ADVANCES IN BIORESEARCH, Vol 1 [1] JUNE 2010: 189 - 198

Society of Education, India
http://www.soeagra.com
ISSN 0976-4585

RESEARCH ARTICLE

Micro-Analytic Study on the Effect of Oil Pollution on Local Plant Species and Food Crops

Nkwocha, Edmund E. and Duru, Patricia O.
Department of Environmental Technology,
School of Engineering and Engineering Technology
Federal University of Technology, Owerri, Nigeria
E-mail: eenkwocha@yahoo.com
Department of Geography and Environmental Management
Faculty of Environmental Sciences
Imo State University, Owerri, Nigeria

ABSTRACT

Oil pollution has been reported to affect humans, soils and vegetation, but little is known about its impact on local plant species. Our goal in this study was to determine the effect of oil pollution on local plant species in terms of abundance and composition, and to investigate the levels of contamination in two local food crops. Four impacted and two reference sites were identified; observations were made for a period of fifteen months and samples collected for analysis. Results showed that local plant species were greatly affected at the impacted sites, and the leaves of the two crops contained significant levels of the contaminants examined. At the control sites, the distribution frequency of plants ranged between 13.5% and 93.4% while at the impacted sites it ranged between <2% and 39%. A total of 43 species distributed into 20 families of plants were recorded at the control sites while only 25 species in 10 plant families were enumerated at the polluted sites. The values of heavy metals were relatively higher in the leaves of food crops at the polluted sites than those at the control site. The high values recorded on heavy metals were associated with crop species, soil types, and age of crops but most importantly due to the acidic nature of the soils resulting from oil pollution. Results showed that oil pollution constitute a potential danger to the food chain, food security and general health of the local population.

Key Words: *cassava, contaminants, impact, oil spills, plant species, pumpkin.*

INTRODUCTION

The exportation of petroleum contributes over 90 percent of Nigeria's economy. The aggressive crude oil extraction by the multinational corporations (Shell Petroleum Development Corporation, Exxon Mobil, Chevron Oil Company, Elf Aquitaine, etc.) for more than fifty years in the Niger Delta has inadvertently transformed the area into a *region in captivity*, with more environmental degradation than visible signs of improvement in the quality of life of the local communities [1]. Presently, there are eleven oil corporations operating about 159 oil fields and 1481 oil wells in this oil producing region [2].

The incidence of oil pollution has been extensively studied in many parts of the world [3-5].Most importantly, various publications on oil spillage containing relevant information and new understanding on its effect on specific environmental components have been made [6,7]. For example, in one of the studies in a community in the Niger Delta Region, Osuji, et al [8] observed that hydrocarbons and heavy metals from crude oil negatively affected flora and fauna, enhanced the absorption and bioaccumulation of heavy metals in plant cells. It has also been reported that acute exposure to oil spills can potentially affect clean-up crews, regulatory and emergency officials, coastal residents and members of scientific teams investigating the spills, causing various diseases such as vomiting, abdominal pains, skin irritation, and some cancers [9]. Reports have been made that constant exposure to high concentration levels of lead from oil may be associated with elevated high blood pressure [10] and cardiovascular diseases [11]; and exposure to cadmium from oil with renal dysfunction [12]. Also, consumption of polluted homegrown vegetables has been identified as a probable exposure pathway to cadmium among local population [13]. As no evidence shows the threshold for the adverse effect of some of these heavy metals especially lead, cadmium, nickel and chromium [14], increasing awareness and concerns about environmental pollutants and their health effects have led to increase in measures to protect the public from avoidable contamination and exposure [15]. Oil pollution has also been observed to cause the death of several hectares of mangrove forests, and swamps as well as making it impossible for plants to survive [16-18]. Most recently, Duru [19] tried to investigate the effects of oil pollution on the nature and chemistry of soils of impacted sites at Egbema and Oguta Local Government Areas (LGAs) and found out that it increased, to a considerable extent, the concentration levels of cadmium, chromium, lead and nickel in these soils.

These results corroborate the argument that tropical ecosystems are particularly vulnerable to petroleum pollution [20]. However, despite these results, little is known about global and specific losses of tropical vegetation due to oiling [21]; more information is needed concerning the recovery rates of plants after oil spills [22]. Most importantly, previous studies did not investigate the effects of oil pollution on local plant species and food crops which are good indicators of habitat change and degradation in tropical ecosystems [23]. There is need therefore, to investigate the effect of oil pollution on local plant species where information is very limited [24]. This research was carried out under the premise that oil pollution eliminate the most sensitive local plant species, drastically affect their growth, and in fact, contaminate local food crops widely consumed by the local population in the study area. Our goal was to determine the effect of oil pollution on local plant species in terms of abundance and composition, and to investigate the levels of contamination in two local food crops (pumpkin and cassava) with particular reference to chromium, cadmium, nickel and lead.

MATERIALS AND METHODS

The study focused on the oil producing areas of Imo State within the Niger Delta geopolitical zone of South-Eastern Nigeria. Two main Local Government Areas (LGAs), namely Ohaji/Egbema and Oguta LGAs constitute the study area. With an annual temperature hovering between 200C and 350C, average annual rainfall of about 384cm, relative humidity between 80 to 92 percent, the typical vegetation in these two LGAs is the dense tropical rain forest made up of varied plant associations and several hundreds of species [25]. However, the present vegetation in the area is a regeneration of the original tropical rain forest, transformed over the years by traditional subsistence agricultural practices, characterized by multiple cropping (cassava, maize, yams, pumpkin, coco-yams), and shifting cultivation, usually followed by a period of fallow (5 years). These secondary forests constitute natural habitats for wildlife (antelopes, snake species, birds, grass cutters) while the undergrowths harbor, snails, insects, rats, squirrels and reptiles. These two LGAs are contiguous, have similar customs and traditions, and are the major suppliers of most food and vegetable items consumed in the three urban centers in Imo state (Owerri, Orlu and Okigwe). Many communities in the area have suffered from series of oil spills since 1980, but very few of them have been documented [26]. The study was therefore focused on some of the unreported spills that occurred in June 2006 involving thousands of barrels of light crude, caused by a ruptured Shell pipeline. These particular spills affected many communities in Ohaji/Egbema and Oguta LGAs covering over 85 hectares of cultivated and fallow farmlands. The study lasted for a period of fifteen months (February 2007 to May 2008) which covered a farming season, barely eight months after the spills occurred, and four months after the clean-up exercises at the impacted sites. Establishing ecological effects of oil pollution depends on having reliable impacted and reference sites as well as having a sufficiently long series of measurements at the sites of concern so that effects of pollutants can be distinguished from natural variability [27]. To this end, six different sites were chosen for the study with two impacted sites (Akri and Izombe) and one control site at Izombe in Oguta LGA; and two impacted sites (Asaa and Awara) and a reference site at Awara in Ohaji Egbema LGA. The two control sites were carefully selected in each of the LGAs, and had not suffered from oil pollution. The various sites in the two LGAs are only 2 kilometers apart. At each of the sites, a sampling area measuring 30 x 30 meters was delineated around the epicenter of the spill (for the impacted sites). From each of them, transects were made in all directions for our study on the local plant species and the two selected food crops (cassava and pumpkin). The composition, structure and species abundance were carefully observed and analyzed at both the impacted and reference sites. Floristic assessment was equally carried out with special reference to chlorosis, wilting, stunting of growth and other manifestations. Measurement of tree growth after oil pollution is a useful index of knowing the effect of oiling over time [28,29]. The method used by Kirshaw [30] was adopted in the analysis of species abundance: species with high frequency of occurrence (very abundant) were represented with four pluses (++++), moderate frequency with three pluses (+++), low frequency (scarce) with two pluses (++), and those with very low frequency (very scarce) with just a plus sign (+). In the second level of analysis, six different samples (3 in dry season and 3 in wet season) of pumpkin and cassava leaves were collected from the six sites and subjected to laboratory analysis. Sampling was done at different seasons of the year to accommodate variations in concentration levels of contaminants (cadmium, chromium, lead, nickel) in the leaves of these highly consumed food crops. These metals represent some of the normal constituents of oil in varying proportions [9]. Analysis was done using Atomic Absorption spectrophotometer (AAS) to know the concentration levels of these contaminants [31]. In the same vane, three soil samples were collected from each of the polluted and reference sites at 20m interval in order to obtain information over a wide area. A total of 18 soil samples were thus collected and analyzed. Two levels of analysis were carried out on soil samples. Firstly, their chemical characteristics (pH, organic carbon, potassium, etc) were examined to know their concentration levels as a consequence of oil pollution. Secondly, the concentration levels of heavy metals (chromium, cadmium, lead and nickel) were equally examined.

The mean values and standard deviations of each of these parameters were computed and recorded. These analyses were carried out in the soil laboratory of the Department of Soil Science, Federal University of Technology, Owerri in accordance with the procedures specified in B.S 1377 [32] and the Standard Operating Methods [33]. Although the actual dose of specific pollutants received by plants from oiling is very difficult to assess [27], results obtained from our analyses gave an insight on the level of danger posed by the consumption of these crops by the local population.

In the primary analysis, univariate statistics were used to describe frequency counts and percentages for local plant species. In the secondary analysis, the concentration levels of contaminants in the soils and in the leaves of food crops were obtained from the four impacted sites and their corresponding controls and were presented in averages with corresponding standard deviations. The values obtained from the leaves of the food crops were further subjected to further analyses using conditional logistic regression. Because of the unequal levels of contamination among the sites, non-parametric methods were used to examine levels of variations in relation to study characteristics. Analysis of variance (ANOVA) was used to find out statistically significant differences in concentration levels of contaminants in the leaves of crops from different sample sites based on the assumption that oil pollution affected the sites equally. Data were subjected to statistical analysis using SPSS version 13.0 (SPSS, Chicago, IL, USA), and the limit for statistical significance was set at $p< 0.05$. All significance testing was two-sided.

RESULTS AND DISCUSSION

The pH mean values at the impacted sites were within the acidic range showing that oil pollution affected the pH level of the soils. The chemical characteristics of the soil samples were equally affected by oil pollution. While potassium, available phosphorus, magnesium showed high mean values at the control sites, they were greatly reduced at the polluted sites. For example, with reference to the sample mean, the concentration levels of potassium were reduced by 5.26% at Akri, 5.20% at Awara, and 15.79% at Izombe; those of available phosphorus were reduced by 14.01% at Asaa ,9.45% at Awara, and 12.70% at Izombe; and finally, those of magnesium by 24.30% at Akri, 2.70% at Asaa, 18.90 at Awara, and 21.60% at Izombe. Conversely, the concentration levels of organic carbon, total hydrocarbon content, and C/N ratio showed high mean values at the impacted sites than at the control sites as shown in Table 1.

The high mean values obtained at the polluted sites indicated high level of biodegradation due to oil pollution [34,35]. Results on heavy metals equally showed high mean values at the polluted sites than at the control sites. For example, with reference to the sample mean, concentration levels of chromium at the impacted sites increased by 40% at Akri, 30.90% at Asaa, 56.50% at Awara and 30.60% at Izombe. The same trend was observed on cadmium which increased by 20.96% at Akri 48.40% at Asaa, 57.30% at Awara, and 59.70% at Izombe. The concentration levels of these heavy metals at the control sites were very minimal as shown in Table 2**.**in the family of Rubiaceae (*Oldenlandia corymbosa, Zutracarpus scarba succ, Craterispernium cerinanthum* Hiern); Euphorbiaceae (*Phyllanthus amarcus, Alchornea cordifolia, Mallotus subulatusmul*-Ag) and Amaranthaceae (*Alternanthera sessilis, Triumfetta cordifolia, Cyanthula prostrata*) decreased from <34.4 %, <40 % and <26.6 % respectively at the two control sites to zero percent at all the impacted sites as shown in Table 3.

Table 1: Chemical characteristics of soils from polluted and control sites

Parameters/ Sites	pH	Organic carbon (%)	Potassium (Cmol/kg)	Available phosphorus (mg/kg)	Total Hydrocarbon (mg/kg)	Magnesium (C mol/kg)	C/N Ratio
Akri (polluted)	6.30	1.87	0.18	13.56	71991.18	0.28	38.40
Asaa (polluted)	5.98	1.39	0.19	15.90	63067.02	0.36	32.00
Awara (polluted)	6.23	1.40	0.16	14.28	59827.13	0.29	36.02
Izombe (polluted)	6.27	1.92	0.18	13.77	59827.13	0.29	36.02
Awara (Control)	5.50	0.74	0.21	18.10	94.10	0.48	10.20
Izombe (Control)	5.71	0.81	0.23	19.05	93.56	0.51	12.03
Mean	5.99	1.35	0.19	15.77	43365.52	0.37	26.97
SD	0.04	0.03	0.01	0.04	-1.92	0.00	0.00

Table 2: Average concentration levels of heavy metals in the soils of polluted and control sites

Parameters/ Sites	Chromium (mg/kg)	Nickel (mg/Kg)	Cadmium (mg/Kg)	Lead (mg/Kg)
Akri (polluted)	11.52	15.03	1.95	48.20
Asaa (polluted)	9.83	15.09	1.84	44.08
Awara (polluted)	10.75	14.77	1.50	48.20
Izombe (polluted)	9.81	14.80	1.98	46.73
Awara (control)	1.50	2.03	0.10	5.21
Izombe (control)	1.69	1.62	0.08	5.28
Mean	7.51	10.56	1.24	32.44
SD	0.04	-0.02	0.01	-0.03

Some plant species were particularly more resistant to oil pollution and appeared very abundant (++++). Notable among them were *Cyperus esculentus* (Cyperaceae) that were 53.4 % and 54.7 % respectively at Izombe and Awara control sites, but were reduced to not less than 39 % at all the four impacted sites; and Manniophyton fulvium (Euphorbiaceae) which reduced from 13.4 % at control sites to less than 7 % at all the impacted sites.

In all, a total of 43 species distributed into twenty families of plants were recorded at the control sites while only 25 species in ten families of plants were enumerated at the impacted sites.

Results equally showed variations in the concentration levels of contaminants in cassava and pumpkin leaves at both the impacted and reference sites. At the reference sites, their average concentration levels were from negligible to none with the exception of Izombe where a maximum lead level was detected in cassava (0.02mg/kg), and that of nickel at Awara (0.02mg/kg). However, at the four impacted sites, the results were variable. In cassava leaves, average concentration levels of lead ranged from 0.11mg/kg at Awara to 0.16mg/kg at Izombe; cadmium from 0.13mg/kg at Asaa to 0.17mg/kg at Izombe; chromium from 0.30mg/kg at Akri to 0.70mg/kg at Izombe; and nickel from 0.03mg/kg at Asaa and Awara to 0.04mg/kg at Akri and Izombe. For the pumpkin leaves, the concentration levels of lead ranged from 0.20mg/kg at Izombe to 0.22mg/kg at both Akri and Awara; cadmium from 0.06mg/kg at both Izombe and Asaa to 0.08mg/kg at Akri; chromium from 0.7mg/kg at Awara to 1.10mg/kg at Akri; and nickel from 0.03kg/mg at Izombe to 0.05mg/kg at Asaa as shown in Table-4.

Table 3: Distribution Frequency of various local plant species at the polluted and control sites

Plant species	Family	Frequency (%)		Remark	
		polluted sites	control sites	polluted sites	Control sites
Chromolaena odorata (Linn, King and Robinso)	Asteraceae	26.6	93.4	++	++++
Ageratum conyzoide (Linn)	Asteraceae		26.6	-	++
Aspilia Africana latifolia (Pers. Adams)	Asteraceae		26.6	-	++
Panicum maximum (Jacq.)	Graminaea	20	80	++	++++
Sorghum arudinaceum (Desvstap)	Proteaceae	13.3	26.6	+	++
Axonopus compressus (Beaur)	Proteaceae	7	40	+	++
Eragrostis tenella (Roem and schutt)	Proteaceae	7	53.4	+	+++
Eleusine indica (Linn and Gaertn)	Proteaceae	7	13.4	+	+
Andropogon spp	Proteaceae	20	-	++	-
Setaria barbata (Linn and Kunth)	Proteaceae	-	40	-	++
Sporobolus pyramidals (Beaur)	Proteaceae	-	60		+++
Chloris pilosa schumach	Proteaceae	-	13.4	-	+
Mimosa spp (Linn)	Febaceae-Mimo	13.3	53.4	+	+++
Pueraria phaseoloides (Roxb) Benth	Febaceae	13.3	53.4	+	+++
Desmodium scoporius	Febaceae	20	-	++	-
Indigafera spicata Forssk	Febaceae-Papi	-	26.6	-	++
Senna hirsute (Linn, Irwin & Barneby	Febaceae Cassal	-	13.4	-	+
Schrankia leptocarpa DC	Febaceae-Mmio	-	13.4	-	+
Desmodium tortosum (SW) DC	Febaceae-Papi	7	-	+	-
Zonia Latifolia sm	Febaceae-Papi	7	-	+	-
Centrosema pubescens(Benth)	Febaceae-caesal	7	13.4	+	+
Caloponium mucunoides (Desv)	Febaceae-Papi	20	66.6	++	+++
Mucuna pruriens(Wight Burck, c vars)	Febaceae-Papi	20	-	++	-
Cyperus esculentus (Linn)	Cyperaceae	38.2	53.4	++	+++
Cyperus rotundus (Linn)	Cyperaceae	7	13.4	+	+
Marcus cuternitoluis (Linn)	Cyperaceae	-	26.6	-	++
Kyllinga punilla (michx)	Cyperaceae	-	13.4	+	-
Phyllanthus amarus (Schum & Thorn)	Euphorbiaceae	-	40	-	++
Alchornea cordifolia (Schum & Thonn) Mull-Arg	Euphorbiaceae	-	53.4		+++

Mallotus subulatus Mull-Arg	Euphorbiaceae	-	40	-	++
Mallotus oppositifolius (Geisel) Mull-Arg	Euphorbiaceae	-	26.6	-	++
Manniophton fulvum Mull-Arg	Euphorbiaceae	7	13.4	+	+
Oldenlandia corymbosa(Linn)	Rubiaceae	-	13.4	-	+
Zutracarpus scaber Zucc.	Rubiaceae	-	13.4	-	+
Psychotria spp	Rubiaceae	-	26.6	-	++
Craterispernium ceriman Thum Hiern	Rubiaceae	-	13.4	-	+
Sida acuta Burm F.	Malvaceae	13.3	38.2	+	++
Urena lobata (Linn)	Malvaceae	-	26.6	-	++
Alternanthera sessilis (Linn)	Amaranthaceae	-	26.6	-	++
Triumfetta cordifolia (A.Rich)	Amaranthaceae	-	53.4	-	+++
Cyathula prostrate (Linn) Blume	Amaranthaceae	-	40	-	++
Spigella anthenia (Linn)	Loganiaceae	7	-	+	-
Costus lucanusianus (J.Brain & K schum)	Costaceae	20	20	++	++
Desplatzia sammatti (kulm)	Athyriaceae	13.3	80	+	++++
Harungana madagascarensis	Guttiferae	-	40	-	++
Funtumia Africana (Benltr)	Apocynaceae	-	66.6	-	+++
Smilax anceps.Willd	Smilacaceae	-	26.6	-	++
Carpolobica lutea G.Don	Polyalaceae	-	26.6	-	++
Dioda scandense	-	7	-	+	-
Pleridium acquilinum (Linn)	Dennstaedtiaceae	7	40	+	++

Key: ++++ very abundant +++ moderate; ++ scarce; + very scarce

Table 4: Average concentration levels of pollutants in the leaves of food crops (mg/kg) at polluted and control sites

Sites	Cadmium		Chromium		Nickel		Lead	
	C	P	C	P	C	P	C	P
Akri (polluted)	0.16	0.08	0.30	1.10	0.04	0.04	0.12	0.22
Asaa (polluted)	0.13	0.06	0.35	0.81	0.03	0.05	0.15	0.21
Awara (polluted)	0.16	0.07	0.57	0.70	0.03	0.04	0.11	0.22
Izombe (polluted)	0.17	0.06	0.70	0.85	0.04	0.03	0.16	0.20
Awara (control)	0.01	0.00	0.01	0.00	0.01	0.02	0.00	0.00
Izombe (control)	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.00
Mean value	0.16	0.06	0.48	0.87	0.04	0.04	0.14	0.21
SD	-0.02	0.03	0.00	-0.02	-0.02	0.00	-0.02	0.00

Key: C = cassava P = pumpkin

The results of multiple regression analysis showed that concentration levels of these heavy metals in the leaves of the two plants from the impacted sites were significantly high and are associated with four variables, namely, crop species (cassava leaves recorded higher levels than pumpkin leaves; $p = 0.012$, partial correlation = 0.372); increasing age of crops ($p = 0.013$, partial correlation = 0.368); soil types (sandy clay soil at Izombe and Akri recorded higher levels than sandy loam soil at Awara and Asaa, $p = 0.019$, partial correlation = 0.353); and time (high concentration levels in March 2007 than in May 2008, $p = 0.028$). These four variables explained 68 percent of the total variance. But most importantly, they could be explained by the high concentration levels of these micro minerals recorded in the soils of the polluted sites.

The present study showed that oil pollution has specific impacts on local plant species as well as on the cultivated food crops at the four polluted sites. At these sites, the effect of the spilled oil was more important than other environmental factors [36]. It was generally observed that the young plants at the impacted sites were more vulnerable to oil pollution than the old plants after a period of fifteen months, even though the latter also showed signs of wilting. Also, nine months after the spills, the young plants, to a large extent at Akri and Izombe polluted sites, showed partial defoliation, leaf loss and sometimes died than those at Awara and Asaa. The former recorded the highest levels of heavy metals, pH, organic carbon, total hydrocarbons, C/N ratio and the least levels of potassium, available phosphorus and magnesium in their soils. This particular observation corroborated the argument that variable pollutant loads in oil may have different effects in different circumstances [27]. It was equally observed that fifteen months after remediation at the polluted sites, recovery rate of plants still remained very slow with none exceeding 2 percent per 6 months. Such an observation may also corroborate previous findings that crude oil reduces the level of essential elements in the soil necessary for plant growth [37]. The persistence of pollutants from oil caused extensive damage to plants at the impacted sites leading to the predominance of grasses and few shrubs that seem to withstand the toxic environment resulting from the spill. It is likely that the observed heavy metals in the soils of the polluted sites followed a pattern of distribution almost similar to one another since they were emitted from the same spill and because they share similar chemical properties. While it was clear that oil pollution caused the reduction in the number and death of plants at the impacted sites, the concentrations of pollutants from oil in plant leaves also differed from site to site. Some vegetal changes such as the chronic signs of chlorosis generally observed at Izombe and Akri and to a smaller extent at Awara and Asaa helped to confirm these claims. Also, the poor growth of cassava plants, mainly observed at Izombe and Akri (quite unlike those at Awara and Asaa) whose stems appeared very tiny with string-like roots, are some of these observed differences. Our findings in this area generally agree with the results of a recent study that oil pollution causes changes in foliage color, poor canopy formation, poor productivity, and death of plants [38]. Concerning the high frequency of chlorosis and stunted growth observed among many plants species, it is highly probable that the high level of heavy metals obtained in the leaves of the examined plants at the polluted sites initially caused cytological changes, followed by a breakdown of the chloroplast, which later led to gradual loss of chlorophyll which in some cases caused their death [39]. These manifestations may also be associated with the acidification of the polluted soils which affected the solubility of essential minerals thereby reducing their availability and uptake for plant growth and maintenance [40,41]leading to nutritional imbalances such as the disruption of nitrogen/magnesium andcarbon/nitrogen ratios [42]. Acidic soils usually have high concentration of soluble minerals which at certain levels become toxic to plants and affect nitrogen fixation and plant growth [43]. Although it did not enter into our analysis, it was observed that oil pollution in the four communities surveyed directly and indirectly affected the socioeconomic lives of the local population who are predominantly subsistence farmers and hunters. Aside the contamination of food crops, there was high mortality rate of the local faunal population especially small animals (rabbits, squirrels, snails, etc).For example, about 60 percent of local rats were eliminated by the pollution. Other bigger animals(snakes, lizards, alligators) migrated to other areas for want of smaller preys whose populations were also drastically reduced by the pollution. Two major reasons could explain these phenomena. First, the hydro-washing technology used for remediation of the impacted sites contaminated the available surface water consumed by these animals which affected their health. With frequent rains and a high water table at the impacted sites, oil continued to float on small water bodies all through the rainy season thereby reducing the level of dissolved oxygen in water and consequently the number of preys they contain. Secondly, during the dry season, characterized by high temperatures (hovering between 30 and 35 degrees Celsius), the choking effect resulting from the evaporation of volatile organic compounds contained in the oil that seeped into the soils also affected these faunal population on considerably.

CONCLUSION

This study constituted one of the evidences that support the argument that frequent oil spillage in the Niger Delta Region of Nigeria is causing enormous environmental degradation[44,45]. The results of the case examined showed that oil pollution not only led to the extinction of the most vulnerable plant species but also drastically reduced their distribution frequencies. At the impacted sites, it raised the acidic level of soils, reduced the level of their essential minerals, and increased their levels of heavy metals. The most outstanding result of this study was that oil pollution led to the contamination of local food chain. It is most probable that the source of traces of heavy metals found in the leaves of the food crops at the polluted sites was from oil pollution. The levels of contamination observed in cassava and pumpkin leaves at the polluted sites, which are essential components of the local staple food is most worrisome. If the high level of contamination observed in this study was occasioned by just an incidence of oil spill, urgent and serious studies are therefore required to assess the levels of contamination in the entire food crops in many rural communities that have been experiencing frequent oil spills in the region. Another important observation was that oil pollution provoked systemic changes among local animal and plant species; while some were endangered, others became more vulnerable, rare and even extinct. There were several limitations to this study. First, the small number of sample sites led to small statistical power, which nonetheless was sufficient to detect significant relationships. Second, the concentration levels of pollutants were analyzed only in the leaves of two local food crops (cassava and pumpkin), it would have been more interesting to investigate the effect of these contaminants on many other food crops such as maize, yam tubers, coco-yams, etc, at the impacted sites. Third, a series of confounders were not considered, such as the level of bioavailability of contaminants in plants, etc. Among the strengths of the study are that the impacted and reference sites respectively showed signs of homogeneity in terms of seasons, soils and plant species, which implied that selection bias would not have had much influence on the results obtained from these sites. Despite these few limitations, the results of this study are sufficiently compelling to warrant future studies in the area to obtain regular information on the general and specific effects of oil pollution on plant biology, plant community and especially on food crops, as this area remains the major food basket of Imo State. This will help in understanding the level of danger and various health implications of regularly consuming such crops and the precautionary measures to be taken by the local population to ensure food security both in the present and in the future.

ACKNOWLEDGEMENTS

We wish to express our profound gratitude to the Ministry of Petroleum and Environment, Imo State for their financial support in carrying out this study. We are also grateful to the members of a Joint Team of our Post graduate students from Imo State University, Owerri and the Federal University of Technology, Owerri for their invaluable contributions especially in the area of data collection during the study period.

REFERENCES

[1] Hinrichsen, D. (1990). Our Common seas coasts in crisis. Earthscan Pub. London p184.

[2] Nigerian Environmental Study/Action Team (NEST) (1992). Nigeria's Threatened Environment: A National Profile, NEST Publications: Ibadan. p132

[3] Baker, J. M., Clark, R. B. Kingston, P. F. (1991). Two years after the Spill : Environmental recovery in Prince William Sound and Gulf of Alaska. Institute of offshore Engineering, Heriot-Watt Uni. Of Edinburgh, Scotland.

[4] Maki, A. W. (1991). The Exxon Valdezoil spill: Initial Environment Impact Assessment. Part of a five-part series *Environ. Sci Technol.* **25** (11), 24-29.

[5] Osuji, L. C. and Onojake, C. (2004). Trace Heavy Metals associated with crude oil: A case study of Ebocha-8-oil spill polluted site in Niger Delta, Nigeria. *Journal of chemistry and Biodiversity* **1** (2), 1569-1577.

[6] Odu, C. T. (1982). Study of Environmental and Social Impact of Oil Spillage in the Oyakama area. Snamprogetti SP.A TETEC/AMB/59/82 Milan

[7] Evoh, C. (2002). Gas Flares, Oil Companies and Politics in Nigeria. Retrieved 21st March 2002 from http://ww.waado.org/.environment.

[8] Osuji, L.C., Adesiyan, S. O. and Obute, G. C. (2004). Post-Impact Assessment of Oil Pollution in Agbada West Plain of Niger Delta, Nigeria: Field reconnaissance and total extractable hydrocarbon content. *Journal of Chemistry and Ecology*, Vol.1 p1569-1577.

[9] National Research Council (NRC) (1985). Oil in the seas. Inputs, fates and effects. National Academy Press, Washington, DC.

[10] Martin, D.; Glass, T. A.; Todd, A. C.; Shi, W et al (2006). Association of blood and tibia lead with blood pressure and

hypertension in a community of older adults. *Am J Epidemiol.* **163** (5), 467-478.
[11] Menke, A.; Muntner, P.; Batuman, V. (2006). Blood lead below 0.48 micromol/l and mortality among US adults. *Circulation* , **114** (13), 1388-1394
[12] Jarup, L. and Alfven, T. (2004). Low level cadmium exposure, renal and bone effects-The OSCAR study. *Biometals,* 17 (**5**): 505-509.
[13] Hellstrom, L. Persson, B. Brudin, L., Petersson, G. K., Oborn, I., Jarrup, L. (2007). Cadmium exposure pathway in a population living near a battery plant. *Sci Total Environ*, 373, 447-455.
[14] Lanphear, B. P. (2007). The conquest of lead poisoning: A Pyrrhic Victory. *Environ Health Perspect*, **115** (10), 484-485.
[15] Mckelvey, W.; Charon, G. R.; Jeffery, N (2007). A biomonitoring study of lead, cadmium and mercury in the blood of New York City adults. *Environ Health Perspect,* 115 (**10**), 1435-1441.
[16] Raufu, A. (2001). Nigeria Oil Workers and families. Rage against foreign companies Retrieved on March 21st, 2003.
[17] Ufot, O., Uwakwe, V.C., Akande, O. and Lekwa, G. (2003) The Effects of oil Exploration on the soil of Izombe in Imo State, Nigeria. Paper presented at 28th Annual Conference of the Soil Science Soc. of Nigeria at National Root Crops Research Inst. Umudike, Abia State, 4-7 Nov. (2003).
[18] Obilo O. P. and Ogunyemi, S. (2002). The use of Maize as an indicator crop and in the reclamation of farmland laden with heavy metals as a result of crude oil pollution. Paper presented at 36th Annual Conf. of Agric. Society of Nigeria held at the Federal Univ. of Tech. (FUT), Oct. 20-24, Owerri.
[19] Duru, P.O. (2005). Impact of Oil spillage on Soils in some Oil producing communities of Imo State, unpublished PhD Desertation, Imo State University, Owerri. p238
[20] Ballou, T.G; Dodge, R. E; Hess, S. C. et al (1989). Tropical oil pollution investigations on coastal ecosystems (TROPICS): The effects of untreated and chemically dispersed Prudhoe Bay Crude oil on mangroves, sea- grasses and corals in Panama. In Oil Dispersants: New Ecological Approaches,ASTM, STP, Philadelphia.
[21] GESAMP (1993). Impacted of oil and related chemicals and wastes on the marine environment, Imo/UNESCO/WHO/IAEA/UN/UNEP, No.50., London.
[22] Teas, H. J. (1989). Mangrove restoration after the 1986 Refineria panama oil spill. Proceedings 1989 Inter. Oil conference, Amer. Petrol Inst. Washington, DC. P.I. Publ. **4479**, 433-437.
[23] Niger Delta Environmental Survey Group (NDESG) (1997). Environmental and Socio-economic characteristics, Phase I, Vol. I, p128.
[24] Paine, J. R. and Phillips, C.R. (1985). Petroleum spills in the marine environment: Chemistry and formation of water in emulsions and Tar Balls. Chelsea, Michigan Lewis Pub. 44-62
[25] Iloeje, N. (1980). A New Geography of Nigeria: London; S.B Ltd.
[26] Okpara, E. E. (2004). Post-Rio Realities of Sustainable Development in the Niger Delta Region of Nigeria, N-COGEP-D, Owerri, Ihem Davis Press. p109.
[27] Innes, J.L. and Cook, E.D. (1989) Tree-ring analysis as an aid to analysis evaluating the effect of pollution on tree growth.*Canadian Journal of Forest Research* **19**, 1174-1189
[28] Becker, M. (1987). Bilan de sante actual et retrospective du sapin (Abies alba Mill) dansles' Vosges. Etudes ecologiques et dendrochronologiques. *Annales des Sciences forestieres* 44 **(2)** 297-401.
[29] Barnard, J. E. and Scott, C. E. (1988). Changes in tree growth in Vermont. U. S Department of Agriculture, Forest Service, South-East Forest Experimental Station Research Note SE-350.
[30] Kirshaw, K. A. (1979). Quantitative and Dynamic Plant Ecology, 2nd Ed. London: Edward Arnold.
[31] Butt, J. A., Duckwork, D. F. and Perry, S. G. (1986) Characterization of spilled oil samples-Purpose, samples, analysis and interpretations. Institute of Petroleum, London, John Wiley and Sons Chichester.
[32] B, S 1377 (1975). Methods of Test for Soils for Engineering Purposes, 2.6.2, Tests (6A), Methods for Test for Chemical Properties. p28.
[33] American Public Health Association (APHA) (1995). Standard Methods for Examination of Water and Waste Water (19th Edition) Washington, DC. USA: American Public Health Association.
[34] Emara, H. I. (1990). Oil pollution in the Southern Arabian Gulf and Gulf of Oman. Mar. Pollution Bull. 21 **(8)**, 399-401.
[35] Bartha, R., Shen, J. and Wang, X. (1993). Effects of bioremediation on Toxicity and Murtagenecity of Soil contaminated by Hydrocarbon fuels, Dept. of Biochemistry and Microbiology, Cook College, Rutgers University, New Brunswick, N.J. USA.
[36] Brooks, R.T. (1989). An analysis of regional forest growth and atmospheric deposit patterns, Penyslvania (USA). In Air Pollution and Forest Decline. J.B. Bucher and I. Bucher-Wallin (eds), Eidgenosisische Austalt fur das forstliche Versuchswesen Birmensdorf. 3, 283 – 288.
[37] Odum, E.P. (1971). Fundamentals of Ecology. W.B. Saunders Coy, Philadelphia 98-106
[38] Akwiwu C.D., Nwajiuba C.U. and Nnadi, F.N (2002). Pollution and Agro-Forestry Practices of Farmers in Imo State. Implications for Household livelihood. Paper presented at 36th Annual Conference of the Agricultural Society of Nigeria held at Federal Uni. of Tech. Oct. 20-24, Owerri.

[39] Fink, S. (1988). Histological and cytological changes caused by air pollutants and other abiotic factors. In, Air pollution and plant metabolism. S. Schulte-Hostede, N.M.Darrall, Low.Blank and A. R. Wellburn (eds) Elsevier Applied Sciences, Oxford 36-54.
[40] Kaupenjohann, M., Zech, W., Hantschel, R., Horn, R. and Schneider, B. U. (1989). Mineral Nutrition of forest trees original survey. In, forest decline and air pollution. A study of spruce (Picea abies) on acid soil. D. Schulze, O.L. Lange and R.Oren (eds) Springer-Verlag Berlin. 7, 282-294.
[41] Manahan, S.E. (1994). Environmental Chemistry, London: CRS Press, Inc.
[42] Hauhs, M. (1989). Lange Branke: an ecosystem study of a forested catchment. In, Acidic precipitation. Case study, D.C. Adriano M. Havas (eds) Springer-Verlg, New York 1**(1)** 275-305.
[43] The Shell Petroleum Development Company, SPDC .(2004). Accompanying Guidelines for SPDC EIA Process: Data Collection, Vol III, HSE-ENV.12-17.
[44] Chinedum, O. (2007). Nigeria at 47: Niger Delta violence and the Biafra connection. *Focus Monthly* **2 (2)**, 7-11.
[45] Cookey, P. (2006). A peep into Shells questionable community development strategy. In Cleaning the flow, protecting the nations water resources. *Earthwatch*, 4 **(1)**, 27-33.