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Spatial analysis of heavy metal accumulation in *Mangifera indica* and *Pentaclethra macrophylla* near Owaza gas flaring station in Abia State, Nigeria

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ABSTRACT

The menace of gas flaring in the Niger Delta Region of Nigeria has continued unabated despite incessant promises by the Federal Government to put an end to it. In this study, a spatial analysis of the accumulation of heavy metals in leaves of *Mangifera indica* and *Penthaclethra macrophylla* and the soils on which they are growing was carried out. Three sites – 1, 2 & 3, were selected based on the availability *M. indica* and *P. macrophylla* at 100 m, 250 m and 350 m distances respectively, from the gas flaring source. Three individual trees were randomly selected from each of *M. indica* and *P. macrophylla* for soil and leaf sampling at each site. The collected soil and leaf samples were analysed for Zinc (Zn), Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni) and Copper (Cu), using standard methods. There was no significant difference ($p > 0.05$) in the concentrations of the heavy metals in soils around the roots of *M. indica* at the 3 sites except for Cd. Copper (Cu), Zn and Cr varied significantly ($p < 0.05$) in soils around the roots of *P. macrophylla* at the sites. Cadmium and Ni were almost absent in soils and leaves of both species at the sites. There was no significant difference ($p > 0.05$) in the concentrations of heavy metals in soils around the roots of *M. indica* and *P. macrophylla* at each site except in Site 1 where Cu, Zn and Cr, and Site 3 where Cr, varied significantly between the two species. Copper (Cu), Zn, Cr and Pb in leaves of both *M. indica* and *P. macrophylla* varied significantly ($p < 0.05$) among the sites. Concentrations of the heavy metals in leaves of both species at each site did not vary significantly ($p > 0.05$) except for Cr in Site 2. The concentrations of the heavy metals in both soil and leaves of the two tree species were within the permissible limits except for Chromium.

***Keywords*:** Gas flaring, heavy metals, tree leaves, Soil, Owaza

1. INTRODUCTION

Gas flaring in the Niger Delta Region of Nigeria has remained a great source of environmental concern which end appears to be far from sight despite several unmet deadlines by the Nigerian Government to put an end to it. Nigeria flares more natural gas associated with oil extraction than most countries. Estimate suggests that about 70% of the gas is wasted via flare. This equals about 25% of the UK's total natural consumption and is equivalent to 40% of the entire African continent's gas consumption in 2001.

The health and environmental consequences of gas flaring are well documented. The burning of gas releases huge volumes of greenhouse gases into the atmosphere, while emitted sulphur dioxide returns to the soil as acid rain. It is the singular and most common source of global warming which contributes to emissions of carbon monoxide, nitrogen(II) oxide and methane which have the possibility of causing environmental pollution and ecological destruction or disturbances. It can impact negatively on the health and livelihood of the communities within its vicinity, as it releases various poisonous chemicals.

Heavy metals are naturally occurring elements and are present in varying concentrations in all ecosystems. However, the main anthropogenic sources of heavy metals are various industrial processes such as mining, foundries, and smelters, combustion of fossil fuels, gasoline and waste of incinerators. Mercury (Hg), Cadmium (Cd), and Lead (Pb), are the heavy metals of concern because they are the most toxic with known serious effects on human and environment. Environmental exposure to high concentrations of heavy metals has been linked to various cancers and kidney damage.

Mangifera indica L. and *Pentaclethra macrophylla* Benth are two important tree species that support rural livelihoods in diverse ways. *Mangifera indica* also known as mango has been an important herb and indigenous medicinal material for over 4000 years. The ripe fruits are also consumed by many. *Pentaclethra macrophylla* (African oil bean) is found in the forest zone of west and central Africa. It is planted or retained along the edges of home gardens and farms mainly for its seed from which edible oil can be extracted. Throughout the forest zone of West Africa, the seeds are eaten boiled or roasted. They are also fermented to yield snack or condiment with a meaty taste. It is also used in traditional human medicine and veterinary medicine. For instance, the mature fruits are applied externally to heal wounds; extracts of the leaf, stem, bark, seed and fruit pulp, have anti-inflammatory and anthelmintic activity and are used to treat gonorrhea, convulsions and also used as analgesic.

Owaza - a Community in Ukwa East Local Government Area of Abia State faces a lot of environmental challenges stemming from its gas flaring station and oil production in the area. Several promises by the Government to stop gas flaring in Nigeria are yet to be fulfilled. Naturally, the community has fertile land that can sustain forestry and agricultural activities. However, activities associated with oil production in the area and their concomitant effects continue to pose environmental challenges. For quite a long time, there have not been concerted and effective efforts on the part of the government let alone the oil and gas operators to control environmental problems associated with the industry.

Despite the long history of gas flaring at Owaza, no studies have been carried out to ascertain the effect on important tree species that contribute to rural livelihoods in the community. From the available literature also, no study has linked bioaccumulation of heavy metals to gas flaring. This study carried out a spatial analysis of heavy metals in *M. indica* and *P. macrophylla* near Owaza gas flaring station in Abia State, Nigeria, with a view to ascertaining the spatial trend in heavy metal accumulation in the two species from the gas flaring source, and to know if there are potential health hazards associated with their consumption.

2. MATERIALS AND METHODS

Study Area

The study area is located at Owaza in Ukwa East Local Government Area of Abia State, Nigeria. Its geographical coordinates are 4° 57' 47" North and 7° 11' 15" East. The climate is tropical. An average daily maximum and minimum temperatures of 28 °C and 23 °C respectively, and an average annual rainfall of about 2400 mm, have been reported by for Ukwa West which is a neighbouring Local Government Area in the same climatic zone with Ukwa East. There are two seasons in Ukwa East - the rainy season which is experienced between March to October and the dry season which occurs between November to February. The population of Ukwa East, as at the 2006 Census, was 58,865 people. It has an area of 280 km^2. The people of Ukwa East are predominantly traders and farmers.

Selection of Study Sites and Sample Trees

Three study sites were purposively selected for the study. Site1 was selected from the closest point (100 m) from the gas flaring source where *M. indica* and *P. macrophylla* occur, while sites 2 and 3 were selected at 250 m and 350 m distances away from the gas flaring source, respectively. Two tree species - *M. indica* and *P. macrophylla*, were purposively chosen for the study based on their economic importance and availability in the three sites considered for the study. Three individuals belonging to each of the selected tree species were selected for soil and leaf sampling at each site.

Soil Sampling

Soil samples were collected separately up to a depth 25 cm at four points- north, south, east and west, around each of the selected tree species at each site. The collected soil samples were bulked separately for individual trees in each Site, enclosed in poly-bags and taken to a soil laboratory for analysis of heavy metals - Zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cr), Nickel (Ni) and copper (Cu), using standard laboratory methods.

Leaf Sampling

Leaves were collected from all sides of the tree canopy in the north, south, east and west directions, and from above and inside the tree canopy. Leaves for each tree species at each site were bulked and enclosed in perforated transparent plastic plates, and taken to the laboratory for analysis of heavy metals - Zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cr), Nickel (Ni) and copper (Cu), using standard laboratory methods.

Laboratory Analysis of Soil and Leaf Samples

2 g of soil of each sample was wet-digested using 30 ml conc. HNO_3 of high purity, followed by 30 ml of 2 M HCl. The digested samples were warmed in 30 ml of 2 M HCl to re-dissolve the metal salts. Leaf samples collected from the two species were washed with

deionized water, dried at 80 °C for 24 hours and digested according to the method by. 2 g of each tree leaf samples was charred and ashed in a muffle furnace at 500 °C. The ash was dissolved in 1:1 $HClO_4$ - HF mixture and heated until a transparent solution was obtained. The soil and plant digested solutions were separately cooled to room temperature, filtered, transferred quantitatively to 25 ml volumetric flask and made up to volume with distilled water. Sample digestion was carried out in three. Quantification of metallic content in samples was carried out using Flame Atomic Absorption Spectrophotometer.

Data Analysis

Student t-test was used to test for significant differences in heavy metal concentrations in leaves and soil between the two species at each Site.

One –way analysis of variance was used to test for significant differences in heavy metal concentrations at different locations from the gas flaring source for each species.

3. RESULTS

Heavy Metal Accumulation in Soils around the Two Tree Species at different Distances from the Gas Flaring Source

The concentrations of heavy metals in soils around the roots of *M. indica* and *P. macrophylla* at the various sites are presented in Tables 1 and 2 respectively. There were no significant differences ($p > 0.05$) in the concentrations of the heavy metals around the roots of *M. indica* except for Cd (Table 1).

Table 1. Heavy metal concentration of soil around the roots of *M. indica* at different sites

Heavy metal	Site 1*	Site 2 **	Site 3***	Standard Limits+		
				EU	UK	USA
Cu (mg/kg)	2.65 ± 0.23[a]	2.73 ± 0.75[a]	3.23 ± 0.32[a]	140.00	63.00	80.00 - 200.00
Zn (mg/kg)	14.17 ± 0.27[a]	14.90 ± 1.40[a]	14.40 ± 1.85[a]	300.00	200.00	200.00 – 300.00
Cr (mg/kg)	14.20 ± 2.17[a]	9.00 ± 2.78[a]	7.03 ± 1.33[a]	180.00	6.40	400.00
Cd (mg/kg)	0.60 ± 0.03[a]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	3.00	1.40	3.00
Pb (mg/kg)	2.88 ± 0.09[a]	2.06 ± 0.39[a]	2.62 ± 0.40[a]	300.00	70.00	300.00
Ni (mg/kg)	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]	-	-	-

Means on the same row with the same alphabet are not significantly different ($p > 0.05$)
*100 m from the gas flaring source; **250 m from the gas flaring source; ***350 m from the gas flaring source
+ Standard limits were adapted from Hong *et al.* (2014)

Table 2. Heavy metal concentration of soil around the roots of *P. macrophylla* at different sites

Heavy metal	Site 1*	Site 2 **	Site 3***	Standard Limits		
				EU	UK	USA
Cu (mg/kg)	1.82 ± 0.16[a]	3.12 ± 0.14[b]	2.51 ± 0.05[c]	140.00	63.00	80.00 – 200.00
Zn (mg/kg)	9.17 ± 0.62[a]	12.30 ±1.82[ab]	5.12 ± 0.22[c]	300.00	200.00	200.00 – 300.00
Cr (mg/kg)	44.07 ± 11.06[a]	10.13 ± 2.34[b]	29.33 ± 10.76[abc]	180.00	6.40	400.00
Cd (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.00	1.40	3.00
Pb (mg/kg)	3.58 ± 0.66[a]	3.44 ± 0.47[a]	2.47[a] ± 0.72[a]	300.00	70.00	300.00
Ni (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	-	-	-

Means on the same row with the same alphabet are not significantly different ($p > 0.05$)
*100 m from the gas flaring source; **250 m from the gas flaring source; ***350 m from the gas flaring source
+Standard limits were adapted from Hong *et al.* (2014)

Table 3. Variation in heavy metal accumulation in soils around the roots of the two tree species at each site

Heavy metal	Site 1*		Site 2 **		Site 3***	
	M. indica	*P. macrophylla*	*M. indica*	*P. macrophylla*	*M. indica*	*P. macrophylla*
Cu (mg/kg)	2.65 ±0.23 [a]	1.82 ±0.16[b]	2.73±0.75 [a]	3.12±0.14 [a]	3.23±0.32[a]	2.51±0.05[a]
Zn (mg/kg)	14.17±0.27[a]	9.17±0.62[b]	14.90±1.42[a]	12.30±1.82[a]	11.40±1.85[b]	5.12±0.22[c]
Cr (mg/kg)	14.20±2.17[a]	44.07±11.06[b]	9.00±2.78[a]	10.13±2.34[a]	7.03±1.33[d]	29.33±10.76[d]
Cd (mg/kg)	0.06 ±0.03[a]	0.00 ± 0.00[a]	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Pb (mg/kg)	2.88±0.09[a]	3.58±0.66[a]	2.06±0.39[a]	3.44±0.47[a]	2.62±0.40[e]	2.47±0.72[e]
Ni (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Means on the same row with the same alphabet for each site are not significantly different ($p > 0.05$)
*100 m from the gas flaring source; **250 m from the gas flaring source; ***350 m from the gas flaring source

Copper (Cu), Zn and Cr varied significantly ($p < 0.05$) in soils around the roots of *P. macrophylla* at the various sites (Table 2). Cd and Ni were almost absent in soils around the roots of both species except for *M. indica* at Site 1. No particular trend (increasing or decreasing) was observed in the concentrations of the heavy metals from Site 1 to Site 3.

There were no significant differences ($p > 0.05$) in the concentrations of heavy metals in soils around the roots of *M. indica* and *P. macrophylla* at each site except in Site 1 where Cu, Zn and Cr, and Site 3 where Cr, varied significantly between the two species (Table 3).

Heavy Metal Accumulation in Leaves of the Two Tree Species at different Distances from the Gas Flaring Source

Table 4. Heavy metal concentration of leaves of *M. indica* at different sites

Heavy metal	Site 1*	Site 2 **	Site 3***	Recommended Limit in Medicinal Plants
Cu (mg/kg)	10.01 ± 0.29^{a}	4.17 ± 0.44^{b}	6.77 ± 0.43^{c}	10.00^{+}
Zn (mg/kg)	31.87 ± 2.47^{abc}	34.67 ± 3.56^{a}	25.47 ± 1.16^{c}	$50.00^{\#}$
Cr (mg/kg)	3.33 ± 0.58^{a}	4.45 ± 0.33^{a}	4.40 ± 0.44^{a}	$1.50^{\wedge}$
Cd (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.30^{+}
Pb (mg/kg)	1.25 ± 0.45^{a}	0.10 ± 0.0^{b}	2.47 ± 0.72^{a}	$10.00^{\wedge}$
Ni (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.50^{+}

Means on the same row with the same alphabet are not significantly different ($p > 0.05$)
*100 m from the gas flaring source; **250 m from the gas flaring source; ***350 m from the gas flaring source
+ WHO(2005); ^WHO (1998); #Khan *et al.* (2008)

Table 5. Heavy metal concentration of leaves of *P. macrophylla* at different sites

Heavy metal	Site 1*	Site 2 **	Site 3***	Recommended Limit in Medicinal Plants
Cu (mg/kg)	8.08 ± 0.87^{a}	6.17 ± 0.73^{a}	6.43 ± 0.58^{a}	10.00^{+}
Zn (mg/kg)	40.13 ± 8.08^{b}	35.16 ± 8.81^{b}	30.33 ± 2.17^{b}	$50.00^{\#}$
Cr (mg/kg)	4.03 ± 0.38^{a}	5.70 ± 0.12^{b}	5.47 ± 0.71^{bc}	$1.50^{\wedge}$

Cd (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.30^{+}
Pb (mg/kg)	0.17 ± 0.04^{a}	0.07 ± 0.01^{b}	0.00 ± 0.00^{bc}	$10.00^{\wedge}$
Ni (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.50^{+}

Means on the same row with the same alphabet are not significantly different ($p > 0.05$)
*100 m from the gas flaring source; **250 m from the gas flaring source; ***350 m from the gas flaring source
+ WHO(2005); ^WHO (1998); #Khan *et al.* (2008)

The heavy metal concentrations in leaves of the two tree species are shown in Tables 4 and 5 for *M. indica* and *P. macrophylla* respectively. Copper (Cu), Zn, Cr and Pb in leaves of both *M. indica* and *P. macrophylla* varied significantly ($p < 0.05$) among the sites. Cadmium (Cd) and Ni were not detected in leaves of both *M. indica* and *P. macrophylla* at the various sites. Concentrations of the heavy metals in leaves of both species at each site did not vary significantly ($p > 0.05$) except for Cr in Site 2 (Table 6).

Table 6. Variation in heavy metal accumulation in leaves of the two tree species at each site

Heavy metal	Site 1*		Site 2 **		Site 3***	
	M. indica	*P. macrophylla*	*M. indica*	*P. macrophylla*	*M. indica*	*P. macrophylla*
Cu (mg/kg)	10.01 ± 0.29^{a}	8.08 ± 0.87^{a}	4.17 ± 0.44^{a}	6.17 ± 0.73^{a}	6.77 ± 0.43^{a}	6.43 ± 0.58^{a}
Zn (mg/kg)	31.87 ± 2.47^{b}	40.13 ± 8.08^{b}	34.67 ± 3.56^{b}	35.17 ± 8.81^{b}	25.47 ± 1.15^{b}	30.33 ± 2.17^{b}
Cr (mg/kg)	3.33 ± 0.58^{c}	4.03 ± 0.38^{c}	4.45 ± 0.33^{c}	5.70 ± 0.12^{d}	4.40 ± 0.44^{c}	5.47 ± 0.71^{c}
Cd (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Pb (mg/kg)	1.25 ± 0.45^{d}	0.17 ± 0.04^{d}	0.10 ± 0.03^{d}	0.07 ± 0.01^{d}	0.00 ± 0.00	0.00 ± 0.00
Ni (mg/kg)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Means on the same row with the same alphabet for each site are not significantly different ($p > 0.05$)
*100 m from the gas flaring source; **250 m from the gas flaring source; ***350 m from the gas flaring source

4. DISCUSSION

To a large extent, the accumulation of heavy metals in leaves and soils around *M. Indica* and *P. macrophylla* did not show any direct relationship with distance from the gas flaring source. For example, higher concentrations were observed at farther distances from the gas flaring source in some instances. This may not be out of place as the flare through smoke can move to distances away from the source and be deposited at farther locations through acid rain. Gas flaring contribute to acid rain, which can have several detrimental effects leading to altered microbial communities, including the mobilization of several toxic metals (mercury, lead, cadmium, arsenic, selenium), a reduction in the soil pH which could have effects on the viability of various groups of organisms, and leaching of essential nutrients from the soil. Moreover, other sources outside gas flaring may also have contributed to heavy metal accumulation in the evaluated soils and tree species. It was reported by that soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition.

The near absence of both Cadmium and Nickel in soils and leaves at the various sites is a good development as heavy metals generally have grave health implications especially when their concentrations exceed the permissible limits. Continuous exposure of Cadmium (Cd) in edibles and water, results in accumulation of cadmium in kidneys causing kidney diseases. Nickel, although a micronutrient to most organisms, is known to be carcinogenic when consumed in excessive quantities. It leads to respiratory disorder, lung cancer, dermatitis and inhibition of enzymatic activities in the body and photosynthesis and respiration in plants. The toxicity of heavy metals has been attributed to their cumulative deleterious effects that can cause chronic degenerative changes especially to the nervous system, liver, and kidneys.

The observed lack of significant difference in bioaccumulation of heavy metals in leaves of *M. indica and P. macrophylla* at the various sites may probably be attributed to their physiological similarity in terms of uptake or rejection. It has been observed by that several plants exert control over uptake or rejection of some elements by appropriate physiological reactions.

Using the European Union (EU), United Kingdom (UK) and United States of America (USA) standards as reported by, all the evaluated heavy metals in soils around the roots of *M. indica* and *P. macrophylla* were below the maximum limits at all the sites except for Chromium when the UK standard alone was considered. Similarly, the concentrations of the evaluated heavy metals in leaves of both tree species were within the recommended limits in medicinal plants as reported by except Chromium which was found to be far above the recommended limit in all the sites. Experiences have shown that chromium compounds are respiratory tract irritants causing airway irritation and obstruction, and lung, nasal, or sinus cancer, when inhaled. However, its adverse health effects are determined by the specific compound involved and the dose, exposure and duration of exposure.

Although, the concentrations of most of the evaluated heavy metals were within the permissible limits, it should be noted that they can pose health hazards over time due to their cumulative nature. For instance, lead which is a known cumulative metal is known for its negative health impacts which include: constipation and anaemia, fatigue, loss of appetite, constipation, colic anaemia, neuritis, seizure, general weakness, insomnia, hypertension and renal dysfunction, sperm count depression and death.

5. CONCLUSION

Concentrations of the evaluated heavy metals were within the permissible limits except Chromium, especially in leaves of both *M. indica* and *P. macrophylla*, which was observed to be far above the permissible limit in medicinal plant materials. Cadmium and Ni were almost absent in soils and leaves of both species at the various sites. The concentrations of some of the heavy metals in both soils and leaves of both tree species varied significantly between sites while some did not. However, the concentrations of the evaluated heavy metals in soils and leaves of both species did not vary significantly at each site. No definite trend (increasing or decreasing) in the concentrations of the heavy metals was observed with increase in distance from the gas flaring source.

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