the Niger Delta Region of Nigeria is from crude oil exploration activities, which has brought about oil spills due to leakages from oil pipelines as a result of blow out which may be caused by corroded pipes, vandals, dumping of crude wastes into the environments and tank leakages (Inyang *et al.*, 2018) [27]. These unwholesome activities have rendered our environments unfit for agriculture (farming and fishing) and other social activities associated with water bodies, rivers, lakes and creeks (Adeniyi and Afolabi, 2002; Edori and Marcus, 2019) [2, 17, 18]. Greater percentage and quantity of these pollutants/contaminants enter into the rivers through industrial discharges, runoffs, domestic effluents, transportation activities, willful dumping and discharge by operators of illegal refineries/petroleum dealers, emission from incomplete combustion and automobile wastes (Hatje

*et al.*, 2003, Kachel, 2008, Olver, 2008) [26, 31]. Total petroleum hydrocarbons are the major known pollutant that humans regularly discharge into the rivers and creeks of the Niger Delta Region and poses a lot of challenges for man and aquatic organisms which are abundant in the region. Petroleum hydrocarbons are highly insoluble in water, so they float on the surface and others are partitioned to particulate matters such as muds, sticks and debris and drown to the river bottom (sediment) which serves as final reservoir for water pollutants and contaminants (Ali *et al.*, 2015, Adeniji *et al* 2017) [6, 1]. Petroleum hydrocarbons come from refined crude oil products, such products include engine oil, gasoline, kerosene and diesel oil (de Abreu-Mota *et al.*, 2014) [13] and other components. Due to the presence of these hydrocarbons in the rivers, metabolic activities of living organisms have been impaired and the lives of water organisms have been put into danger due to the effects of total petroleum hydrocarbons (Irshad *et al.*, 1997) [27]. The coastal waters and the survival of man and aquatic organisms in the Niger Delta Region is under threat due to oil production and its associated activities. The concentration of petroleum hydrocarbons is on the daily increase in the estuaries, lakes, creeks and rivers of the region and thereby forcing changes in the composition of the sediments and surface water through variations and fluctuations in temperature, pH, microbial activities, availability of oxygen, nutrients and salinity (Whitehead, 2013) [57]. These occurrences due to anthropogenic and natural events, results in biogeochemical stress and bring about certain conditions which are unbearable to aquatic dwellers. The resultant effect is the possible migration of certain species due to the inability to the present situation (Ezekwe and Utong, 2017) [21]. The pollution due to total

petroleum hydrocarbons in the rivers has led to the reduction of oxygen for water creatures, increased toxicity, reduction in gaseous exchange, asphyxiation, coating of the water surface by oil, and other such as imbalances pose threat to the ecosystem and life supporting mechanisms in the system (Luoma *et al.*, 1997, Mendelsohn *et al.*, 2012) [33, 35]. These shortfalls in the river ecosystem affects the population and resilience of the aquatic dwellers.

This paper is aimed at the assessment of total petroleum hydrocarbons content in the surface water and sediments of the Engenni axis of Orashi River. The presentation was based on the different categories of total petroleum hydrocarbons which are; the gasoline range organics (GRO), diesel range organics (DRO) and the lube oil range and the degree of contamination in the river.

## Materials and Method

### Study Area and Location

The study area is Engenni axis of Orashi River in Ahoada West Local Government Areas of Rivers State, Nigeria. The Orashi River is a tributary of River Niger and runs from Imo State through Ogba Egbema Ndoni Local Government Area to Engenni in Ahoada west Local Government Area of Rivers State. The sample location points in the Engenni axis of the Orashi River were within longitude 4°107.3'N, 6°30'6.6"E and 4°59'10.1"N, 6°27'2.5"E. The main occupation of Engenni people is farming and fishing. The activities that are common within the Engenni Axis of Orashi River are oil exploration and exploitation, sand dredging, transportation and illegal oil bunkering. Oil production facilities that are owned by the oil production companies include oil fields, gas plants and flow Station that has brought constant environmental contamination of the river. The impact created due to oil exploration, exploitation and production over the years in Engenni axis of the river have been a source of worry to the people.

### Sample Collection

Amber glass bottles (1 litre) were used in the collection of both water and sediment samples. The bottles were thoroughly washed with tap water and detergent and distilled water and acetone were used to rinse the bottle. Samples were collected from four stations for the period of four months at two months interval from December 2019 to June 2020. Water samples were collected in triplicates at 50cm below the water surface in each sampling station. The collected water samples in the amber bottles were then pooled together in order to obtain a sample that represents all (Olajire *et al.*, 2007) [42]. Hydrochloric acid of 6M concentration was added to keep the pH below 2. The sediment samples were collected with the aid of Van Veen Grab Sampler from each station and kept in amber bottles. Both water and sediment samples were kept at a temperature of 4°C with the aid of ice chest to prevent evaporation of the sample and for sample preservation and then Trans ported to the laboratory for analysis (Suratman, 2013).

### Total Petroleum Hydrocarbons Extraction from Surface Water and Sediment Samples

With the aid of separatory funnel and 20ml of n-hexane, 400ml water samples were extracted. The extract were then dried with the aid of anhydrous sodium sulphate and a rotary evaporator was used at 35°C to concentrate the water sample at a very reduced pressure to 2 ml (LAWI, 2011).

The sediment samples were air dried at room temperature for five or more days and ground to powder form. In order to further reduce the moisture content of the sediment sample, about 10g of the dried sediment sample was mixed with anhydrous sodium sulphate. The sample was then extracted with dichloromethane (200ml) in a Soxhlet apparatus and left running for twenty-four hours. The extract was allowed to pass through a glass funnel that contains anhydrous sulphate which was concentrated using a rotary evaporator and the solvent was changed to n-hexane before cleanup (Sakari *et al.*, 2012) [49].

### Column Cleanup and Separation

A chromatographic column was used to clean up both water and sediment samples. The column was packed with slurry that was prepared with 10g activated gel and a layer of anhydrous sodium sulphate was placed at about 2cm on the slurry. Precisely, 20ml n-pentane was used to elute.

### Sample Analysis Using Gas Chromatography

The concentrated samples (water and sediment) were transferred with the aid of rubber crimp caps into a labeled glass vial for Gas Chromatography-Flame Ionization Detector (GC-FID) analysis. With a micro-syringe 1ml of the sample previously concentrated was injected into the chromatographic column from a rubber septum. Separation takes place as the aspirated vapour is being partitioned by the liquid and the gas phase. The detection of the sample is automatic as it comes out from the column at an already programmed constant flow rate by the detector of the GC-FID (Alagoa *et al.*, 2018) [4].

### Results and Discussion

The result for the concentrations of the different categories of total petroleum hydrocarbons in the surface water of Orashi River are presented in Table 1. In Table 1, the values for the different total petroleum hydrocarbons categories in the various stations of Orashi River were, gasoline range organic (GRO), 0.331±0.0256, not detected, 0.846±0.061 and not detected, diesel range organic (DRO); 8.914±2.1256, 7.645±2.683, 7.625±2.0524 and 11.962±3.293 mg/L and lube oil range; 1.668±0.051, not detected, 0.603±0.052 and 0.25±0.0104 mg/L for stations 1, 2, 3 and 4 respectively. The average concentration values of total petroleum hydrocarbons in the surface water for the stations of Orashi River were GRO; 0.2943±0.021 mg/L, DRO; 9.0365±3.3847 mg/L and lube oil range; 0.6303±0.0518 mg/L. In the sampled months, the average concentration for GRO were 0.445±0.105, not detected, 0.732±0.092 mg/L and not detected for December, February, April and June, DRO, 5.399±1.126, 8.767±2.501, 14.808±2.91, and 6.672±1.041 mg/L for December, February, April and June and lube oil range, not detected for December and February, 1.346±0.155 and 0.599±0.069 mg/L for April and June. The average concentration values in the surface water of Orashi River recorded for the four months were GRO; 0.2943±0.0493 mg/L, DRO; 9.6615±1.8945 mg/L and lube oil range; 0.4863±0.056 mg/L.

The surface water of Orashi River was contaminated with total petroleum hydrocarbons which ranged from gasoline range organic [GRO; (C<sub>6</sub>-C<sub>10</sub>)], diesel range organic [DRO, (C<sub>11</sub>-C<sub>28</sub>)] and lube oil range (C<sub>29</sub>-C<sub>40</sub>). The observed range of total petroleum hydrocarbons in this work agreed with

results reported by Daniel and Nna (2016) in Cross River Estuary's surface water. The total petroleum hydrocarbons categories were arranged according to the pattern of DEQ (2000) and Dibofori-Orji *et al.*, (2018) [14]. The results indicated that the surface water of Orashi River was contaminated with total petroleum hydrocarbons categories in the pattern DRO > lube oil range > GRO. The contamination of the water body was as a result of constant runoffs of petroleum products from nearby farm lands, due to illegal oil activities, artisanal refining sites, direct human discharge, outboard boat engines used for transportation (Suratman *et al.*, 2012; Ali *et al.*, 2015) [53, 6]. The low levels of gasoline range organic or volatile range hydrocarbons may be due to rapid evaporation, which is caused by wind and strong wave (Hanson *et al.*, 2003; Rauckyte *et al.*, 2010; Edori and Kpee, 2019) [25, 47, 17, 18].

Also, total petroleum hydrocarbons of lighter weight such as GRO category lose a large portion of their total mass due to their high volatility and rapid evaporation (Mohammadi *et al.*, 2020). The presence of these hydrocarbon categories in

Orashi River pose great challenge and danger to both aquatic organisms and human life (Al Darwish *et al.*, 2005) [5], since they depend on these rivers for daily living and survival.

Certain fractions of total petroleum hydrocarbons burn with ease and evaporate easily (gasoline range organic) while others are thick dark coloured liquids and are semi solid in nature (lube oil range) and do not easily evaporate. Many of the petroleum hydrocarbon fractions (gasoline and Kerosene) have oily odour (ATSDR, 1999) [5] and this affects the surface water of any river impacted by total petroleum hydrocarbons pollution such as in Orashi River. The situation has rendered the water unfit for both commercial and private use which may pose great health hazard to aquatic organisms (especially surface feeders) and man (Nardini *et al.*, 2010) [39]. The negligence during the production processes of petroleum products by oil multinationals, illegal bunkery and the transporting systems of these products bring about environmental pollution and degradation (Darae, *et al.*, 2013) [12].

**Table 1:** Spatial Variation of the different Categories Total Petroleum Hydrocarbons in the Surface Water of Orashi River at Different Stations and Months

Stations/Months	Total Petroleum Hydrocarbons Categories		
	Gasoline Range Organic (GRO) C <sub>6</sub> -C <sub>10</sub>	Diesel Range Organic (DRO) C <sub>11</sub> -C <sub>28</sub>	Lube Oil Range C <sub>29</sub> -C <sub>40</sub>
1	0.331±0.0256	8.914±2.1256	1.668±0.051
2	-	7.645±2.683	-
3	0.846±0.061	7.625±2.0524	0.603±0.052
4	-	11.962±3.293	0.25±0.0104
December	0.445±0.105	5.399±1.126	-
February	-	8.767±2.501	-
April	0.732±0.092	14.808±2.91	1.346±0.155
June	-	6.672±1.041	0.599±0.069

The results for the concentrations of the different categories of total petroleum hydrocarbons in the sediments of Orashi River are presented in Table 2. Table 2 showed the concentration values for the different hydrocarbon categories in the various stations of Orashi River were, gasoline range organic (GRO); 1.0795±0.512, 5.335±1.23, 2.7922±0.9211 and 8.6913±2.413 mg/Kg, (DRO); 17.575±4.7044, 26.1561±7.9213, 42.9514±14.5235 and 19.3526±5.5566 mg/Kg and lube oil range; 3.738±0.354, 3.616±0.8139, 4.6995±0.547 and 1.343±0.0714 mg/Kg for stations 1, 2, 3 and 4 respectively. The average concentrations of total petroleum hydrocarbons recorded in the sediments for the stations were GRO; 4.4745±1.179 mg/Kg, DRO; 26.5088±8.1765 mg/Kg and lube oil range; 3.3491±0.4466 mg/Kg. In the months, the average concentrations for the different total petroleum hydrocarbons categories were for GRO; 11.9523±4.461, 4.899±0.24, 1.135±0.012 mg/Kg and not detected, DRO; 27.6844±8.935, 22.0206±4.499, 39.4842±13.496 and 16.0511±3.24 mg/Kg and lube oil range; 0.206±0.104, 2.7017±0.562, 9.8841±3.305 and 0.6034±0.103 mg/Kg for December, February, April and June respectively. The average concentration values in the sediments of Orashi River recorded for the four months under study were GRO; 4.445±1.1858 mg/Kg, DRO; 26.3101±7.5443 mg/Kg and lube oil range; 3.3488±1.0185 mg/Kg.

Petroleum products such as engine oils, diesel fuels and gasoline are major contaminants/ pollutants in the aquatic environment. High molecular weight hydrocarbons like lubricating oil with both low and high molecular weight

hydrocarbons (C<sub>21</sub>-C<sub>50</sub>) (Rauckyte *et al.*, 2010) [47] were found in the sediments of the two rivers. The presence of individual total petroleum hydrocarbons that were obtained in the bottom sediment of the rivers were lubricating oils (C<sub>21</sub>-C<sub>50</sub>), fuel oil (C<sub>17</sub>-C<sub>26</sub>), diesel (C<sub>8</sub>-C<sub>20</sub>) and gasoline (C<sub>6</sub>-C<sub>10</sub>) (George, 1994), which agreed with the findings of this work and this revealed that the total petroleum hydrocarbons that were obtained in the river were gasoline range organics (C<sub>6</sub>-C<sub>10</sub>), diesel range organics (C<sub>11</sub>-C<sub>28</sub>) and lube oil range (C<sub>29</sub>-C<sub>40</sub>). These hydrocarbon pollutants were released into the water bodies through natural and man-made processes which may be biological, chemical or physical and thereby contaminating the rivers (Wang *et al.* 2002, Riccardi *et al.*, 2008, Pawlak *et al.*, 2008) [56, 48, 44]. Due to the hydrophobic nature of total petroleum hydrocarbons contaminants and their insoluble nature in water they are quickly adsorbed by particulate matter and readily sink to the sediment of the river (Jones *et al.*, 1999) [30]. The gradual sedimentation of these petroleum hydrocarbon contaminants poses danger and bioconcentration in the organisms that dwell in the bottom (sediment) of the river overtime (Muthukumar *et al.*, 2013, Farrington *et al.*, 2014, Adeniji *et al.*, 2017) [38, 22, 1].

The crude oil (petroleum hydrocarbons) is among one of the several toxic compounds that affect varieties of plants and animals in the aquatic environment. The presence of different categories of hydrocarbons in the marine environment at lower concentrations can lead to disorders (behavioural and Physiological) and at severe situations lead to death (El-Din and Abdel-Moati, 2001) [19]. The presence

of large quantities of total petroleum hydrocarbons on the shorelines during large spills can cause increased erosion and has great interference with the soil matrix (Silliman *et al.*, 2012) [51]. The presence of diesel range organics (DRO) has a higher effect of inhibition as compared to the gasoline range organics (Mohammadi *et al.*, 2020) and the accumulation of heavier categories of total petroleum hydrocarbons such as lube oil range (LOR) in the sediment of the water body affect the life of sedentary organisms (Ahmed and Anm, 2018) [3]. The spawning of fish and other aquatic organisms occurs on the sea or river beds (sediments), therefore the presence of these hydrocarbon categories (GRO, DRO and Lube oil range) in large quantity can affect the bottom river dwelling organisms. The resultant effect on the marine environment is the reduction of the bottom feeders and dwelling organisms and this may

possibly eliminate algae and plankton and also have great influence in the spawning portions of the river (Jack *et al.*, 2005) [29]. Petroleum hydrocarbons when present in the river produces toxic effects and an increased concentration of total petroleum hydrocarbons on the aquatic organisms also hinder the physiological characteristics of aquatic plants and animals (Connell and Miller, 1980, Edori and Marcus 2019) [10, 17, 18]. The inability of these bottom loving and dwelling organisms to swim away (the slow movers) from the polluted water may lead to death when total petroleum hydrocarbons are assimilated and adsorbed. Bioaccumulation of hydrocarbons by organisms that dwell at the bottom of the river results in reduction of several marine species due to death and possible extinction (Filho *et al.*, 2013, Ogeleka *et al.*, 2016, Edori and Marcus, 2019) [23, 40, 17, 18].

**Table 2:** Spatial Variation of the Different Categories of Total Petroleum Hydrocarbons in the Sediments of Orashi River at Different Stations and Months

Stations/Months	Total Petroleum Hydrocarbons Categories		
	Gasoline Range Organic (GRO) C <sub>6</sub> -C <sub>10</sub>	Diesel Range Organic (DRO) C <sub>11</sub> -C <sub>28</sub>	Lube Oil Range C <sub>29</sub> -C <sub>40</sub>
1	1.0795±0.512	17.575±4.7044	3.738±0.354
2	5.335±1.23	26.1561±7.9213	3.616±0.8139
3	2.7922±0.9211	42.9514±14.5235	4.6995±0.547
4	8.6913±2.413	19.3526±5.5566	1.343±0.0714
December	11.9523±4.461	27.6844±8.935	0.206±0.104
February	4.899±0.24	22.0206±4.499	2.7017±0.562
April	1.135±0.012	39.4842±13.496	9.8841±3.305
June	-	16.0511±3.24	0.6034±0.103

The percentage concentrations of the various categories of total petroleum hydrocarbons in the surface water Orashi River are shown in Tables 3. Table 3 revealed that the percentage of the various categories of total petroleum hydrocarbons of the surface water in the various stations of Orashi River were GRO; 3.03, 0.00, 9.32 and 0.00%, DRO; 81.69, 100, 84.03 and 97.95% and lube oil range; 15.28, 0.00, 6.65 and 2.05% for December, February, April and June respectively. The average percentage value for the surface water in the stations of Orashi River were GRO; 3.09%; DRO, 90.91% and lube oil range; 6.00%. In the months the average concentrations for the different total petroleum hydrocarbons categories were, GRO; 7.61, 0.00, 4.33 and 0.00%, DRO; 92.39, 100, 87.70 and 91.76% and lube oil range; 0.00, 0.00, 7.9 and 8.24% for December, February, April and June respectively. The average percentage value for the surface water in the sampled months of Orashi River were GRO; 2.99%; 92.96% and lube oil range; 4.05%.

The analysis of total petroleum hydrocarbons often, are given in bulk, but when such analyses are reported in ranges which total hydrocarbons occur (WHO, 2018), it provides a clearer picture on the pattern of remediation to be applied in order to restore the affected environment. In the evaluation of the hazards brought about due to total petroleum hydrocarbons concentration in the surface water, a clear and proper approach to evaluate the risk of an affected site (river) require an adequate understanding of the nature and composition of the hydrocarbons present in the water (API, 1993) [8]. The understanding of the composition and the ranges of total petroleum hydrocarbons in the surface water in their proper quantities and actual percentages of

occurrence in the surface water will help to provide specific and adequate information on the nature of the pollutant or contaminant. The appropriate approach to apply in remediation or restoration of polluted water (river) is a proper understanding of the categories of petroleum hydrocarbons involved and the concentration levels of the petroleum fractions involved. In conducting a true risk-based analysis where pollution took place, there is the need to detect the hydrocarbon range (number of carbon atoms) and the level of occurrence or presence of these different categories (TPHCWG, 1998) [55], hence the right and appropriate method will then be applied.

Total petroleum hydrocarbons ranges, provides information on the components of petroleum hydrocarbons in the samples and give room for the right and adequate effect of the different components on the environment. The presence of these hydrocarbon categories in percentages of in the river is a pointer to the actual health condition of the river and also a veritable tool for understanding the mode of contamination and the major contaminants of the surface water (Zaghden *et al.*, 2005, Zrafi *et al.*, 2013) [59, 60]. For proper diagnosis of a contaminated river and an adequate rehabilitation procedure and mechanism, there is the necessity of measuring the correct amount of total petroleum hydrocarbons that contaminated any given river (Schartz, *et al.*, 2012). Products of total petroleum hydrocarbons such as gasoline, lubricants, oils diesel and many others have been used on many occasions as the indices in measuring and quantifying the level of contamination of the environment (ESD, 1993) [20].

**Table 3:** Percentage Concentrations of Different Categories of Total Petroleum Hydrocarbons in the Surface Water of Orashi River in the Stations and Months

Stations/Months	Total Petroleum Hydrocarbons Categories		
	Gasoline Range Organic (GRO) C <sub>6</sub> -C <sub>10</sub>	Diesel Range Organic (DRO) C <sub>11</sub> -C <sub>28</sub>	Lube Oil Range C <sub>29</sub> -C <sub>40</sub>
1	3.03	81.69	15.28
2	0.00	100	0.00
3	9.32	84.03	6.65
4	0.00	97.95	2.05
December	7.61	92.39	0.00
February	0.00	100	0.00
April	4.33	87.70	7.97
June	0.00	91.76	8.24

From Table 4, the data revealed that the percentage concentrations of the different categories of total petroleum hydrocarbons in the sediments of Orashi River in the sampled stations were GRO; 4.82, 15.20, 5.45 and 29.58%, DRO; 78.47, 74.50, 85.14 and 65.85% and lube oil range: 16.71, 10.30, 9.32 and 4.57% for stations 1, 2, 3 and 4 respectively. The average percentage concentration values in the sediments of Orashi River in the stations under investigation for the different categories of total petroleum hydrocarbons were GRO; 13.79%, DRO; 75.99% and lube oil range; 10.22%. In the sampled months, the observed concentration values of the different categories of total petroleum hydrocarbons in percentages were GRO; 30.00, 16.26, 2.25 and 0.00%, for the sampled months, DRO; 69.48, 74.56, 78.18 and 96.38%, and lube oil range; 0.52, 9.15, 19.57 and 3.62% for the sampled months of December, February, April and June respectively. The average percentage concentration values in the sediments of Orashi River in months under investigation for the different categories of total petroleum hydrocarbons were GRO; 12.13%, DRO; 79.65% and lube oil range; 8.22%.

The prevention of contamination and pollution of any environment is the best and only way to respond to pollution occasioned by total petroleum hydrocarbons in the sediments of any river, and a good understanding and knowledge of the mode and pattern of pollution is needed to facilitate a thorough clean up. The proper understanding of hydrocarbon pollution occasioned by total petroleum hydrocarbons in the sediment indicates the nature of the

environment and its biodegradable properties (Prince *et al.*, 1994, Mills, 1994) <sup>[46, 36]</sup>. A clearer view and understanding of the hydrocarbon categories in the sediments of any river is a useful instrument in remediation processes and thorough assessment of the sediment environment and proper clean-up procedure to be applied (Douglas *et al.*, (1991) <sup>[16]</sup>. The GRO group in the sediment are the most volatile and can be easily recovered using techniques such as stripping or purge and trap (Rauckyte, 2010) <sup>[47]</sup>. Having a clearer view on the ratio of their presence in a contaminated sediment or site will help improper application of the recovery technique. The DRO group is semi-volatile, while the lube oil range are semi-solid and has very low volatility rate and tend to be more stable in the sediments. To understand better the impact total petroleum hydrocarbons have created in the environment, the knowledge of the processes that occur when total petroleum hydrocarbons are present in the present in the environment is necessary (Mohammadi *et al.*, 2020). The contamination of the sediments brought by the hydrocarbon categories differ from one group to the other. Physical processes like evaporation, temperature, water turbulence and the velocity of the wind can easily eliminate the more volatile range organics (Payne *et al.*, 1991), hence the low presence of GRO in the sediments. Immediately spill occurs, the lighter hydrocarbons easily lose greater part of their mass up to 99% or even more to evaporation. Such alkanes or total petroleum hydrocarbons include the GRO group of propane, butane and pentane (Mango, 1997) <sup>[34]</sup>. Which have low molecular weight and low volatility.

**Table 4:** Percentage Concentrations of Different Categories of Total Petroleum Hydrocarbons in the Sediments of Orashi River in the Stations and Months

Stations	Total Petroleum Hydrocarbons Categories		
	Gasoline Range Organic (GRO) C <sub>6</sub> -C <sub>10</sub>	Diesel Range Organic (DRO) C <sub>11</sub> -C <sub>28</sub>	Lube Oil Range C <sub>29</sub> -C <sub>40</sub>
1	4.82	78.47	16.71
2	15.20	74.50	10.30
3	5.54	85.14	9.32
4	29.58	65.85	4.5
December	30.00	69.48	0.52
February	16.29	74.56	9.15
April	2.25	78.18	19.57
June	0.00	96.38	3.62

## Conclusion

The contamination and pollution of the Orashi River is a big threat to man and other living organisms that make use of the river for sustenance of daily life and therefore the river need urgent attention from relevant agencies to forestall any health issues such may give rise to in the life of the inhabitants and other aquatic organisms. Effective measures should be put in place to reduce the rate at which pollution

due to total petroleum hydrocarbons occur in the environment. The present level of concentration of total petroleum hydrocarbons in the Orashi River is due mainly to anthropogenic activities and it is enough to warrant in order to avoid bioaccumulation in organisms that make use of the river and also increased concentration in the river system. A remediation process should be put in place by the government in collaboration with the oil nationals to give

restorative measures to pollution effect due to total petroleum hydrocarbons.

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