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Evaluation of Soil and Ground Water Quality Around an Oil Loading Facility at Eleme, Rivers State

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Abstract: Soil and groundwater quality around an oil leading facility were evaluated. The facilities are located in Eleme, Rivers state Nigeria. Sampling of soils was done at 2 depths (0 - 15 and 15 – 30cm) at 8 stations and one control point. AAS was used to analyze heavy metals, Hydrocarbons were analyzed with GC- FID and VOCs were analyzed with Headspace analyzing techniques respectively.The transfer ration of heavy metal and hydrocarbons in soil and groundwater were less than one. The concentration of underground water Cd, Ni obtained were below WHO permissible value for water, while Vi was not detected. The concentration of Pb in the 3 boreholes each (BH1, BH2 and BH3) for Aba and Eleme were above WHO permissible value for water. The concentration of TPH obtained in groundwater (BH1, BH2 and BH3) exceeded the permissible limit stipulated by WHO (2011). This study has revealed that refined hydrocarbon from loading facilities are sources of heavy metals and hydrocarbons contamination of the environment. Hence it will be very necessary to monitor loading activities in refined Hydrocarbon loading facilities.

I. INTRODUCTION

The process of crude oil exploration, production, refining, transportation and storage could result in oil leaks and accidental spills causing environmental pollution.Petroleum hydrocarbon has tremendous impact on the world civilization as it is the major source of energy for industries and daily life. The increase in demand for petroleum product has result in an increase in their production, transportation and refining which in turn has resulted in gross pollution of the environment (Gutnick and Rosenberg, 1997). Kvenvolden and Cooper (2003) estimated annual petroleum hydrocarbon seepage of 600,000 metric tons. Accidental or anthropogenic release of petroleum hydrocarbon into the environment is a main cause of water and soil pollution. Soil contaminated with hydrocarbons causes extensive damage to plants and animal tissues and could lead to death or mutation.

The increased oil activities have resulted to extensive environmental pollution by oil spills involving blowouts, leakages from tanks and tanker trucks and dumping of waste petroleum products into the environment. Crude oil when refined contains a wide range of components such as hydrocarbons, heavy metals, dye additives, antioxidants, corrosion inhibitors, etc. The refined products show higher toxicity compared to crude oil since metal speciation is altered and new metals added to the matrix during the refining process. The waste generated from such process may contain spent catalysts which are not recovered in most cases but discharged into soil and receiving water bodies these accumulate in surface water, sediments of rivers and ultimately ground water.

> Petroleum is a natural resource of global importance; it is used by many industries of the world for different purposes. PIEP (1995) noted that despite improvements in the technical conditions of involved in the production storage, and distribution of liquid fuels, the threat to the environment posed by petroleum substances is real, Kolzwan*et al.*, (2001), observed that contamination of soil and water by petroleum substances negatively affects plants production, and puts health of people and animals at risk as most of the substances are toxic to living organisms.

A group of organic pollutants comprising benzene, toluene, ethyl benzene, and xylene (BTEX) contains volatile organic compounds (VOCs) and Heavy metals which can contaminate or pollute soils through spills involving the release of petroleum products such as gasoline, Automotive gas oil, lubricating oil and heating oil from leaking oil tanks (Salanitro*et al.*, 1997 and Nwankwoala, 2014). BTEX have in recent years, attracted much attention, since they constitute one of the most common major threats to ground water reservoirs. (UzoekweandOghosanine, 2011). This is mainly due to the potential effects of benzene, which is considered a strong carcinogen and is highly mobile in the soil and ground water environments. Activities involving the use of petrol, heating fuel, and kerosene containing significant percentages of BTEX can produce pollutants and contaminants. BTEX are prime pollutants/contaminants that have attracted wide attention because of their high-water solubility and toxicity (Li and Zhou, 2011 andNourmoradi, *et al*., 2012). Petroleum is an extremely complex mixture of hydrocarbon and non-hydrocarbon Compounds (Chilingarian and Yen, 1978). Petroleum can be separated roughly into eight fractions based on carbon numbers because of the relationship between boiling point and molecular weight (Morrison and Boyd, 1966). The eight different fractions include natural gas, petroleum ether, Ligroin (Light naphtha), gasoline, kerosene, gas oil (diesel) lubricating oil and asphalt (petroleum coke). However, each fraction is still a very complicated mixture since each carbon number is represented by numerous isomers.

Mecham (1993), noted that during releases from leaking tanks and pipes, gasoline rises to the top of the water table, where a fraction of the soluble components (BTEX)

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dissolve into the water. These compounds are toxic and/or carcinogenic to humans. Dean, (1985). MFE (1999), observed that where fresh petrol is present on a site as a floating layer of liquid phase hydrocarbon, the potential human health and environmental risk is likely to be high. This is principally because of the presence of high vapor concentration, high concentrations of BTEX compounds to leach into an underlying groundwater system (Finley *et al*., 1994).

Polycyclic Aromatic hydrocarbons (PAHs) are aromatic hydrocarbons with two or more fused benzene rings in various structural configurations and do not contain hetero-atom or carry substituents (Abdulazeez, 2017; Blumer *et al*., 1977; Vichi*et al*.,2015, Haritash and Kaushik 2009, Kim *et al*., 2014, Masih and Lal, 2014; Nguyen *et al*., 2014. Sharma, 2014). PAH only consist of carbon and hydrogen bound in simple to complex ring systems, their benzene ring arrangements have a wide range diversity of physical, chemical and toxicological characteristic (Abdulazeez, 2017; Cerniglia, 1992).

Today's society is increasingly concerned about soil degradation, the sustainability of soil productivity, ground water quality and maintenance of biodiversity. Water quality is of vital concern to mankind, since it is directly linked with human welfare (Balakishnan*et al*., 2011). Water supports all forms of biological resources (plant and animal life) and are normally obtained from two major natural sources which are water (water bodies) such as rivers, streams, fresh water lakes and ground water (geological water) such as borehole and well water (Mendie, 2005). Water is capable of dissolving, absorbing, and adsorbing or suspending many different compounds as well as contaminants from its surrounding and those arising from humans and animals as well as other biological activities due to its distinctive chemical properties. Ground water contamination is one of the essential environmental issues confronting mankind today (Vodela*et al*.,1979) and between the wide diversity of contaminants affecting water resources in recent time heavy metals receive particular concern as a result of their strong toxicity even at low concentrations (Olowu*et al*., 2012). Ground water contamination with its subsequent degradation is more threatening, more so when it is realized that dynamic equilibrium maintained by gravity and capillary exists between surface and groundwater (OtokuneforandObiukwu, 2005). land is a receiver of contaminants from both soils and surface water and from other direct sources like leakages from buried chemical tanks (Majolagbe*et al*., 2011). The environmental consequences of soil pollution include adverse effect on the soil microflora all of which assist in soil fertility (Odu, 1977 and Torstenssone*t al*., 1998).

II. MATERIALS

Eight (8) soil samples were collected from the loading facility. Soil samples was also be collected from 1km away from the loading facility as control.

Soils were collected at 01-15cm and 15-30cm depths at each station using the soil Auger. The collection of samples wasachieved by taking 2-3 auger borings of soil at the loading facility and bulked together to make a composite sample. The bulking of the samples from the two depth regimes (0-15cm) and (15-30cm) was done separately. Soil samples were collected in well-labelled Ziploc bags and taken to the laboratory where the sampleswere air-dried prior to laboratory analysis. Three(3) water samples were collected from 3 existing boreholes randomly selected from within the study area and one (1) sample was collected from an existing borehole with proximity of 1km away from the loading facility as the control sample.

III. METHOD

Sampling of soils was done at 2 depths (0 - 15 and 15 – 30cm) at 8 stations and one control point and Eleme station. Soil samples were kept in clean polyethylene bags and carefully labelled for easy identification and to reduce the effect of contamination. Thereafter, samples were transported to the laboratory to be air-dried at room temperature, crushed and passed through 2mm mesh sieve and late stored in clean plastic bags with proper labelling. AAS was used to analyze heavy metals, GC- FID was used to analyze the hydrocarbon and Headspace was used to analyze the VOCs respectively. Soil and groundwater samples were analyzed for the following parameters; pH, electrical conductivity, organic matter content, organic carbon content, available nitrogen, particle size distribution, cation exchange capacity, heavy metals (Pb, Cd, Ni, V, Zn and Fe) and Hydrocarbons (PTH, BTEX, and PAHs) content.

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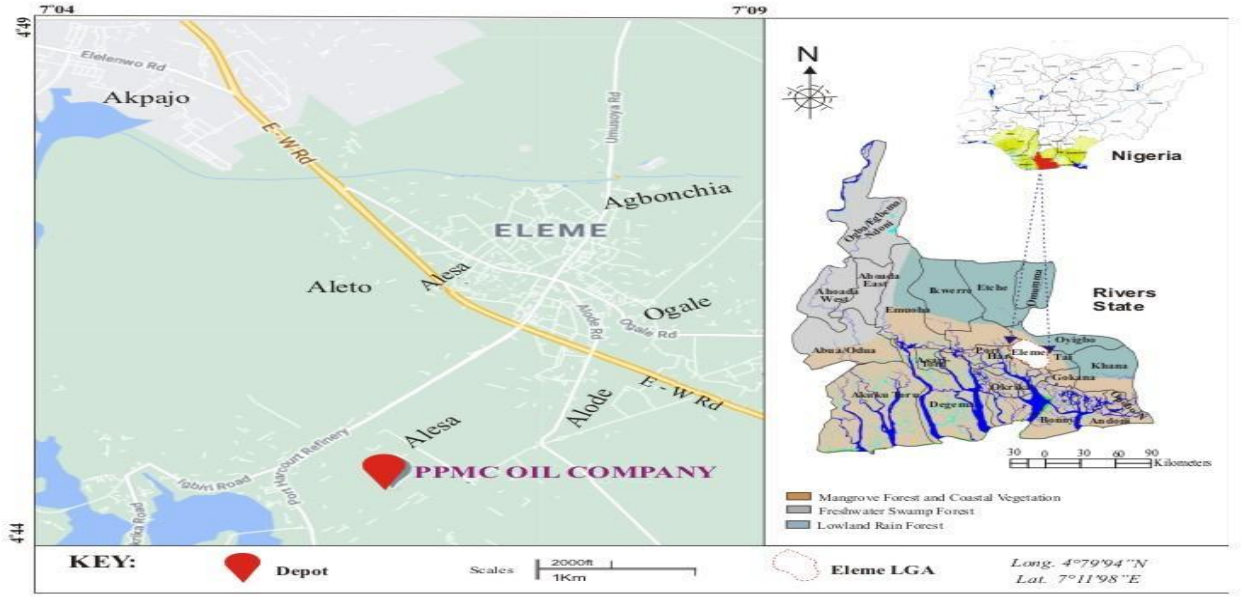
IV. STUDY AREA DESCRIPTION



The study area was Eleme Rivers State, Nigeria.

V. RESULT

A. SOIL

Analytical Report for 0-15cm Soil Samples at Eleme

PARAMETERS	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	Control
pH	6.54	6.40	5.85	6.80	6.33	5.02	6.78	5.88	5.96	6.54
Conductivity	34.86	40.77	38.96	40.66	43.76	39.62	42.64	38.54	37.80	34.86
CEC	1.86	2.05	1.77	2.31	2.65	1.76	2.50	2.42	2.65	1.86
TOC	0.3	0.4	0.3	0.32	0.43	0.38	0.45	0.44	0.37	0.3
Phosphate, mg/kg	0.06	0.18	0.08	0.23	0.16	0.28	0.14	0.07	0.22	0.34
Nitrate, mg/kg	1.05	1.25	0.93	1.12	0.86	0.96	0.86	1.03	0.85	1.53
Sulphate, mg/kg	0.88	0.54	0.74	0.32	0.06	0.14	0.65	0.44	0.42	0.93
% Sand	56	60	57	62	59	57	54	62	57	60
% Silt	33	28	25	30	26	29	21	24	28	22
% Clay	11	12	18	8	15	15	15	14	15	18

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Analytical Report for 15-30cm Soil Samples at Eleme

PARAMETERS	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	Control
pH	6.55	6.40	5.85	6.80	6.34	5.03	6.78	5.88	5.96	6.54
Conductivity	34.86	40.77	38.96	40.66	43.76	39.62	42.64	38.54	37.80	34.86
CEC	1.86	2.05	1.77	2.31	2.65	1.76	2.50	2.42	2.65	1.86
TOC	0.3	0.4	0.3	0.32	0.43	0.38	0.45	0.44	0.37	0.3
Phosphate, mg/kg	0.06	0.19	0.08	0.24	0.16	0.28	0.14	0.07	0.21	0.34
Nitrate, mg/kg	1.05	1.25	0.92	1.12	0.88	0.96	0.86	1.04	0.85	1.53
Sulphate, mg/kg	0.88	0.55	0.74	0.32	0.08	0.14	0.63	0.44	0.42	0.93
% Sand	56	61	57	63	59	57	55	62	57	60
%Silt	33	28	25	30	26	29	21	24	27	22
% Clay	11	12	18	8	15	16	16	14	15	18
BTEX	BDL	BDL	BDL 3	BDL	BDL	BDL	BDL	BDL	BDL	BDL

PAH in 0-15cm Soil Samples at Eleme

Component (mg/kg)	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	Control
Naphthalene	0.56	0.55	0.001	1.02	0.001	0.001	0.001	0.001	0.66	0.002
Acenaphthalene	0.18	0.02	0.001	0.21	0.001	0.001	0.12	0.001	0.83	0.001
Acenaphthene	0.53	2.64	0.001	0.54	0.001	0.001	0.06	0.001	0.45	0.001
Florene	0.06	0.65	0.001	0.22	0.001	0.001	0.001	0.001	0.01	0.001
Phenathrene	0.001	0.11	0.001	0.001	0.001	0.73	0.001	0.001	0.001	0.001
Anthracene	0.001	0.75	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0,001
Fluoranthene	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Pyrene	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Benzo(a)anthracene	0.16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Crysene	0.001	0.001	0.001	0.36	0.001	0.001	0.001	0.001	0.001	0.001
Benzo(b)fluoranthrene	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.22	0.001
Benzo(a)pyrene	0.001	0.001	0.54	1.06	0.001	0.001	0.001	0.001	0.001	0.001
Benzo(k)fluoranthrene	0.33	0.54	0.08	3.01	0.001	0.84	0.001	0.001	0.001	0.001
Indeno(1,2,3)perylene	1.86	2.06	0.26	0.64	0.001	1.35	0.001	0.33	2.42	0.003
Dibenzo(a,h)anthracene	2.65	0.33	1.03	2.38	0.001	0,42	1.33	1.98	1.65	0.001
Benzo(g,h,i)perylene	0.11	0.001	0.01	0.12	0.001	0.001	0.86	2.05	0.001	0.001
Total PAH	6.45	4.44	1.92	9.56	0.001	3.34	2.37	4.36	6.24	1.55

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PAH in 15-30cm Soil Samples at Eleme

Component (mg/kg)	**SS1**	**SS2**	**SS3**	**SS4**	**SS5**	**SS6**	**SS7**	**SS8**	**SS9**	**Control**
Acenaphthalene	0.18	0.02	0.001	0.21	0.001	0.001	0.12	0.001	0.83	0.001
Acenaphthene	0.53	2.64	0.001	0.54	0.001	0.001	0.06	0.001	0.45	0.001
Florene	0.06	0.65	0.001	0.22	0.001	0.001	0.001	0.001	0.01	0.001
Phenathrene	0.001	0.11	0.001	0.001	0.001	0.73	0.001	0.001	0.001	0.001
Anthracene	0.001	0.75	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0,001
Fluoranthene	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Pyrene	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Benzo(a)anthracene	0.16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Crysene	0.001	0.001	0.001	0.36	0.001	0.001	0.001	0.001	0.001	0.001
Benzo(b)fluoranthrene	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.22	0.001
Benzo(a)pyrene	0.001	0.001	0.54	1.06	0.001	0.001	0.001	0.001	0.001	0.001
Benzo(k)fluoranthrene	0.33	0.54	0.08	3.01	0.001	0.84	0.001	0.001	0.001	0.001
Indeno(1,2,3)perylene	1.86	2.06	0.26	0.64	0.001	1.35	0.001	0.33	2.42	0.003
Dibenzo(a,h)anthracene	2.65	0.33	1.03	2.38	0.001	0,42	1.33	1.98	1.65	0.001
Benzo(g,h,i)perylene	0.11	0.001	0.01	0.12	0.001	0.001	0.86	2.05	0.001	0.001
Total PAH	6.45	4.44	1.92	9.56	0.001	3.34	2.37	4.36	6.24	1.55

TPH in 0-15cm Soil Samples at Eleme

TPH COMPONENT	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	CONTROL
nC6-nC12	2.13	1.48	4.88	6.82	4.26	5.45	3.63	3.45	5.22	<0.001
nC13-nC22	6.84	10.75	18.20	12.66	13.52	8.65	17.33	5.42	3.46	<0.001
nC23-nC40	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total TPH (mg/kg)	8.97	12.23	23.08	19.48	17.78	14.10	20.96	8.87	8.68	<0.001

TPH in 15-30cm Soil Samples at Eleme

TPH COMPONENT	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	CONTROL
nC6-nC12	2.18	1.48	4.88	6.88	4.26	5.45	3.63	3.45	5.22	<0.001
nC13-nC22	6.86	10.75	18.20	12.66	13.57	8.65	17.35	5.42	3.49	<0.001
nC23-nC40	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total TPH (mg/kg)	9.04	12.23	23.08	19.54	17.83	14.10	20.98	8.87	8.71	<0.001

BTEX and Heavy Metals in 0-15cm Soil Samples at Eleme

PARAMETER	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	Control
BTEX	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fe	87.8	73.2	71.76	82.54	103.10	96.80	104.65	86.70	59.55
Mg	10.63	14.11	14.03	21.84	4.45	22.54	7.25	39.50	16.23
Pb	1.58	0.78	0.70	1.07	0.34	1.22	1.03	0.84	1.28
Cd	0.51	0.02	0.025	0.02	0.01	0.04	0.03	0.04	0.01
V	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	4.82	4.92	4.85	9.83	6.61	8.51	1.84	3.43	4.25
Ni	6.85	6.22	7.41	5.26	4.64	3.86	4.61	3.04	3.14

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BTEX and Heavy Metals in 15-30cm Soil Samples at Eleme

PARAMETER	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	Control
BTEX	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fe	87.85	73.5	71.82	82.56	103.10	96.80	104.65	86.70	59.62
Mg	10.64	14.16	14.03	21.85	4.47	22.66	7.26	32.50	16.28
Pb	1.56	0.77	1.07.	1.03	0.35	1.22	0.70	0.86	1.26
Cd	0.51	0.02	0.42	0.02	0.01	0.05	0.03	0.04	0.01
V	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	4.86	4.91	4.86	9.83	6.61	8.54	1.86	3.43	4.25
Ni	6.84	6.23	7.41	5.28	3.64	3.87	4.65	3.06	3.14

- **Poly Aromatic hydrocarbon (PAH) in soil**
  In surface soil sample, the order of PAH concentrations obtained ranged from 1.92 mg/kg to 9.56mg/kgwith mean value of 4.30 mg/kg. the PAH concentration obtained in control study sample is 1.55mg/kg. In subsurface of study sample, PAH concentration obtained ranged from 1.93 to 9.58 mg/kg with mean value of 4.30 mg/kg.
- **TPH**
  The TPH concentration obtained in surface soil ranged from 8.68 to 23.08mg/kg with a mean value of 14.91mg/kg
  The TPH concentration obtained in subsurface soil ranged from 8.71 to 23.08mg/kg with mean value of 14.93mg/kg
- **HEAVY METALS IN SOIL**
  Iron Fe
  Iron concentration for surface soil sample ranges from 71.76 to 104.650mg.kg with a mean value of 88.32 mg/kg. The concentration in subsurface soil sample ranges from 71.82 to104.65mg/kg with mean value of 88.37mg/kg, and concentration of 59.55mg/kg and 59.62 mg/kg for control samples respectively.
- **Magnesium Mg**
  The concentration of Magnesium ranges from 4.45to39.50mg/kg with a mean value 19.4mg/kg. in surface soil sample.The concentration of Magnesium in subsurface of soil samplesranges from 4.47 to 32.50mg/kg. the concentration values obtained in the control samples are 16.23mg/kg and 16.28mg/kg for surface and sub surface control soil samples respectively.
- **Lead Pb**
  The concentration Lead ranges from 0.34 to 1.58mg/kg in the surface soil sample. The concentration of Pb obtained in subsurface soil sample is from 0.35 to 1.56mg/kg. The concentration value obtained at the controls sample are 1.28mg/kg and 1.26mg/kg for surface and sub surface soil samples respectively.
- **Cadmium Cd**
  The concentration of Cadmium obtained ranges from 0.01 to 0.51mg/kg and 0.01 to 0.52mg/kg in surface and subsurface soil samples respectively. The concentration of Cadmium obtained at the control soil samples 0.01mg/kg for both surface and sub surface soil samples respectively.
- **Vanadium V**
  In all the study samples, vanadium was found to be below detectable level (<0.001mg/kg) of then machine.
- **Zinc Zn**
  Zinc concentration obtained ranges from 1.84 to 9.83mg/kg and 1.86 to 9.83mg/kg for surface and sub surface soil samples respectively. In the control soil samples,the concentration of Cadmium obtained is 0.01mg/kg for both surface and sub surface samples.
- **Nickel Ni**
  The Nickel concentration obtained in surface soil sample ranges from 3.04 to 7.41mg/kg. In the subsurface soil sample, the Nickel concentration ranges from 3.06 to 7.41mg/kg. at the control study samples, the concentration of Nickel is 3.14mg/kg for both surface and sub surface samples.
- **BTEX**
  BTEX concentrations recorded in both study and control samples for both surface and subsurface soils were below equipment detection limit of 0.001mg/kg.

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B. Groundwater

Physico-Chemical Properties of Water Samples in Eleme

PARAMETER	ELEME			CONTROL ELEME
	BH1	BH2	BH3	
pH	6.9	6.4	6.2	6.9
Temp (^{0} C)	26.8	26.8	26.8	26.7
Conductivity(µs/cm)	220	158	159	171
Turbidity(NTU)	0.4	0.5	0.5	0.5
Total Hardness(mg/l)	11.2	11.1	10.9	10.7
Nitrate(mg/l)	0.02	0.04	0.02	0.03
Sulphate(mg/l)	0.05	0.06	0.06	0.04
Total dissolved Solids(mg/l)	99	88	78	89
Hydrogen Sulphide(mg/l)	<0.01	<0.01	<0.01	<0.01
Salinity as in Chloride(mg/l)	8.2	8.1	8.1	8.5
Total suspended Solids(mg/l)	0.06	0.06	0.06	0.6
Alkalinity(mg/l)	28	28	29	30
Fe(mg/l)	0.08	0.06	0.06	0.07
Mg(mg/l)	2.4	2.4	2.1	2.05
Pb (mg/)	0.09	0.09	0.08	0.10
Cd (mg/l)	0.01	0.01	0.01	0.02
V (mg/l)	<0.01	<0.01	<0.01	<0.01
Zn (mg/l)	0.01	0.01	0.01	0.01
Ni (mg/l)	0.01	0.05	0.05	0.04

Environmental Guidelines and Standards for Soil for the Petroleum Industry in Nigeria (EGASPIN) (2018 Revised)

PARAMETER (mg/kg)	Target Values (DPR, 2018) (mg/kg)	Intervention Values (DPR, 2018) (mg/kg)
THC	50	5000
TPH	50	5000
PAH	1	40
BTEX	-	-
Nickel	35	210
Iron	-	-
Chromium	100	380
Cadmium	0.8	12
Zinc	140	720
Lead	85	530
Copper	36	190
Barium	200	625
Mercury	0.3	10
Vanadium	-	-

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World Health Organization (WHO) and Nigerian Industrial Standard (NIS) Limits for Potable Water

PARAMETER	REGULATORY STANDARD	
	WHO (2011)	NIS (2007)
Colour	Clear	Clear
pH	6.5 – 8.5	6.5 – 8.5
Temperature (ºC)	25 -30	Ambient
Conductivity (µS/cm)	250	1000
Turbidity (NTU)	5	5
DO (mg/l)	-	-
TDS (mg/l)	500	500
TSS (mg/l)	-	-
BOD (mg/l)	-	-
COD (mg/l)	-	-
Bicarbonate (mg/l)	-	-
Phosphate (mg/l)	250	250
Sulphate (mg/l)	250	100
Nitrate (mg/l)	50	50
Ammonium (mg/l)	-	-
TPH (mg/l)	0.01	0.01
Nickel (mg/l)	0.2	0.2
Chromium (mg/l)	0.05	0.05
Iron (mg/l)	2	0.3
Lead (mg/l)	0.01	0.01
Vanadium (mg/L)	0.01	

Sources: WHO Guidelines (2011), and Nigerian Industrial Standards (2007)

- **Heavy Metals**
  - Iron: The concentration of Iron Fe obtained in the study samples are 0.08 mg/l, 0.06 mg/l and 0.06mg/l for BH1, BH2 and BH3 respectively.
  - Magnesium: The concentration of Magnesium Mg obtained in the study sample are 2.4mg/l, 2.4mg/l and 2.1mg/l for BH1, BH2 and BH3 respectively.
  - Lead: The concentration of Lead Pb obtained in the study sample are 0.09mg/l, 0.09gm/land 0.08mg/l for BH1, BH2 and BH3 respectively.
  - Cadmium: The concentration of Cadmium Cd obtained in the study are 0.01mg/l, 0.01mg/kgand 0.001mg/l for BH1, BH2 and BH3 respectively.
  - Vanadium: The concentration of Vanadium V obtained in the study sample are <0.001mg/l for all the borehole in study stations
  - Zinc: The concentration of Zinc Zn obtained in the study sample 1 are 0.01mg/l, 0.01mg/l and 0.01mg/l for BH1, BH2 and BH3 respectively.
  - Nickel: The concentration of Nickel Ni recorded in study sample are 0.01 mg/l, 0.05mg/l and 0.05 mg/l for BH1,BH2 and BH3 respectively.
- Hydrocarbons
  - BTEX: BTEX concentration obtained in the study sample are below equipment detection limit in all the study sample in BH1, BH2 and BH3.
  - Polycyclic Aromatic Hydrocarbon: The PAH concentration obtained in study samples are <0.01mg/l, (below detectable limit) for BH1, BH2 and BH3 respectively.
  - Total Petroleum Hydrocarbon: The TPH concentration obtained in study samples are <0.01mg/l, (below detectable limit) for BH1, BH2 and BH3 respectively.

VI. DISCUSSIONS

A. Soil and groundwater pH

The soil pH was moderately acidic across the study samples (soil and ground water). The mean values of pH obtained across the study samples were surface study sample 6.55, subsurface study sample 6.60. These values were expected because according to Alloway and Aryes, (1997), most soils in the tropics have pH ranging from strong to weakly acidic and in some cases tends towards slightly alkaline.

There was no significant variation ($p>0.05$) among the 3 boreholes in the Aba and Eleme study areas respectively. The temperature values recorded in this study was ambient and consistent with the Nigerian Industrial Standards (NIS) recommended as well as within 25-30^{0}C stipulated by the WHO. The temperature values obtained in this study were similar to those reported by Onwugharaet *al*., (2013); Obi and Okocha (2007).

B. Polycyclic Aromatic Hydrocarbon (PAHs)

The Total PAH concentrations obtained in this soil study ranges from 0.001 to 6.45mg/kg, this value exceeded the Department of Petroleum Resources (DPR) target value of 1.0 mg.kg for a spill site in Nigeria, it is still below 40 mg/kg intervention value. The value of PAH concentrations obtained in the ground water samples were below detectable limit.

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C. Benzene, Toluene, Ethylbenzene and Xylene(BTEX)

BTEX concentrations recorded in soiland groundwater samples were below equipment detection limit of 0.001mg/kg. This finding can be attributed to their volatility, which is in agreement with the previous studies conducted by Echem*et al*. (2019), in Gokana; Duan and Li (2017), in China, Benzene, Toluene, Ethylbenzene and Xylene are classified as priority pollutants regulated by many environmental organizations around the globe including USEPA and DPR.

D. Iron Fe

Iron concentrations obtained in this study (Eleme) for soil samplesare much higher than 0.3mg/l permissible limit of the WHO (2011) and NIS (2007). Iron concentration obtained in the groundwater samples ranges from 0.06 to 0.08mg/kg. These values obtained were lower than 2.5mg/l, 1.804mg/l, 1.6mg/l, previously reported by Nwankwoala and Ngah(2014); Ogbunek*et al.*,(2020); Nwankwoala and Udom, (2011) respectively in the Niger Delta region.

E. Lead Pb

The concentration of Pb obtained in the soil and ground water samples ranges from 0.03 to 1.48 mg/kg, these values exceeded 0.01 mg/l permissible limit by WHO (2011) and NIS (2007).

Pollution of groundwater with Pb possess a potential threat to the health of people living in the area., as groundwater is their major source of portable water.

VII. RECOMMEDATION

There is need to regulate and enforce the best standard practice in storage, loading and transportation of refined petroleum products in all oil loading facilities, there should be regular inspection of all loading facility and asset management and qualitytraining of all personnel involved in refined petroleum product storage, loading and transportation.

VIII. CONCLUSION

This study has revealed that refined petroleum products from loading facilities are major sources of heavy metals and hydrocarbons contamination of the environment. It has specifically shown that release of various contaminants resulting from leaking trucks, human error during loading, operational failure or old age, can infiltrate the soil and in turn the groundwater. Therefore, continuous leakage of underground petroleum facilities such as pipelines, flow stations, depots, and service stations have potential of exposing man to high concentrations of toxic metals and hydrocarbons such as Pb, Ni, TPH etc., beyond their threshold levels. The concentrations of TPH and PAH obtained in the soil in this study exceeded their respective target values of the Department of Petroleum resource (DPR) in oil spilled soil nevertheless, below their respective intervention limits.

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