Post-Impact Assessment of Oil Pollution on Some Soil Characteristics in Ikot Abasi, Niger Delta Region, Nigeria

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Abstract
Following a large-scale crude oil spillage in 2007, soil surveys were conducted in 2008 and in 2012 for post-impact assessment of the pollution on some soil characteristics in Ikot Abasi, Niger Delta Area, Nigeria. Soil characteristics examined include: pH, organic carbon (C), total nitrogen (N), available phosphorus (P), exchangeable cations (Ca, Mg, Na, K) exchangeable acidity (EA), effective cation exchange capacity (ECEC) base saturation (BS), total petroleum hydrocarbons (TPH), micronutrients (Fe, Mn, Zn, Cu) and heavy metals (Cadmium (Cd) and lead (Pb)). Soil analysis results in 2008 showed phenomenally greater values in some characteristics compared to 2012 results – five years after the pollution. In 2008, soil pH (6.8), organic (201.4 g/kg), N (5.65 g/kg), TPH, Pb, Fe, Mn, Zn, Cu, and Cd (3294.9, 2316.3, 23086.8, 189.4, 31.25, 29.1 and 4.22 mg/kg, respectively), were extremely (between 1.77 x 10^5 and 1.2 x 10^2 percent) higher than the respective values in 2012. On the other hand, available P(6.8 mg/kg), Ca, Mg, Na, K, EA, ECEC (2.2, 1.1., 0.04, 0.08, 1.6, 5.0 cmol/kg, respectively) and BS (68.5%) in 2008 were relatively higher in 2012, indicating a suppressive effect of oil pollution on these characteristics. The results showed that oil pollution is accompanied by major soil nutrient imbalances and phenomenal increases in soil TPH and some heavy metals. However, the impact of the pollution diminishes with time. This has serious implications on agricultural productivity of the land, ground water pollution and health of the people. Also, remediation approach to adopt and payment of compensation should be based on the magnitude of the pollution and persistence of the impact of the pollution.
Keywords: Impact assessment, oil pollution, soil characteristics, Niger Delta, Nigeria.

1.0 Introduction

Environmental pollution through oil spills and industrial effluence can cause serious damages to both aquatic and terrestrial ecosystems and destruction of forest and farmland through deforestation and burning and also severely affects the characteristics and management of agricultural soils (Dambo, 2000). Generally, the introduction of contaminants in the soil may result in damage to or loss of individual or several functions of soils and the possible contamination of water. The occurrence of contaminants in soils above certain levels entails multiple negative consequences for the food chain and thus for human health, and for all types of ecosystems and other natural resources (Nortcliff, 2012).

Local contamination is generally associated with mining, industrial sites, waste landfills and other facilities both during their operation and after closure. These activities can pose risks to both soil and water. Oil exploitation and industrial activities can contribute to localized loadings of total petroleum hydrocarbons and heavy metals into the environment through accidental spillages or leaks of oil from producing wells, storage tanks, gathering lines, transportation lines and pits and from industrial dump sites.

Oil pollution alters both chemical and physical properties of soil and degrades the soil fertility. Crude oil exploitation has had adverse environmental effects on soil, forests and water bodies in host communities in the Niger Delta area of Nigeria (Worgu 2000).

Ikot Abasi Local Government Area in Akwa Ibom State, in the Niger Delta Region of Nigeria, is a major oil producing area having both on-shore and off-shore fields. It also has a large deposit of gas. Oil exploration in Ikot Abasi by the Shell Petroleum Development Company (SPDC) started in the nineteen forties. Ikot Ada Udo village in the area was one of the on-shore areas where oil was discovered in commercial quantities but had been preserved with corked wells, untapped for over 50 years. During the years, oil and gas have spilled from the corked well several times (Udo, 2008). The most devastating oil spillage in the area occurred between August and November, 2007, when a large volume of oil from one of the corked wells spilled and spread over an extensive area of land causing serious environmental pollution and damages.

Following the oil spillage, a study was commissioned in 2008 to assess the effects of the pollution on land/soil, plants and aquatic lives and other components of the environment affected by the pollution (Udo, 2008). Among other findings, it was observed that the physico-chemical characteristics of the soils were highly affected by the pollution. Extremely high concentrations of certain elements and heavy metals and nutrient imbalances caused by the pollution, were observed in soils in the community. The aim of this study, therefore, was to assess the persistence of the impact of the oil pollution on some soil characteristics by comparing the present (2012) result with that obtained at the time (2008) of the pollution. It is hoped that the result of this study will be useful in proper soil management for agricultural production for the farming community. It could also guide in decisions on effective remediation approach to adopt in similar occurrence in future as well also on issues of adequate compensation for the affected community.

2.0 Materials and Methods

2.1 The Study Area

Ikot Abasi Local Government Area is on the coastal, south western part of Akwa Ibom State in the Niger Delta area of Nigeria. It is situated between latitudes 4°28' and 4°43'N and longitudes 7°30' and 7°50'E with an area of approximately 451.727 km^2 (Udo *et al.,* 2001).

The area is of the humid tropical climate with high annual rainfall of about 4000mm, mean annual temperature of about 27°C and relative humidity of above 80%. The soils in the area are formed mainly from the coastal plain sands and the beach ridge sands parent materials.

2.2 Field Work: This study was carried out in April 2012. The site of the study was Ikot Ada Udo village in Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria. Soil samples were collected in three locations within the area of the corked oil well where massive crude oil spillage had occurred in 2007. Samples were collected between 0 – 30 cm soil depth. The soil samples were taken to the laboratory, air-dried and sieved with a 2mm mesh sieve and subjected to analysis using appropriate procedures.

2.3 Laboratory analysis

The following physico-chemical analyses were carried out. Particle size distribution was determined by hydrometer method according to the procedure of Gee and Or (2002). Soil pH was determined using pH meter and read at a soil: water ratio of 1:2.5. Available phosphorus was determined by Bray P – 1 extractant as described by Udo *et al.* (2009). Exchangeable acidity (H^+ and Al^{3+}) was extracted with 1NKCl and titrated against 0.05M NaOH. Organic carbon was measured by Walkley and Black Wet digestion method (Nelson and Sommers, 1982), while total nitrogen (N) was estimated from organic carbon. Exchangeable bases were extracted with neutral normal ammonium acetate (at pH 7), K^+ and Na^+ contents were read with the aid of flame photometer while Ca^{2+} and Mg^{2+} were determined by EDTA complexiometric titration method (Jackson, 1962). Effective cation exchange capacity (ECEC) was determined by summation of exchangeable acidity and exchangeable bases (Soil Survey Staff, 2010). Base saturation was calculated as percentage of ECEC occupied by Ca, Mg, Na and K. Heavy metals/micronutrients (Cd, Pb, Cu, Mn, Fe, Zn) were determined using total elementary analysis of perchloric and nitric acid digestion and read using atomic absorption spectrophotometer (AAS), while total petroleum hydrocarbon (TPH) was extracted with xylene and measured using AAS as described by Osuji and Nwoye (2007).

2.4 Post-impact assessment

The persistence of the impact of oil pollution on soil characteristics was assessed by comparing the soil analysis data obtained in this (2012) study and the result obtained by Udo (2008), following the oil pollution.

3.0 Results and Discussion

3.1 Range and Mean Values of some Soil Characteristics as Influenced by oil Pollution.

In Table 1 are the range and mean values of some soil physico-chemical characteristics determined in 2008 following a massive oil spillage, as well as in 2012, five years after the oil pollution in the study area. The mean value of each soil property for 2008 was compared with the value obtained for the same property in 2012 using t-test analysis. The result of the test is presented in Table 2. The result (Table 1) shows that both in terms of ranges and means, the values of all the 21 soils physico-chemical properties as determined in 2008 varied from the values determined for the same soils in 2012.

For the particle sizes (sand, silt and clay), while there was an increase in sand content from 822 g/kg (2008) to 905 g/kg (2012), both silt (68 g/kg) and clay (115 g/kg) in 2008 reduced to 30 and 57 g/kg, respectively in 2012. However, the differences were not significant (Table 2). Previous studies (Kayode *et al.,* 2009) had showed that oil spillage altered physical properties of soil and resulted in increased bulk density, reduced soil capillarity, soil aeration and water holding capacity. It can also destroy soil structural classes which can reduce root penetrations of crops and subsequently impedes nutrient uptake from the soil.

Soil pH (7.0) in 2008 was lower (5.6) in 2012 (Table 2). Also, the mean value for organic carbon, 201 g/kg (2008) was significantly higher ($P \leq 0.05$) than (19 g/kg) in 2012. Similarly, total N was significantly higher in 2008 (5.70 g/kg) than (0.70 g/kg) in 2012.

On the other hand, oil pollution had a depressing effect on the values of the following soil characteristics: available phosphorus, exchangeable cations (Ca, Mg, Na, K) and consequently effective cation exchange capacity (ECEC) and base saturation, which were relatively higher in 2012 due to the diminishing impact of the pollution, compared to the low values obtained when the impact of the pollution was very strong in

2008.

Soil characteristics most influenced by the oil pollution were total petroleum hydrocarbon (TPH), available micronutrients (Fe, Mn, Zn, Cu) and heavy metal (Cadmium). From the results in Tables 1 and 2, TPH, Fe, Zn and Cd, had significantly higher values: 3294.9 mg/kg; 23086.8 mg/kg; 31.3 mg/kg and 4.20 mg/kg, respectively, in 2008 (due to the strong impact of the oil pollution), than the respective values: 140, 28.1, 1.8 and 0.29 mg/kg, in 2012 when the impact of the pollution had diminished.

The above results have confirmed the observations of Dejong (1980) that oil pollution alters both chemical and physical properties of soil and degrades soil fertility. Oil is known to exert adverse effects on soil properties and plant community. Barker (1976), Amadi *et al* (1993) and Osuji *et al* (2005), observed that beyond three percent concentration oil has been reported to be increasingly deleterious to biota and crop growth.

3.2 Magnitude of Differences in Soil Characteristics Between 2008 and 2012 Soil Analysis Data

The magnitude of the differences in the values of some of the soil characteristics analysed in 2008 (when the oil pollution was still fresh) and 2012 (when the effects of the pollution have diminished), is also demonstrated in Figure 1 (a-m).

The results showed that the soil pH as tested in 2008 (following the oil spillage) was neutral (7.0). But in 2012 (five years after the pollution), the pH had gone down to acidic condition (5.6). Since the soils derived from the beach ridge, sands are known to be strongly acidic (Unyienyin, 2010), the results show that the pollution has increased the pH value of the soil by about 1.24 x 10^2. This may be attributed to the high pH level of the crude oil.

Similarly, the results in Fig.1 (b and c) also show that the values of organic carbon and total nitrogen in 2008 were, respectively, 1.06 x 10^3 and 8.14 x 10^2 higher than their respective values in 2012. These were extremely high values compared with the established ratings for normal soils (Enwezor *et al;* 1989).

On the other hand, available P in 2012 was 2.78 x 10^2 higher than its value in 2008 when the effect of the oil spillage was strong (Fig. 1 d). The result showed that oil pollution brought about a reduction in soil available phosphorus. This may be due to the formation of insoluble phosphorus compounds arising from the reaction of the heavy metals present in the spilled oil with soluble phosphorus compounds in the soil solution (Udo, 2008).

Similarly, both the effective caution exchange capacity (ECEC) and base saturation (Fig. 1 (e and f), was relatively higher (1.79 x 10^2 and 1.16 x 10^2, respectively) in 2012 compared with 2008 values, when the influence of the oil spillage was very strong. These results showed clearly that oil pollution has a depressing effect on soil exchangeable cations and hence the cation exchange capacity and consequently base saturation. But as the effect of the pollution diminishes, the values of these soil characteristics begin to rise.

Furthermore, the comparison of the magnitude of differences in the values of some soil characteristics between 2008 and 2012 soil analysis data (Fig. 1a-m), showed that there were high increases in the soil contents of total petroleum hydrocarbon (TPH), heavy metals (lead (Pb)) and cadmium (Cd). The results showed that the soil contents of TPH, Pb and Cd in 2008, following oil pollution were, respectively, 2.60 x 10^3, 1.77 x 10^5 and 1.45 x 10^3 higher than the respective values in 2012, when the effects of the pollution had diminished.

Moreover, all the micronutrient elements (Fe, Mn, Zn, and Cu) had extremely higher values in 2008 due to the effects of the pollution, than in 2012 when the effects had diminished. The value of available Fe in 2008, was 8.20 x 10^4 higher than in 2012 (Fig. 1j). Similarly, the values of Mn, Zn and Cu in 2008 were, respectively 7.75 x 10^2, 1.74 x 10^3 and 2.67 x 10^2 higher than the respective 2012 values (Fig. 1 (k, l, m)). The results showed that the value for Fe content (23086.8 mg/kg) in 2008 was above the permissible level (3,000 – 5000 mg/kg) for natural soils (European Commission, 1986). But in 2012, the level of Fe in the soil had decreased to 28.1mg/kg, within the permissible level. Similarly the soil content of Pb in 2008 (2316 mg/kg) was above the permissible level for normal agricultural soils (10 – 30 mg/kg) due to the effect of the oil pollution. However, in 2012 the value had diminished to 1.31 mg/kg, within the permissible level, as the effect of the pollution wears off.

This study shows that crude oil spillage has serious deleterious impact on the environment in general, and the soil in particular. The result of this study is in line with the observation of Wang and Feng (2009) that the level of soil contamination and impact of oil residuals on soil quality greatly depends on the length of time the oil well was in production. Also the volume of spillage determines the extent and duration of the impact of the pollution. Baker (1976), Amadi *et al.* (1993) and Osiji *et al*. (2005), observed that beyond three percent concentration, oil has been reported to be increasingly deleterious to biota and crop growth. Furthermore, Ekundayo *et al.* (1989) had also observed that a marked change in properties occurs in soils polluted with petroleum hydrocarbons, affecting the physical, chemical and microbiological properties of the soil. The results of the study showed a phenomenal increase in total petroleum hydrocarbon content of the soils in 2008, ranging from 1372 – 4800 mg/kg, following oil pollution. This partly accounts for the wide variations in the values of some soil characteristics between 2008 when the impact of the pollution was very fresh and 2012 when the impact has considerably reduced. Similar observations had been made by Osuji *et al.* (2004), who observed that high hydrocarbon content of 3400 – 6800 mg/kg affect both above ground and subterranean flora and fauna which are essential adjuncts on the biogeochemical cycle that affects availability of plant nutrients.

4.0 Conclusion

This study was carried out to asses the impact of large-scale oil spillage on some soil characteristics as influenced by time (by comparing the results of the tests carried out in 2008, when the pollution was fresh and 2012, when the affects of the pollution had diminished). The results showed that nearly all the 21 soil physico-chemical properties examined were altered by oil pollution. However the chemical characteristics and the heavy metals were the most seriously affected soil characteristics by the oil pollution. Specifically, total petroleum hydrocarbon (TPH), lead (Pb), available micronutrient elements (Fe, Mn, Zn, and Cn) had phenomenal increases in their values due to the impact of the oil pollution. However, the results showed that the impact of the oil pollution on soil characteristics had reduced drastically between 2008 and 2012, indicating that the soil environment was tending to normal condition after about five years following the oil spillage.

It is hoped that the results of this study will contribute to the body of information required for successful post-spill management programme of affected ecosystem and communities in the oil producing area of the Niger Delta Region, Nigeria. It may also guide in arriving at adequate compensation for the affected farmers and land users.

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Table 1: Range and mean values of some soil characteristics affected by oil pollution as determined in 2008 and 2012

	← 2008 →		← 2012 →	
Soil Properties	**Range**	**Mean**	**Range**	**Mean**
Sand (g/kg)	782-862	822	833-944	905
Silt (g/kg)	48-88	68	25-37	30
Clay (g/kg)	90-140	115	31-149	57
pH	6.70-7.10	7.00	4.70-6.50	5.60
Org.C.(g/kg)	165-212	201	13-25	19
Total N (g/kg)	5.0-6.6	5.7	0.6-1.1	0.7
Av.P (mg/kg)	4.0-13.0	6.1	3.2-30.8	17.0
Ca (cmol/kg)	2.0-2.5	2.2	1.9-4.2	3.0
Mg (cmol/kg)	1.0-1.2	1.1	1.4-2.3	1.9
Na (cmol/kg)	0.03-0.05	0.04	0.08-0.14	0.11
K (cmol/kg)	0.06-0.10	0.08	0.22-4.05	2.14
EA (cmol/kg)	1.12-2.10	1.55	1.0-2.50	1.75
ECEC (cmol/kg)	4.35-5.94	4.96	5.36-8.87	8.92
Base Sat. (%)	60.3-74.9	68.5	71.9-88.2	80.0
TPH (mg/kg)	1372-4800	3294.9	60.0-220.0	140
Pb (mg/kg)	614-6659	2316	1.10-1.31	1.31
Fe (mg/kg)	18662-24163	23086.8	15.0-41.3	28.1
Mn (mg/kg)	41-444	189.4	18.4-28.4	24.4
Zn (mg/kg)	20.46	31.3	1.5-2.1	1.8
Cu (mg/kg)	9-54	29.1	5.4-18.0	11.7
Cd (mg/kg)	2.6-5.4	4.2	0.15-0.42	0.29

Org.C = organic carbon; Total N = total nitrogen; Av.P = available phosphorus; Ca, Mg, Na, K = Calcium, Magnesium, Sodium, Potassium, respectively; EA = exchangeable acidity; ECEC = effective cation exchange capacity; Base sat = base saturation; TPH = total petroleum hydrocarbon; Pb = lead Fe = Iron; Mn = Manganese; Zn = Zinc; Cu = Copper; Cd = Cadmium.

Table 2: Result of T-tests comparing 2008 and 2012 (approximate) values of some soil characteristics affected by soil pollution.

Soil Properties	Mean (2008)	Mean (2012)	LSD
Sand (g/kg)	822a	905a	140.87
Silt (g/kg)	68a	30a	45.08
Clay (g/kg)	115a	57a	128.04
pH	7.00a	5.60a	1.597
Org.C.(g/kg)	201a	19b	35.97
Total N (g/kg)	5.70a	0.70b	14.90
Av.P (mg/kg)	6.1a	17.0a	15.12
CA (cmol/kg)	2.2a	3.0a	2.89
Mg (cmol/kg)	1.1a	1.9a	0.95
Na (cmol/kg)	0.04a	0.11a	0.08
K (cmol/kg)	0.08a	2.14a	3.99
EA (cmol/kg)	1.55a	1.75a	2.01
ECEC (cmol/kg)	4.96a	8.92a	4.59
Base Sat. (%)	68.5a	80.0a	27.1
TPH (mg/kg)	3294.9a	140b	2876
Fe (mg/kg)	23086a	28.1b	5073.4
Mn (mg/kg)	189.40a	24.4a	179.4
Zn (mg/kg)	31.30a	1.8b	11.99
Cu (mg/kg)	29.10a	11.7a	44.82
Cd (mg/kg)	4.20a	0.29b	1.50

Values with the same letter in a row are not significantly different.

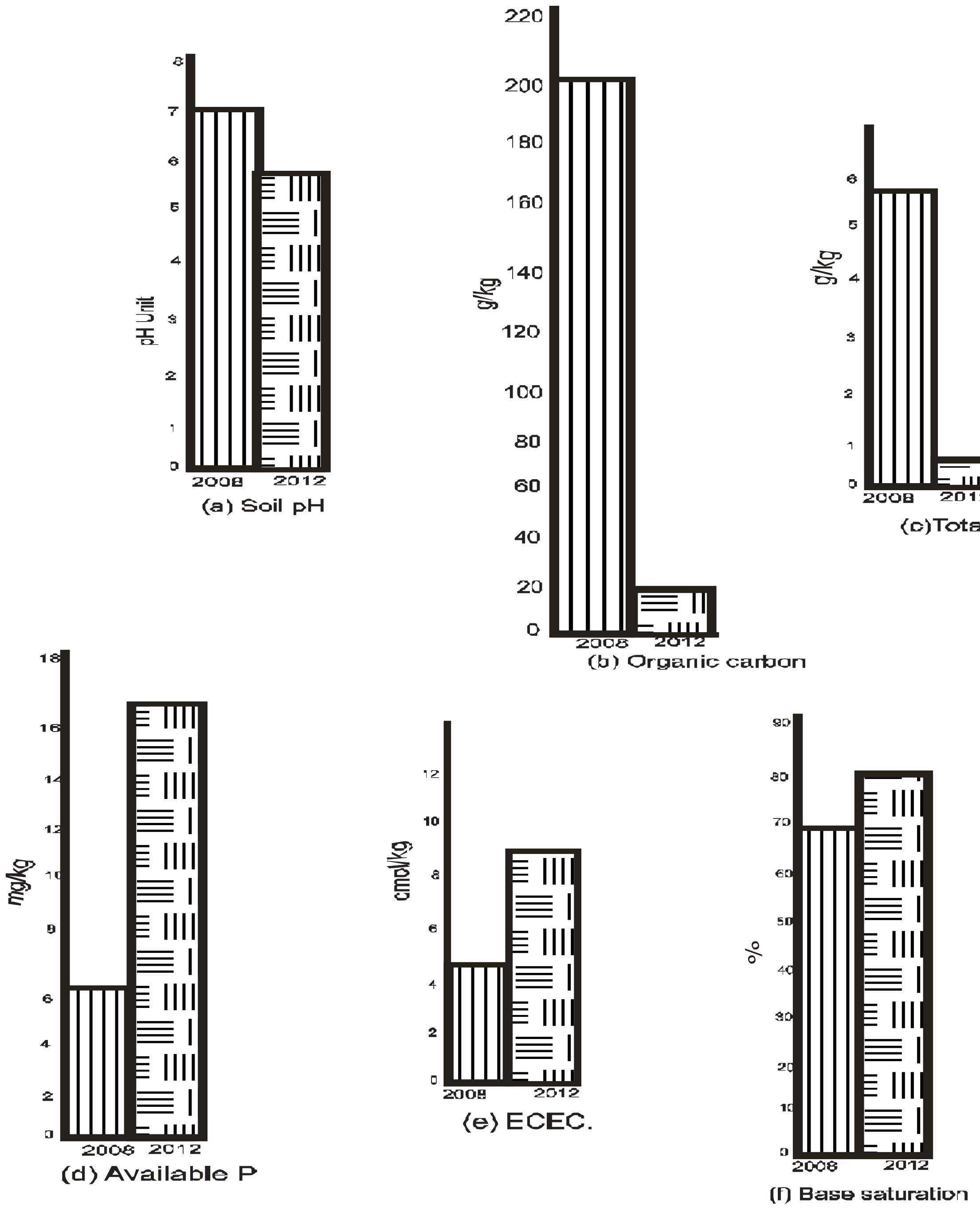
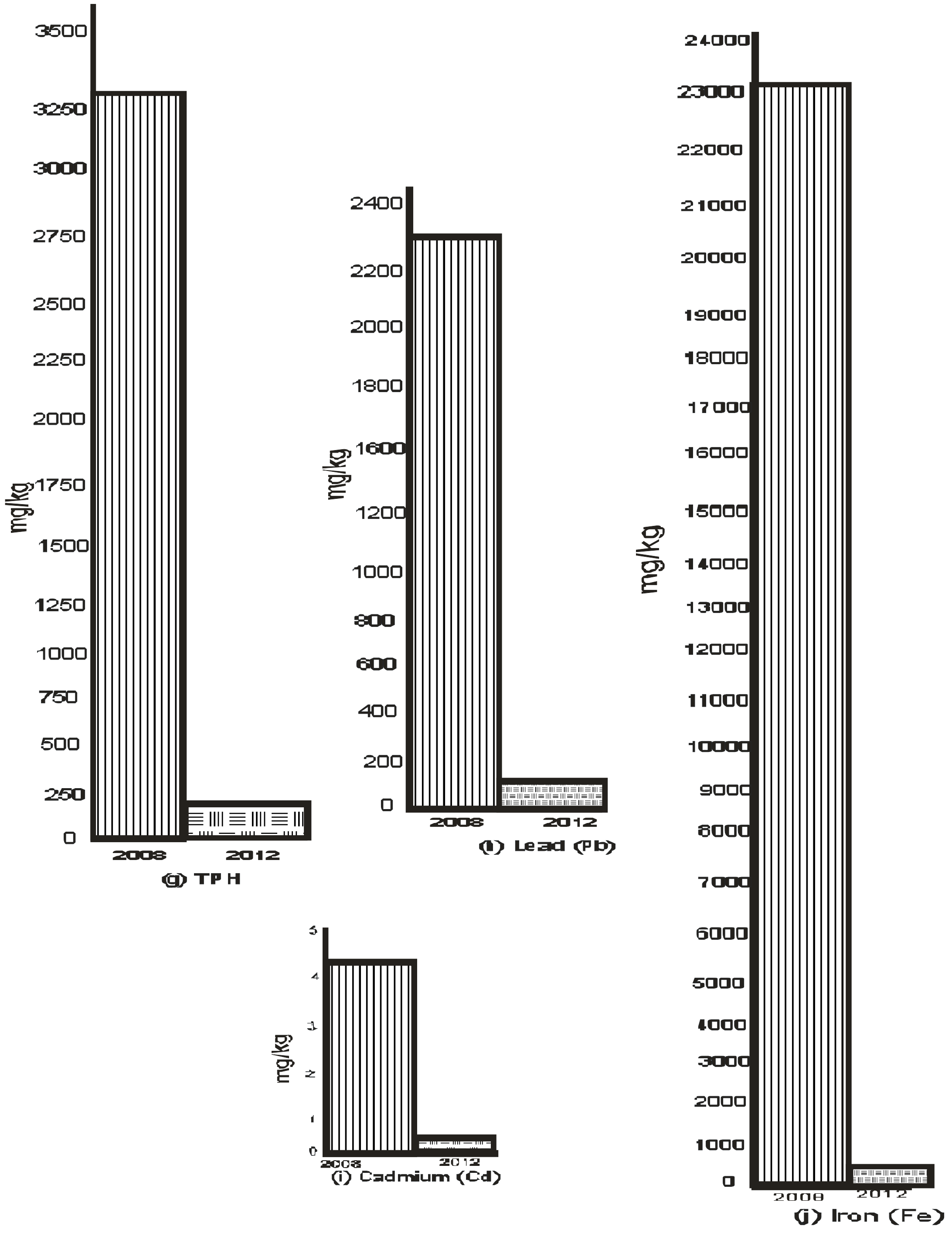


Figure 1: Comparing impact of oil pollution on soil characteristics between 2008 and 2012



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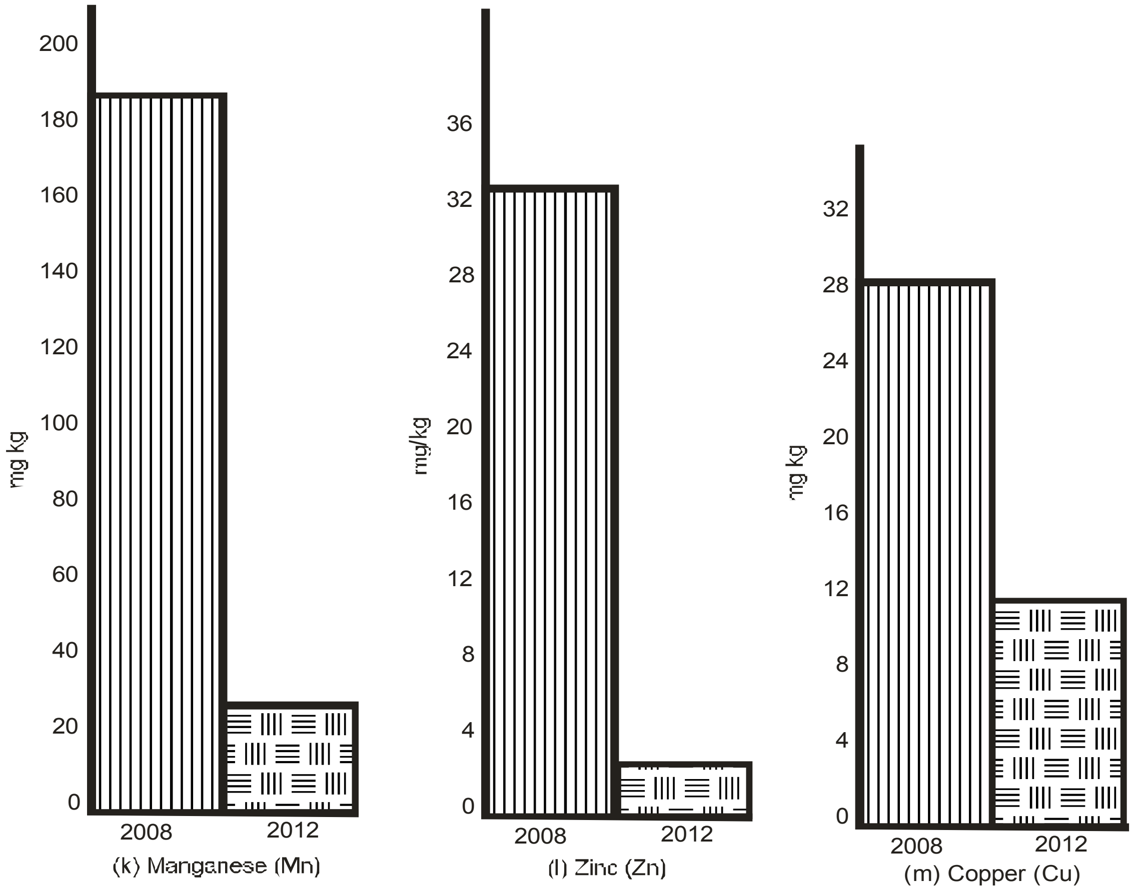

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