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Heavy Metals and Total Petroleum Hydrocarbon Concentrations in Surface Water of Esi River, Western Niger Delta

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ABSTRACT

Water samples from Esi river were analyzed for hydrocarbons and heavy metals to assess the impact of petroleum prospecting activities on the environment of the Western Niger Delta. Important results obtain are for O and G (11600±8600 μg L^{-1}), TPH (4270±3000 μg L^{-1}), Pb (39±33 μg L^{-1}), Cd (2.4±3.1 μg L^{-1}), Cr (42±17 μg L^{-1}), Cu (16.1±7.4 μg L^{-1}) and Zn (107±7.9 μg L^{-1}), showing high concentrations of O and G and TPH. The nickel-vanadium ratio of 1.71 revealed that the measured oil residue had its source from oil drilled in the area. The concentration of Pb was also high relative to Nigerian and International guideline values for drinking water. The water is polluted and not fit for drinking.

Key words: Heavy metals, drinking water, Esi river, Ethiope river, oil and grease, total petroleum hydrocarbons

INTRODUCTION

Heavy metal and petroleum hydrocarbon contamination often results from petroleum prospecting and processing activities (Forstner and Wittman, 1983; NRC., 1985; GESAMP., 1993; NRC., 2003). The degree of contamination may be significant where frequent spillages occur. The Niger Delta region of Nigeria is one of such areas (Hinrichson, 1990). The UNDP (2006) report indicates that between 1976 and 2001, about 7000 spill were recorded in the area which accounted for a loss of about three million barrels of oil, 70% of which were not recovered. Such spillages may lead to damage and loss of biodiversity, depletion of arable land, depletion of available potable water and blockage of waterways. In such circumstances, the concentrations of petroleum hydrocarbons and trace metals in water bodies are often observed to be elevated (NRC., 2003; UNDP., 2006; Luiselli *et al*., 2004, 2006; Udoh and Akpan, 2010; Perez-Casanova *et al*., 2010; Omo-Irabor *et al*., 2011; Almeida *et al*., 2013; Sung *et al*., 2013). Oil spillages in their early stages also have direct adverse effects on human health (Lee *et al*., 2009; Gwack *et al*., 2012). The biodegradation of petroleum hydrocarbons is often made difficult and slow due to the presence of heavy metals, heavy metals show toxicity toward most species of biodegrading microorganisms (Almeida *et al*., 2013; Kalita *et al*., 2009; Plaza *et al*., 2010; Nie *et al*., 2010). Recovery of environments spilled with oil are even more difficult with mangrove forests, it takes up to three decade for a mangrove forest to recover (Ballou and Lewis III, 1989; Ballou *et al*., 1989; UNEP., 2011). A number of studies in the Niger Delta area have focussed on the assessment of levels of petroleum residues (oil and grease, total petroleum hydrocarbon and polycyclic aromatic

Table 1: Incidents of oil Spills above 50 barrels up to December 1999 in the Esi river area (SPDC, 2001)

Date	Location	Volume of oil spilled bbL	Volume of oil recovered during clean-up bbL	SPDC official stated cause of spill	Class	Status of cleaning as at December1999
1/6/93	Kokori flow station	60	0	Corrosion leak of L/P header	Corrosion	-
5/26/97	Eriemu well 13S	410	400	Master valves and survey valves opened by unknown person	Sabotage	-
7/25/84	Utorogu/UQCC delivery line	500	400	Corrosion leak of 16" utorogu delivery line within loc 16	Corrosion	-
8/3/99	Kokori 26/28/29 actual well yet to be determine	65	0	Bubbling of crude oil in a swamp location near wells 26/29/29	Sabotage/theft	Ongoing
9/11/83	Afiesere flare site	625	400	Carry over to the flare delivery closure/reopening	Production operations	Completed 11/10/98
10/4/98	Utorogu flow station	143	136	During routine cleaning of the flow-station saver pit on 04/10/98, crude oil was pumped and channeled to the 3" bund wall flush pipe to flare and un knowingly 68 m of the flush Pipe had been cut by unknown person(s)	Sabotage/theft	
11/3/96	Eriemu-UQCC trunk line	350	341	16" Eriemu-UQCC Delivery Line was cut by unknown person	Sabotage/theft	Ongoing
9/7/99	24" UQCC Rapele at Ekakpamre	200	103	Pipeline blown up with an explosive by unknown person(s)	Sabotage/theft	

UQCC: Ughelli quality control centre

hydrocarbons) and trace heavy metals in aquatic environments where oil spillages have occurred. Results have generally shown the concentrations to be elevated beyond background levels (Ibiebele, 1986; Ekundayo and Obuekwe, 2000; Anyakora *et al*., 2005; Ayotamuno *et al*., 2002; Osuji and Adesiyan, 2005; Olajire *et al*., 2005; Davies *et al*., 2006; Nduka and Orisakwe, 2009; Umoren and Udousoro, 2009; Sojinu *et al*., 2010; Williams and Benson, 2010; Adeniyi and Owoade, 2010; Ossai *et al*., 2010; Anyakora *et al*., 2011; Nduka and Orisakwe, 2011; Akporido, 2013; Akporido and Asagba, 2013).

The Esi river is one river system in the western Niger Delta region which has been impacted by oil spillages and for which only scanty baseline environmental data is available The river's drainage area includes the locations of several oilfields and other industries (Fig. 1). Esi river serves local residents for drinking, fishing, recreation and transportation.

Several major and minor oil spillages have occurred around Esi river (Table 1). Over 2890 bbl was spilled in the area around Esi river between 1983 and 1999 (SPDC., 2001). Yet, literature data on the degree of oil pollution in the area is severely limited.

The present study investigated the extent to which the Esi River and its adjoining areas have been impacted with crude oil spillages. The level of petroleum residue and heavy metals (copper, lead, nickel, cadmium, zinc, vanadium and chromium) in the river water was recently determined.

MATERIALS AND METHODS

The Esi River has its source about 130 km northeast of the study area where several oil fields adjoin its drainage area (Fig. 1). Water sampling stations were governed by factors such as

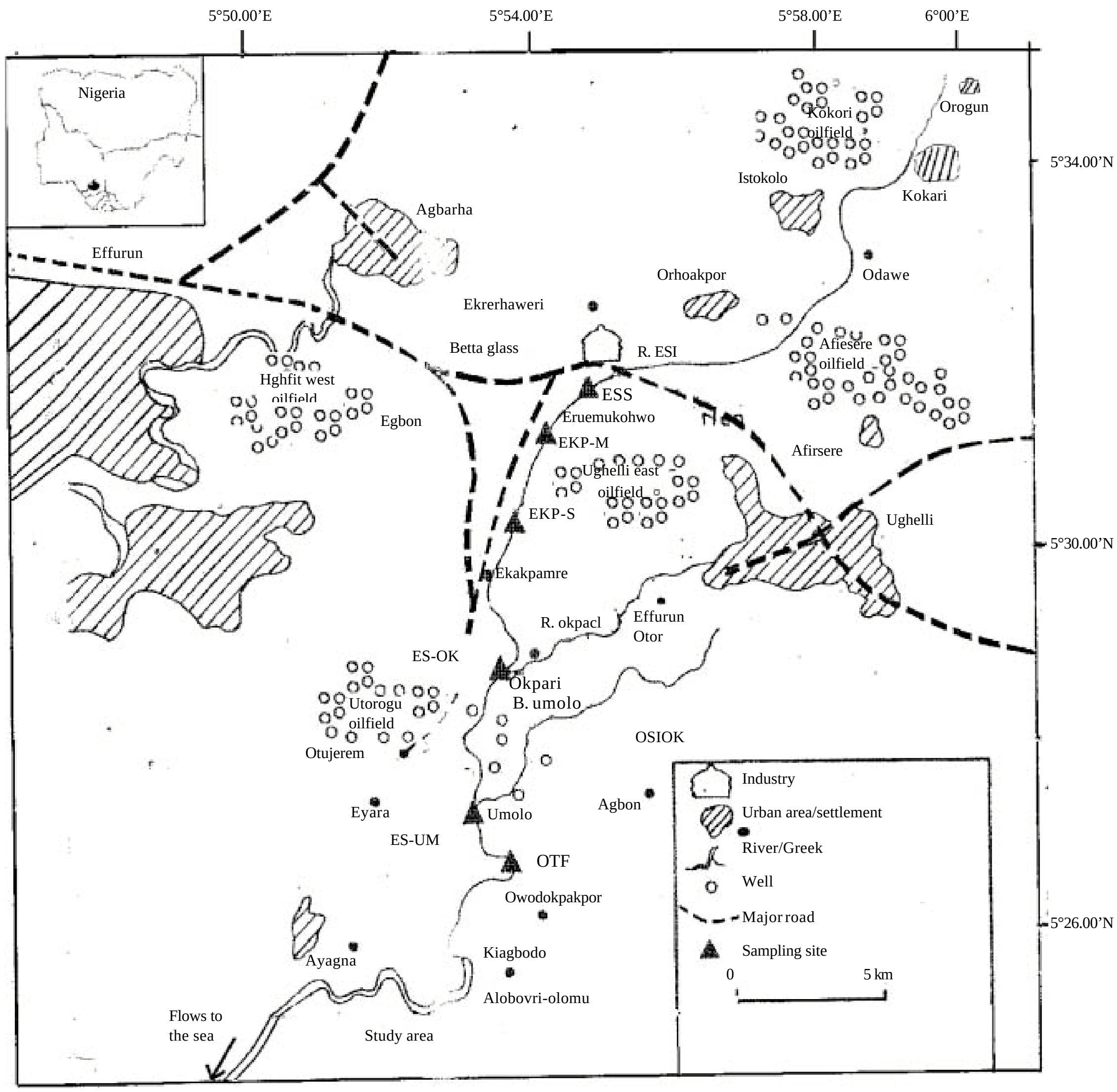

Fig. 1: Map of study area

recent incidents of spillages and confluences with other streams and rivers. Samples were collected quarterly during January 2002 to September 2003. Surface and at mid-depth, major sampling sites were: Ekakpamre Spill Site (ESS) (N 05°31.781' and E 005°54.871'), Ekakpamre middle town (Ekp-M) (N 05°31.175' and E 005°54.638'), Ekakpamre south Town (i.e., south of the town) (Ekp-S) (N 05°30.285^1 and E 005°53.407^1), Esi and Okpari rivers confluence (ES-OK) (N 05°28.629' and E 005°53.571'), Umolo stream and Esi river confluence (ES-UM) (N 05°27.143' and E 005°53.184') and Otujeremi Front (OTF) (N 05°26.734^1 and E 005°53.345^1). Two control area sampling stations (BRB-N 05°49.451^1 and E 006^1 06.504^1; AMB-N 05°48.038^1 and E 006^1 06.059^1) were located on a relatively cleaner river about 100 km away.

Samples for Oil and Grease (O and G) and Total Petroleum Hydrocarbons (TPH) determinations were collected with wide mouth glass bottles. Water samples for heavy metals determination were collected with plastic water bottles which have been washed with detergent, soaked in concentrated HNO_3 overnight and rinsed with distilled water. Samples for O and G and TPH determinations were preserved by adding concentrated HCl to pH<2 and water samples were analyzed within 28 days for heavy metal analysis by adding concentrated nitric acid to pH<2 (Anonymous, 1995).

O and G was determined by the Soxhlet extraction procedure. TPH was obtained from the O and G extract by re-dissolving in hexane and adding 4g of activated silica gel. This mixture was stirred with a magnetic stirrer for five min. Silica gel was filtered out and TPH obtained by distilling off the hexane and drying the residue to constant weight (Anonymous, 1995). Heavy metals (Cu, Pb, Cd, Zn, V, Cr and Ni) were determined by adding 5 mL concentrated nitric acid into 500 mL of water sample in a beaker. This was pre-concentrated and digested to near dryness. The residue was dissolved with a little distilled water and made up to the mark in a 50 mL volumetric flask. Metals were determined in the digest using flame atomic absorption spectrophotometer (Perkin Elmer AA 200, Waltham, USA). Sample and reagent blanks were analyzed for each batch of twenty samples. In addition to these, recovery studies were carried out.

RESULTS AND DISCUSSION

Average of O and G levels were 116000±8600 μg L^{-1} (ND-32600 μg L^{-1}), while TPH levels averaged 4270±3000 μg L^{-1} (ND-14900 μg L^{-1}) (Table 2). Corresponding levels in control site samples were 1070±910 μg L^{-1} for TOE and 506±610 μg L^{-1} for TPH, respectively. These results are indicative of oil contamination in the study areas of the Esi river. Hydrocarbon levels around Ekakpamre Spill site which is located furthest upstream were lowest (2510±240 μg L^{-1}) and the levels increased significantly beyond this point (to about 5000 μg L^{-1}) (Table 3) due to further inputs from oily effluents/runoffs from oil wells at downstream points.

The levels of O and G and TPH are marginally higher at the surface than mid-depth (Table 4) but these differences are not significant. This may be as a result of turbulence which result in mixing during the prolong rainy periods. Seasonal variations in O and G and TPH level (Table 5) were found not to be statistically significant.

Table 2: Average concentrations of heavy metals, oil and grease and total petroleum hydrocarbons in study area and control area samples

	Concentrations (μg L^{-1})	
Heavy metals	Study area	Control area
Oil and grease	11600±8600	1070±910
Total petroleum hydrocarbons	4270±3000	506±610
Copper	16.1±7.4	22±25
Lead	39±33	19±18
Nickel	12±15	8.31±12
Cadmium	2.4±3.1	4.2±5.3
Zinc	107±220	204±280
Vanadium	7.0±7.9	6.3±1.3
Chromium	42±17	13±15

Table 3: Average concentrations of heavy metals oil and grease and total petroleum hydrocarbons at each of the sampling stations

	Concentrations (μg L^{-1})					
Parameters	ESS	Ekp-M	Ekp-S	ES-OK	ES-UM	OTF
Oil and grease	7970±910	12600±700	14500±9100	17300±1200	7340±5800	11100±590
TPH	2510±240	5350±2900	4950±3000	4950±300	2880±2300	5630±410
Copper	13.6±8.1	19±11	10.4±1.8	17.8±7.4	17.2±6.1	15.8±4.5
Lead	17±12	42±54	47±56	51±22	51±22	30±13
Nickel	7.1±3.9	15±12	30±47	10.8±7.4	6.8±4.5	10.1±3.8
Cadmium	1.9±1.4	4.1±4.2	3.0±4.7	2.4±3.0	0.8±1.2	2.4±3.5
Zinc	27±41	21±17	22.8±32	167±240	185±330	178±310
Vanadium	7.0±11	15.0±8.4	6.3±2.4	9.9±6.7	3.9±5.7	6.3±4.8
Chromium	40.9±4.2	39±10	37±12	30±20	38.0±7.4	63±20

Table 4: Concentrations of heavy metals, O and G and TPH at half depth and at surface of Esi river

	Concentration (μg L^{-1})	
Heavy metals	Mid-depth	Surface
Oil and grease	11400±8100	11800±9100
Total hydrocarbon	4300±2600	4230±2500
Copper	14.3±5.5	18.2±8.7
Lead	35±28	43±37
Nickel	12±19	10.6±7.7
Cadmium	2.0±2.9	2.7±3.3
Zinc	105±24	104±200
Vanadium	7.4±7.2	7.9±8.7
Chromium	41±20	42±14

Table 5: Seasonal concentrations of heavy metals, oil and grease and total petroleum hydrocarbons in surface water

	Concentrations (μg L^{-1})			
Heavy metal	1st dry season	1st rainy season	2nd dry season	2nd rainy season
Oil and grease	18300±11000	14600±7400	7760±3700	5520±4500
TPH	4960±2600	4920±2500	3970±2800	3260±4200
Copper	18.2_±9.2	12.5±2.5	14.8±6.5	18.7±8.3
Lead	45±28	36±32	30±20	44±46
Nickel	15±11	16±2.8	8.6±5.2	8.1±5.2
Cadmium	4.1±3.6	1.9±2.9	1.9±3.0	1.5±2.3
Zinc	31.5±5.4	10.5±1.0	380±320	5.4±3.0
Vanadium	10±11	5.5±2.8	9.0±9.6	9.7±5.8
Chromium	51±11	38±14	34±18	44±21

The average nickel-vanadium ratio was found to be 1.71. Nickel-vanadium ratio is an important factor used for fingerprinting the source of oil contamination in environmental media. The ratio obtained from this study is close to the ratio of 2.0 published for Forcados blend (COLG., 2011) which is the predominant oil type in the Western Niger Delta. This confirms the provenance of the hydrocarbons in the water as derived from crude oil related activities in the area. Also the following

Table 6: Comparison of levels of oil and grease, total petroleum hydrocarbon and heavy metals with maximum permissible levels of some drinking water quality standards

Parameters	Results from present study (Esi river water)	Nigerian drinking water standards SON (2007)	WHO (2011)	USEPA (2012)	Health Canada (2012)	Nigerian standard (FMoE and FEPA., 1991)
O and G ($\mu g\ L^{-1}$)	11600±8600	NS	NS	NS	NS	50.0
TPH ($\mu g\ L^{-1}$)	4270±3000	NS	NS	NS	NS	NS
Pb ($\mu g\ L^{-1}$)	39±33	10.0	10.0	15.0	10.0	50.0
Cd ($\mu g\ L^{-1}$)	2.4±3.1	3.00	3.00	5.00	5.00	10.0
Zn ($\mu g\ L^{-1}$)	107±220	3000	NS	NS	5000*	5000
V ($\mu g\ L^{-1}$)	7.0±7.9	NS	NS	NS	NS	10.0
Cr ($\mu g\ L^{-1}$)	42±17	50.0	50.0	100	50.0	50.0
Ni ($\mu g\ L^{-1}$)	12±15	20	70.0	NS	NS	50.0
Cu ($\mu g\ L^{-1}$)	16.1±7.4	1000	2000	1300	1000	100

ns: No standard specified, *Not Maximum Acceptable Concentration (MAC)

pairs of parameters correlate strongly and their correlation coefficient are significant (∞ = 0.05): Pb and Cu (0.505), Ni and Pb (0.505), Cd and Cu (0.456), Cd and Pb (0.485), Cd and Ni (0.634) and V and Cd (0.560). This indicates that members of each pair has identical source which may be from the oil prospecting and processing activities in the area through oil spillages.

The average concentrations of the heavy metals are Pb; 39±33 $\mu g\ L^{-1}$ (ND-160 $\mu g\ L^{-1}$), Cu; 16.1±7.4 $\mu g\ L^{-1}$ (ND-40.0 $\mu g\ L^{-1}$), Ni; 12±15 $\mu g\ L^{-1}$ (ND-100 $\mu g\ L^{-1}$), Zn; 107±220 $\mu g\ L^{-1}$ (1.00-819 $\mu g\ L^{-1}$), Cd; 2.4±3.1 $\mu g\ L^{-1}$ (ND-12.0 $\mu g\ L^{-1}$), V; 7.0±7.9 $\mu g\ L^{-1}$ (ND-35.0 $\mu g\ L^{-1}$) and Cr; 42±17 $\mu g\ L^{-1}$ (ND-100 $\mu g\ L^{-1}$) (Table 2). A comparison of the mean values of metals of all six study sampling stations (Table 3) using analysis of variance shows that the differences in concentrations for Cu, Pb and Cd for the six sampling stations are statistically not significant. The differences in the concentration of Zn, Ni, V and Cr are however statistically significant at 0.05 confidence level when tested with ANOVA single factor. There is no definite trend in the variation of all the metals with respect to distance of sampling stations from upstream to downstream.

A comparison of mean concentration of heavy metals of study area with those of the control area (Table 2) shows that the concentrations of heavy metals with the exception of the concentration of Zn are higher in the study area than in the control area. A paired t-test (Student t-test) however shows that the differences are not statistically significant at six degrees of freedom and at 95% confidence level.

Use of water for drinking purpose is one of the numerous uses to which the water of Esi River is put by the inhabitants close to the river in the absence of pipe-borne water or due to the high cost of other treated waters. A comparison of the concentrations of the parameters measured with national and international guidelines (Table 6) shows that the concentration of O and G (11600±8600 $\mu g\ L^{-1}$) is higher than the permissible limits of Federal Ministry of Environment (FMEnv) (formerly Federal Environmental Protection Agency [FEPA]) guidelines (50.0 $\mu g\ L^{-1}$) (FMoE and FEPA., 1991). The average concentration of Pb in Esi River (39±33 $\mu g\ L^{-1}$) exceeded the Minimum Permitted Levels (MPL) of Nigeria guidelines (10.0 $\mu g\ L^{-1}$) (SON., 2007), Health

Based Guideline (HBG) of WHO (2011) (10.0 μg L^{-1}), Maximum contaminant level of USA water quality standards (15.0 μg L^{-1}) (USEPA., 2012), Maximum allowable concentration Canadian water Quality Guideline (10 μg L^{-1}) (Health Canada, 2012). The water is thus not suitable for drinking.

A comparison of average concentrations of parameters measured in the study area with guideline values for uses of water other than for drinking purpose (Table 7) shows the following: Average concentration of O and G (11600±8600 μg L^{-1}) is higher than that specified for iron and steel water (Not detected) and also higher than the California State Water Quality Control Board (CSWQCB) 1963 guideline for recreational water (5000 μg L^{-1}) (Van der Leeden *et al.*, 1990). The average concentration of Zn in Esi river (107±220 μg L^{-1}) exceeded the Canadian water quality guidelines for power generation (Boiler feed water) (<10.0 μg L^{-1}) (CCREM., 1987). The average concentration of Cu in Esi river (16.1±7.4 μg L^{-1}) exceeded the Canadian water quality guideline for power generating (Boiler Feed water) (<10.0 μg L^{-1}) (CCREM., 1987). The water of Esi River may not therefore be suitable for iron and steel industry, power generating industry and recreational water (it must however be cautioned here that these standards or guideline are not strictly enforceable in Nigeria, they have only been used here to assess the quality of water of Esi river).

In a comparison of the results of determination of parameters in this study with results obtained for other rivers in Nigeria and in other countries which are polluted, it was found that most of the results were comparable with results obtained elsewhere. Some were however higher or lower than results obtained in other places (Table 8). The average concentration of O and G of Esi River, 11600±8600 μg L^{-1} (ND-32600 μg L^{-1}) is comparable with results obtained for Elechi Creek (90.0-1220 μg L^{-1}) by Obire *et al.* (2003). It is also comparable with results for Benin river at Koko (2270±480 μg L^{-1}) (Akporido, 2013). It is however lower than results obtained for Niger river drilling site (1100100 μg L^{-1}) by Ayotamuno *et al.* (2002) and the New Calabar river in the petroleum prospecting area (10-5000000 μg L^{-1}) (Odokuma and Okpokwasili, 1997). The average concentration of TPH in the study area 4270±3000 μg L^{-1}) (ND-14900 μg L^{-1}) is comparable with results obtained for Niger river petroleum Prospecting area (1120-53900 μg L^{-1}) by Ibiebele (1986) and Benin River at Koko (2010±340 μg L^{-1}) (Akporido, 2013) but higher than that for Ponggion river estuary (0.35-1100 μg L^{-1}) (Nayar *et al.*, 2004). The average concentration of Pb in Esi river 39±33 μg L^{-1} (ND-160 μg L^{-1}) is comparable with those results obtained for Elechi Creek (1.00-160 μg L^{-1}) (Obire *et al.*, 2003), Benin river at Koko (146±55 μg L^{-1}) (Akporido, 2013) and Crooked Creek (310±360 μg L^{-1}) (Jennett and Foil, 1979). It is higher than results for Niger River (at Patani) (ND) (Asonye *et al.*, 2007) and Urashi River (ND) (Asonye *et al.*, 2007). It is however lower than those for Ogunpa/Ona (<10.0-8600 μg L^{-1}) (Onianwa *et al.*, 2001), Bietri Bay and Ebrie Lagoon (2400-4800 μg L^{-1}) (Koffi *et al.*, 2014) and New Calabar River (850 μg L^{-1}) (Wegwu and Akiniwor, 2006). The mean concentration of Ni in Esi River (12±15 μg L^{-1}) or the range (ND-100 μg L^{-1}) is comparable with those for Elechi Creek (27.0-945 μg L^{-1}) (Obire *et al.*, 2003). Ogunpa/Ona River (<1.00-27.0 μg L^{-1}) (Onianwa *et al.*, 2001) but much lower than those for Tinto River (160,000±110,000 μg L^{-1}) (Elbaz-Poulichet *et al.*, 1999) and Benin river at Koko (1880±630 μg L^{-1}). The concentrations of the remaining parameters showed the same trend with the parameters discussed above when they were compared with results obtained for the other studies in Table 8 (i.e., some were comparable with these other results while some were either lower or higher).

Table 7: Comparison of mean values of oil and grease, total petroleum hydrocarbon and six heavy metals with internationally acceptable guideline for uses of water other than for drinking

Parameters	Results from present study (Esi river water)	Iron and steel industry (Manufactures) (CCREM., 1987)	Power generating industry (Boiler feedwater) (CCREM., 1987)	Food and beverage industry (Food canning from dried, frozen, fruits, vegetables) (CCREM., 1987)	FAO water quality guidelines for irrigation (Van der Leeden *et al.*, 1990)	CSWQCB 1963 water quality for the protection of aquatic life (Van der Leeden *et al.*, 1990)	CSWQCB 1963 Guideline for recreational water. Water contact-limiting threshold (Van der Leeden *et al.*, 1990)	Ontario min. of the environment 1984 water quality criteria for livestock (Van der Leeden *et al.*, 1990)
O and G ($\mu g\ L^{-1}$)	11600±8600	ND	-	-	NS	-	5000	-
TPH ($\mu g\ L^{-1}$)	4270±3000	-	-	-	NS	-	5000	-
Pb ($\mu g\ L^{-1}$)	39±33	-	-	-	NS	100	-	100
Cd ($\mu g\ L^{-1}$)	2.4±3.1	-	-	-	10.0	10.0	-	50.0
Zn ($\mu g\ L^{-1}$)	107±220	-	<10.0	-	2000	100	-	25000
V ($\mu g\ L^{-1}$)	7.0±7.9	-	-	-	100	-	-	100
Cr ($\mu g\ L^{-1}$)	42±17	-	-	-	100	-	-	1000
Ni ($\mu g\ L^{-1}$)	12±15	-	-	-	200	50.0	-	1000
Cu ($\mu g\ L^{-1}$)	16.1±7.4	-	<10.0	-	200	20.0	-	500

ND: Not detected, NS: Not specified, FAO: Food and agricultural organisation, CSWQCB: California state water quality control board and CCREM: Canadian council of resource and environment ministers

Table 8: Water quality characteristic of some other rivers compared with Esi river

Country	River	Major activities in the area	O and G	TPH	Cu	Pb	Ni	Cd	Zn	Cr	References
			(μg L^{-1})								
Nigeria (Niger delta)	Niger river (at Patani)	Petroleum prospecting	-	-	ND	ND	-	ND	1010	100	Asonye *et al.* (2007)
Nigeria (Niger delta)	New calabar river	Petroleum prospecting	10-5,000,000	-	-	-	-	-	-	-	Odokuma and Okpokwasili (1997)
Nigeria (Niger delta)	New calabar river	Petroleum prospecting	-	-	2080	850	-	560	6590	50.0	Wegwu and Akiniwor (2006)
Nigeria (Niger delta)	Niger river	Drilling site	1,100,100	-	-	-	-	-	-	-	Ayotamuno *et al.* (2002)
Nigeria (Niger delta)	Urashi river (Ahoada-west)	Petroleum prospecting	-	-	ND	ND	-	ND	230	ND	Asonye *et al.* (2007)
Nigeria (Niger delta)	Niger river	Petroleum prospecting	-	1120-53900	-	-	-	-	-	-	Ibiebele (1986)
Nigeria (Niger delta)	Elechi creek	Petroleum prospecting	90-1220	-	1.00-58100	1.00-160	27.0-945	7.00-254	2.00-822	1.00-718	Obire *et al.* (2003)
Nigeria (Niger delta)	Ogunpa/Ona (Ibadan)	Urban area	-	-	<1.00-39.0	<10.0-8600	<1.00-27.0	<1.00-23.0	<1.00-35.0	2.00-19.0	Onianwa *et al.* (2001)
Philippines	Ponggion river estuary	transportation	-	0.35-1100	-	-	-	-	-	-	Nayar *et al.* (2004)
Spain	Tinto river (Ria of huelva)	Industrial area	-	-	15200±1400	-	160,000± 110,000	120±97	3440±33000	-	Elbaz-Poulichet *et al.* (1999)
U.S.A.	Crooked creek	Metal milling a smelting	-	-	24±19	310±360	-	730±350	2770±590	-	Jennett and Foil (1979)
Cote D'ivoire	Bietri bay and ebrie Lagoon	Industrial	-	-	9050-9680	2400-4800	-	20-260	12080-19870	-	Koffi *et al.* (2014)
Nigeria	Elechi creek	Petroleum prospecting	-	-	<1.00		<1.00			<1.00-2.00	Davies *et al.* (2006)
Nigeria	Benin river	Industrial area	2270±480	2010±340	-	146±55	1880±630	3.0±5.3	62±42	0.40±0.59	Akporido (2013)
Nigeria	Esi river	Petroleum prospecting	11600±8600 (0.00-32600)	4270±3000 (0.00-14900)	16.1±7.4 (0.00-40.0)	39±33 (0.00-160)	12±15 (0.00-100)	2.4±3.1 (0.00-12.0)	107±220 (1.00-819)	42±17 (0.00-100)	Present study

CONCLUSION

The study showed that hydrocarbon levels are high in all the sampling stations. These high concentrations of hydrocarbon and lead have obvious effect on human and animal health. Efforts should be made to control emissions of these pollutants into the environment. From the results of this study, there is an indication that Esi river in all locations is polluted with petroleum hydrocarbons that were derived from petroleum prospecting in the area. Furthermore comparison with standards for specific industrial purposes and for drinking showed that the river water is not adequate for drinking and for some of these non-drinking uses.

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