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Bioaccumulations of Heavy Metals on Soil and Arable Crops Grown in Abandoned Peacock Paint Industry in Ikot Ekan, Etinan Local Government Area, Akwa Ibom State, Nigeria

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Abstract:

A study of heavy metals concentrations on soil and some economic crops grown within abandoned Peacock Paints Industry environment in Ikot Ekan, Etinan Local Government Area, Akwa Ibom State, Nigeria was carried out. Heavy metals (Fe, Zn, Mn, Cu, Pb, Cd, Cr and Ni,) were analysed using Unicam Solar 969 Atomic Absorption Spectrophotometer (A.A.S). Levels of these heavy metals in some economic crops and soil obtained from the abandoned Peacock Paint Industry environment were significantly higher ($p<0.05$) than those from the control site, indicating that the activities of paint production and other manufacturing processes which took place when the industry was operational, contributed to the observed higher levels of heavy metals concentrations in the industrial environment. Comparison of heavy metals in crops and soils obtained from abandoned Peacock Paint Industry environment showed that heavy metals in crops were higher than those recorded in the soil obtained from abandoned Peacock Paint vicinity. The higher levels of heavy metals in crops could be attributed to the bioaccumulations and biomagnifications of these metals in crops tissues. The average concentrations of Fe, Zn, Mn, Pb, Cu, Ni, Cd and Cr in pumpkin leaves (*Telfaiferia occientalis)* were (256.13±3.34, 87.49±2.38, 5.29±2.28, 25.13±2.11, 23.13±1.22, 7.17±1.32, 17.01±0.08 and 24.02±0.12) respectively. In okro leaves (*Abelmoschus esculentus)*, the concentration of Fe, Zn, Mn, Pb, Cu, Ni, Cd and Cr were (217.28±3.41, 43.18±2.76, 7.46±1.41, 12.89±2.87, 18.31±2.74, 10.13±2.40, 23.10±1.13 and 21.13±1.02) respectively; and in cassava leaves (*Manihot esculentus)* the concentrations of Fe, Zn, Mn, Pb, Cu, Ni, Cd and Cr were (205.30±2.58, 57.19±8.40, 13.13±2.52, 16.34±2.87, 24.13±2.08, 3.52±2.10, 20.02±2.09 and 25.12±1.07) respectively. The concentrations of heavy metals in soil samples obtained within abandoned Peacock paint industry environment were significantly higher than those obtained from control sites. The levels of heavy metals in both soil and crops samples collected from abandoned Peacock Paint industry environment were significantly high to cause environmental concern as their concentrations exceeded the tolerable limits. However, there is need for suspension of all agricultural activities in the abandoned Peacock Paint industry to prevent the introduction of further heavy metals into the existing food chain. Also, there is need for government to regulate and control agricultural activities in all abandoned industries, and bioremediation of all the abandoned industries to avoid transmission of heavy metals to man through food chain.

Keywords: Abandoned Peacock Paint Industry, Bioaccumulations, Heavy metals, Crops, Soil.

1.0 Introduction:

The role of heavy metals in the soil system is increasingly becoming an issue of global concern, especially as soil constitutes a crucial component of industrial establishment (Amisah, *et Al.*, 2009). Soil contamination with heavy metals through the repeated use of untreated or poorly treated waste from industries is one of the most severe ecological problems in the developing countries. Heavy metals constitute a main group of soil pollutants that their contamination in environment affects all ecosystem components (Edem *et al*., 2008). Although heavy metals are present as natural components of soils, toxic contamination may frequently occurs at industrial and mining sites (Das, 1999 and Kuo *et al*., 2011). Heavy metals such as Cu, Zn, Mn and Fe are essential for plant growth; many of them do not have any significant role in the plant

physiology. The uptake of these heavy metals by plants is an avenue of their entry into the human food chain with harmful effects on health (Abbas *et al*., 2010 and Basta *et al*., 2010).

Paint contained various types of hazardous and non-hazardous wastes that are being discharged from the industries into the surrounding environment. Like other industries most of the paint industries have no wastewater or solid waste treatment plant. Consequently the wastes of these industries are disposed into drains, canals and rivers without treatment and the solid wastes are dumped into surrounding land or water bodies which contaminate the soil or water with highly toxic inorganic or organic pollutants. The continuous receiving of solid waste especially by land poses a great threat to the soil and plant. The harmful inorganic and organic substances in the wastes degrade the soil and changing the composition of existing heavy metals and other organic constituents. As a result the plants and animals that depend directly or indirectly on the polluted soil are affected. When these plants are eaten by man, the heavy metals become bioaccumulated and eventually result in several ailments which may subsequently end up in death (Odiette, 1999; and Adriano, 2003). Plants can accumulate some of these metals which are not injurious to them, but may be poisonous to animals grazing on the plants (Raven and Evert, 2006). Thus, this research work aims at studying the influence of heavy metals on soil and arable crops grown within abandoned Peacock paint industry in Ikot Ekan, Etinan Local Government Area of Akwa Ibom State, Nigeria.

1.1 Study Area:

Peacock Paint Industry was one of the major paint producing industries in the South- South region of Nigeria. Located at Ikot Ekan, Etinan Local Government Area of Akwa Ibom State, Nigeria. The industry was commissioned in 1980, and was known for the production of various types of paint (emulsion, oil, peacotex etc). Some of the wastes generated by this industry were spread in some parts of the environment within the premises. Peacock Paint Industry was closed down in 2007 and has remained abandoned till now. However, due to the closure of the industry, the premises of the abandoned Peacock paint Industry is now used for agricultural purposes by the rural people living around the environment

2. 0 Sample Collection:

Soil sampling was carried out by collecting portions of soil using a soil auger from 0-15 cm and 15-30cm within the abandoned Peacock Paint Industry environment. The samples were put into polyethylene bags, labeled and taken to the laboratory for pre-treatment and analysis. Similarly, the leaf samples of pumpkin (*Telfaiferia occientalis),* okro *(Abelmoschus esculentus),* water leaf *(Talinum triangulare)* and cassava *(Manihot esculentus*) commonly used in making vegetable soup in the area were obtained within the abandoned Peacock Paint industry premises and put into polyethylene bags, labeled and taken to the laboratory for further treatment and analysis. Sampling was carried out within the abandoned industry premises. Samples of both soils and plants were collected in triplicate. Control samples were also collected about 5 km away from the abandoned Peacock Paint Industry environment.

2.1. Sample Treatment and Analysis:

Soil samples were air-dried at ambient laboratory temperature. The soil samples were ground using mortar and pestle and sieved to pass through 2 mm sieve and stored for chemical analysis. Each soil sample (5g) was placed in a Teflon beaker and digestion was carried out using concentrated nitric (10 cm^3) and concentrated perchloric (5cm^3) acids in the ratio of 2:1. This was allowed to cool before leaching the residue with 5 cm^3 of 20% HNO_3. Digested samples were filtered and made up to 50 cm3 with deionized water. A blank determination was treated in the same method but without sample. Solution of samples were then taken and aspirated into Atomic Adsorption Spectrophotometer (Unicam Solaar A.A.S 969 model). Each plant sample was oven-dried at 50˚C - 60˚C. The dry sample was ground into powder and stored. The powdered plant sample (2g) was weighed into a crucible and ashed in a furnace at 500 ˚C-700˚C for 4 hours. It was removed after ashing from the furnace and cooled. The sample (ash) was leached with 5 cm^3 of 6 MHCl and was made to 50 cm^3 of volume of deionized water. Blank determination was also carried out as in a similar way as described above except for the omission of the sample. The solutions were analyzed for metals using A. A. S (Unicam Solaar A.A.S 969 model).

3.0. Results and Discussion:

Table 1 and 2 show that there are variations in the concentrations of heavy metals obtained in soils from abandoned paint industry and the economic crops. The highest concentrations of all the heavy metals determined in both soil and crop samples were observed from abandoned Peacock paint industry environment. The soil and crop samples obtained from control locations recorded least concentrations of heavy metals. The levels of heavy metals obtained in crop samples within abandoned paint industry environment were significantly higher than those in the soil samples. Similar results were also obtained by Udosen *et al.,* (2004), when they study the impact of trace metal concentration in soil and in plant grown with abandoned steel industry in Akwa Ibom State. Ekpo *et al.*, (2011) also observed higher concentrations of some heavy metals in crops within quarry environment and attributed it to bioaccumulation and biomagnifications of metals in plant tissues. Iron (Fe) levels in plant samples obtained from abandoned paint premises and the control locations were generally higher than Fe levels in soil samples. The mean level of Fe in the crop samples *(Telfaiferia occientalis, Abelmoschus esculentus, Talinum triangulare and Manihot esculentus*) within abandoned paint industry were 256.13±3.34; 217.28±3.41; 228.15±1.28 and 205.3±2.58 mg/kg respectively, and the mean level of Fe in crops samples *(Telfaiferia occientalis, Abelmoschus esculentus, Talinum triangulare and Manihot esculentus*) in the control locations were 80.25 ± 8.65, 68.29±1.0, 72.14± 3.14 and 85.18±2.71 respectively. While the mean level of Fe in soil samples within abandoned paint vicinity and control site were 154.19± 5.12 and 95.23±2.13 mg/kg respectively. Of all the metals analyzed for this study, Fe shows the highest concentration in both plant and soil samples collected from abandoned Peacock paint industry and the control sites. The high level of Fe recorded in plants collected within abandoned Peacock paint industry environment and control site shows high uptake of Fe from the soils. The levels of Fe in the plant samples were significantly higher ($p<0.05$) than the levels of Fe in soils obtained from abandoned Peacock Paint environment. The higher level of Fe in the plant species obtained from abandoned paint environment may be due to abundance or availability of this metal in the soil and also bioaccumulations and biomagnifications of Fe in plant tissues (Botkin and Keller, 1998). Although Fe is not generally considered as a pollutant to soil and plant (Huamain *et al.,* 1999), the relatively higher concentrations of Fe observed in soil and plant samples from abandoned Peacock paint environment calls for concern. Since the rural people used the available space within abandoned Peacock paint environment for agricultural activities. The levels of Fe observed in plant and soil samples from control locations were within the natural limit.

Almost all the plant species examined from abandoned Peacock paint environment recorded higher concentration of heavy metal. The mean concentrations of Zn, Mn and Cu in *Telfaiferia occientalis* were (87.49±2.38, 5.25±2.58 and 23.13±1.22) mg/kg respectively in plant samples collected from abandoned Peacock Paint environment. The levels of Zn, Mn and Cu in *Abelmoschus esculentus* from abandoned Peacock Paint environment were (43.18±2.96, 7.46±1.41 and 18.13±2.74) mg/kg respectively. The concentrations of Zn, Mn and Cu in *Talinum triangulare* were (72.14±3.24, 8.51±1.42 and 27.19±1.17)mg/kg respectively. While the levels of Zn, Mn and Cu in *Manihot esculentus* obtained from abandoned Peacock paint environment were (57.19±8.41, 12.13±2.52 and 24.13±2.08) mg/kg respectively. The high levels of Zn, Mn and Cu recorded in all the plant samples from abandoned Peacock paint industry might be due to the use of these metals in paint production and other manufacturing processes, which could result in the high uptake of these metals by plants in the soil from abandoned paint environment. Also, the higher levels of Zn, Mn and Cu in plant samples collected from abandoned paint industry environment might also be as a result of bioaccumulation of the elements in the plant tissues. However, the levels of Zn, Mn and Cu observed in soil within abandoned Peacock paint industry were lower than the concentration observed in the plant species obtained from abandoned Peacock paint environment. The lower concentrations of these metals in soil may be attributed to the leaching.

The levels of these heavy metals in soil and plant samples obtained from abandoned paint industry were above the natural limit. While the levels of Zn, Mn and Cu in soil and plant samples obtained in the control sites were within the natural limit. Although Zn is an essential trace element in low concentration to plant and animal, it high concentration of Zn in plant samples obtained from

abandoned Paint industry is a source of health concerned (Oborn et al., 2005; Khan *et al.,* 2012). Ingestion of Zinc in excess of 12 mg per day may cause lung disturbance (Eka and Udotong, 2003). Zinc is use as an additive in lubricating oil and also use in paint production. Thus, this may be responsible for high level of Zn observed with the soil and plant samples within abandoned Peacock Paint industry. The mean concentrations of manganese obtained within abandoned paint industry were 39.23±2.05 mg/kg in 0-15cm soil depth and 25.06±2.65 in 16-39cm soil depth. The levels of Mn in 0-15cm soil depth and all the plant samples obtained within abandoned paint industry were above natural limit. While the value of Mn in 16-30 cm soil depths was within the permissible limit. The high levels of Mn recorded from soil and plant samples obtained from abandoned Peacock Paint industry environment might be as a result of its use in the paint industry. Exposure to manganese has been indicated to cause lack of control of the bladder (Ayodele and Gaya, 1998). The high level of copper recorded in soil and plant samples obtained within abandoned paint industry may be attributed to the use of Cu in paint production. Excessive amount of Cu in an environment as recorded in abandoned paint industry might be toxic to man and other organisms. Raven and Evert (2006) observed that high concentration of Cu is toxic to plants and indirectly affect the ecosystem through food chain. Excess amount of copper in the human body has been found to cause Wilson's disease (Moore *et al.,* 2005).

The mean levels of Pb and Cd in the soil samples within abandoned paint industry were 18.25±2.25 mg/kg and 12.34±1.30 respectively. The level of Pb and Cd in plant samples obtained within abandoned paint industry were significantly higher ($p<0.05$) than in soils. The high concentrations of Pb and Cd recorded in soil and plant samples obtained from abandoned paint industry might due to its use in the paint industry. Also, the mean concentrations of Pb in soils from the control sites were above the natural limits in both soil and plant samples. The presence of Pb in soil and plant samples obtained from abandoned paint industry and the control sites may have been due to automobile emission and industrial emission (Joesten et al., 1991). However, exposure to Pb can lead to Pb poisoning, which will result in memory loss and restlessness. Pb has been found to inhibit enzymatic activity (Vincoli, 1995). Cadmium levels in both soil and plant samples obtained from abandoned Peacock Paint industry were higher than the natural limits of Cd in plant and in soil. While the concentrations of Cd recorded in the control sites were below the natural limits in both soil and plant samples. The high concentration of cadmium observed in soil and plant samples within abandoned paint industry is therefore considered to pollute the soil and also be toxic to plants. Exposure to high cadmium levels may result in osteoporosis disease (Akesson *et al.,* 2006). Also, cadmium is regarded as the most hazardous trace element, and its poisoning causes damage to kidney and heart, and prolonged exposure results in loss of calcium from the bone (Udoessien, 2003).

The mean concentrations of Cr and Ni in soil and plant samples obtained within abandoned paint industry were higher than those recorded in control sites. The presence of chromium and nickel in abandoned paint industry vicinity might be due to its use in the paint industry. Exposure to chromium has been found to cause dermatitis (Ayodele and Gaya, 1998), perforation of nasal septa and kidney damage. The mean nickel levels in plant samples *Telfaiferia occientalis, Abelmoschus esculentus, Talinum triangulare and Manihot esculentus* from abandoned paint industry were (7.47±2.21, 10.13±2.40, 12.14±1.02 and 3.52±2.10) mg/kg respectively. The levels of nickel observed in plant samples from abandoned Peacock Paint industry were above the natural limit of 1-5 mg/kg. While the level observed plant samples obtained from control sites were within the natural limit. Vincoli, (1995) reported that ingestion of nickel in high concentrations may cause hyperglyanemia, depression of the central nervous system and kidney damage. The high level of nicked recorded in abandoned Peacock Paint industry might be attributed to its use in the paint industry. The mean concentrations of Cr and Ni, were quite low in both soil and plant samples obtained from the control sites, although the level in plant samples were higher than that of soil samples. The high levels of trace metals observed in all plant samples collected from abandoned paint industry may be attributed to bioaccumulations and biomagnifications of these metals in plant tissues. In order to ascertain possible relationship between heavy metals content of soils and some economic crops analyzed, correlations between contents were calculated. The result shows (Table 3) across all vegetable samples, the correlation between soil and plants of different heavy metals varies widely.

Table 1. Mean concentrations (mg/kg) of Heavy metals in some economic crops within abandoned Paint Industry

Plant Samples	Fe		Zn		Mn		Pb		Cu		Ni		Cd		Cr	
	Paint site	Control site	Paint site	Control site	Paint site	Control site	Paint site	Control site	Paint site	Control site	Paint site	Control site	Paint site	Control site	Paint site	Control site
Telfairia occidentalis (Pumpkin)	256.13 ±3.34	80.25 ±8.65	87.49± 2.38	43.09 ±2.38	5.29 ±2.58	2.17 ±1.46	25.13 ±2.11	2.48 ±0.14	23.13 ±1.22	4.18 ±2.21	7.47 ±1.32	1.48 ±1.06	17.01± 0.08	1.58± 2.10	24.02 ±0.21	2.12± 1.11
Abelmoschus esculentus (Okro)	217.28 ±3.41	68.29 ±1.05	43.18 ±2.96	21.10 ±3.74	7.46 ±1.41	1.62 ±1.05	12.89 ±2.19	3.12 ±1.09	18.13 ±2.74	3.16 ±1.58	10.13 ±2.40	2.13 ±1.62	23.10± 1.13	2.19± 1.05	21.13 ±1.02	2.20± 2.14
Talinum triangulare (water leaf)	228.15 ±1.28	72.14 ±3.14	72.14 ±3.24	38.12 ±2.10	8.51 ±1.42	1.96 ±1.59	27.47 ±1.04	3.42 ±2.60	27..19 ±1.17	2.10 ±0.28	12.14 ±1.02	1.74 ±2.16	16.55± 1.12	1.74± 0.16	22.08 ±1.00	1.20± 1.00
Manihot esculentus (Cassava)	205.3 ± 2.58	8518 ± 2.71	57.19 ± 8.41	28.18 ± 1.16	12.13± 2.52	3.48 ± 1.07	16.34 ± 2.87	4.29 ± 1.06	24,13 ± 2.08	3.56 ± 2.10	3.52 ± 2.10	2.13 ± 0.50	20.02 ± 2.09	2.19 ± 0.01	25.12 ±1.07	2.16± 1.70

Table 2. Mean concentrations (mg/kg) of Heavy metals in soil within abandoned Peacock Paint Industry

Heavy metals	Sample Locations			
	Abandoned Paint industry site		Control site	
Soil Depths	**0-15cm**	**16-30cm**	**0-15cm**	**16-30cm**
Iron (Fe)	287.12 ±5. 48	196.18 ±2.34	75.14± 1.98	47.20 ±2.39
Zinc (Zn)	58.31± 1.29	42.14±1.51	17.28±1.23	9.16±2.20
Manganese (Mn)	39.23± 2.05	25.06±2.65	8.18±4.10	3.15±1.28
Lead (Pb)	18.25±2.25	14.18±3.78	3.42± 1.20	1.03±0.12
Copper (Cu)	36.29±2.32	12.46±2.17	5.17±1.41	2.19±1.03
Nickel (Ni)	25.27±1.21	12.46±2.17	1.25±1.70	0.72±1.30
Cadmium (Cd)	12.34±1.30	8.24± 1.15	2.04±1.05	1.29±0.11
Chromium (Cr)	15.19±2.09	7.16± 3.48	2.11±0.67	0.57±1.55

Table 3: Correlation Matrix between Heavy Metals in plant samples obtained from Abandoned Peacock Paint Industry Environment (r at p<0.05).

	Fe	Zn	Mn	Pb	Cu	Ni	Cd	Cr
Fe	1.000							
Zn	0.921	1.000						
Mn	0.956	0.765	1.000					
Pb	0.641	0.814	0.762	1.000				
Cu	0.513	0.267	-0.461	-0.341	1.000			
Ni	-0.240	-0.320	-0.613	0.542	-0.769	1.000		
Cd	-0.156	-0.107	-0.415	-0.465	-0.585	-0.312	1.000	
Cr	-0.265	-0.233	-0.135	0.158	-0.364	-0.586	0.165	1.000

4.0. Conclusion:

The findings of this study show that paint production contributed to the higher levels of heavy metals in soil and plant samples obtained from abandoned Peacock Paint industry than at the control sites. However, levels of heavy metals in the plant samples were generally higher than levels in soil samples; this may be attributed to bioaccumulations and biomagnifications of these metals in plant tissues. The levels of Fe, Zn, Mn, Pb, Cu, Cr, Cd and Ni in both soil and plant samples obtained from abandoned Peacock paint industry were above permissible limits, thus the level of environmental pollution is high in abandoned Peacock paint environment. This may affect human health since the crops grown in this environment are continuously consumed by the rural people living around the abandoned Peacock paint industry. However, there is need for suspension of all agricultural activities in the abandoned Peacock Paint industry to prevent the introduction of further heavy metals into the existing food chain. Also, there is need for government to regulate and control agricultural activities in all abandoned industries, and bioremediation of all the abandoned industries to avoid transmission of heavy metals to man through food chain.

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