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ACCUMULATION AND CONTAMINATION OF HEAVY METALS IN SOIL AND VEGETATION FROM INDUSTRIAL AREA OF IKIRUN, OSUN STATE, NIGERIA.

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ABSTRACT: *Samples of soil and vegetation were analyzed for their heavy metal contents using standard methods. Samples were collected around a steel rolling mill along Ikirun, Osogbo road, Osun State. Results of vegetation revealed highest iron concentration (17305.00mg/kg), highest chromium concentration (1088.00mg/kg), highest nickel concentration (303.40mg/kg), and highest lead concentration (38.88mg/kg) at VG 7. Soil analysis showed highest iron concentration at SS3 (29895 mg/kg), highest cobalt concentration at SS6 (510 mg/kg), highest nickel concentration at SS6 (882 mg/kg), highest lead concentration at SS7 (2525 mg/kg) and highest chromium concentration at SS6 (2935 mg/kg). This suggests that the area was grossly contaminated mostly with iron, chromium, lead and nickel especially in soil. Plant concentration factor was in the range 0.03 – 0.63 for iron, 0.10 – 0.62 for cobalt, 0.01 -0.76 for nickel, 0.00002 – 0.02 for lead and 0.09 – 0.95 for chromium. Plant absorption of heavy metals from soil was in the order Cr>Ni>Fe>Co>Pb. Integrated pollution index of soil showed low to extreme high level of pollution. Statistical significant differences were observed between means of heavy metals in study area and control site. Strong positive correlations were observed between pairs of metal in vegetation and pairs of metal in soil. Inter-element correlations were however observed to be weak between the two media. Levels of metals in control sample were not as high as levels obtained at the steel rolling mill.*

Keywords: Soil, Vegetation, Integrated pollution index, Plant concentration factor, Heavymetals.

INTRODUCTION

Pollution is one of the most important problems around the world today in which thousands of millions of world inhabitants suffer health problems related to industry and atmospheric pollutants (Martinez *et al*., 2001). Recent years have witnessed significant attention being paid to the problems of environmental contamination by wide variety of chemical pollutants including heavy metals. (El-Demerdash and Elagamy, 1999).

Heavy metals enter into our environment from both natural and anthropogenic sources (Kabata-Pendias, 1986). They contaminate food source and accumulate in both agriculture products and seafood through water, air and soil pollution (Lin *et al*., 2004). All heavy metals are toxic at soil concentration above normal level. Addition of heavy metals to soil may affect microbial proliferation and enzymatic activities, possibly leading to a decrease in the rates of the biochemical process in the soil environment. Worldwide increasing level of industrialization and urbanization has lead to environmental pollution (Filazi *et al*., 2003).

Industries have largely been reported to be responsible for discharging pollutants containing heavy metals such as zinc, copper, manganese, cadmium, nickel, mercury, lead, chromium, iron and cobalt into our environments (Chen and Chen, 2001). Heavy metal mobilization in the biosphere by human activities has become an important process in the geochemical cycling of these metals (Chen *et al*., 2005). This is evident in industrial areas where stationary and mobile sources release large quantities of heavy metals into the atmosphere, soil and vegetation exceeding the natural emission levels. (Nriagu, 1989: Bilos *et al*., 2001).

Metal distribution between soil and vegetation is a key issue in assessing environmental effect of metals in the environment (Abulude and Adesoje, 2006). Heavy metal toxicity has an inhibitory effect on plants growth, enzymatic activity, photosynthetic activity and accumulation of other nutrient elements, and also damages the root system (Gune *et al*., 2004).

Soil is not only a medium for plant growth or pool to dispose of undesirable materials, but also a transmitter of many pollutants to surface water, groundwater, atmosphere and food (Chen *et al*., 1997). Therefore, soil pollution may threaten human health through its effects on the hygiene quality of food and drinking water.

Nadal *et al*. (2004) and Onder *et al*. (2007) have observed that the most economical and reasonable method for monitoring heavy metals in the atmosphere is using soil and vegetation samples and have been widely used as cumulative matrices of long and short term exposure respectively to environmental pollutants .

In Nigeria, manufacturing industries constitute a major source of environmental pollution. Some discharge their wastes into rivers and streams untreated. There has been report of contamination of Nigerian environment by petroleum (Kakulu and Osibanjo, 1992). Olayiwola (2011) investigated the effect of heavy metal pollution of soil by various allied artisans in the vicinity of auto-mechanic workshop (Osun State, Nigeria). Yusuf *et al*. (2003) reported the impact of industrial development on the environment of Lagos city and observed that they range from stench and colouration of water bodies to the appearance of surface films.

Literature indicates that studies have been conducted on pollution of some areas in southwestern Nigeria, but nothing of such has been monitored on the heavy metal levels emanating from industrial area in Ikirun, southwestern Nigeria and their possible effects on the quality of soil and vegetation. Therefore, it is important to investigate the level of heavy metals in soil and vegetation around this steel processing industry.

METHODOLOGY

Study Area

The study area is located in Osun State, in the southwestern part of Nigeria. Ikirun is about longitude 4^{o}39.929’E and latitude 7.55^{o}.899’N. There are no other industrial developments within the area. The steel rolling mill plays a significant role in the economy of Nigeria. Scrap and unused iron materials are brought from all parts of Nigeria to this factory which invariably creates a source of income to some of the inhabitants. The factory was established around 2009 and located very close to the main road. It has two rainy seasons with the major rains in April to July, and minor rains between September and November. The factory's surrounding area is essentially rural with minor agricultural activities some distance away. Settlements include a cafeteria for those that brought the scrap iron, a petrol station and a market some kilometers away.

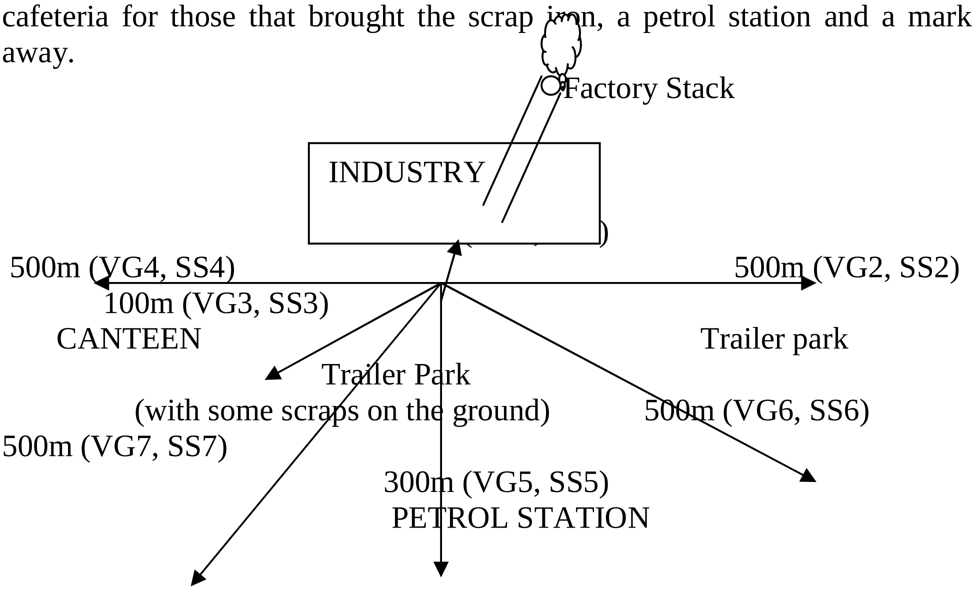

Figure 1: Study area showing sampling points

Sample collection

The sampling sites were selected in such a manner to cover the entire vicinity in front of the factory. To provide a satisfactory environmental representation of the study area, distances between 0m, 100m, 200, 300m, 400m, and 500m around the main stack of the factory was taken into consideration. The west, east and south directions were used. Three plant (*Imperata cylindrica*) samples were randomly collected at each sampling point and combined to form a composite, making a total of 7 composite samples of plant. The plant was selected as an important representative species of the annual vegetation of the area and was collected simultaneously with the soil at the same point where the plants occur. Soil specimens were taken with a small plastic shovel from upper 5cm of the soil and scrapped into a labeled polythene bag. Large stones and irons scraps were removed. In the laboratory, the soil was sieved to obtain more homogenous distribution, which further enabled the removal of small stones, roots and large organic residues. The soil sample was kept in polythene bag for further analysis. The plant samples were oven dried in an oven at a temperature of 60^{o} C after which they were crushed, sieved and kept in polythene bag until analysis. The control sample for soil and plant were taken at the Osun State Polytechnic, Iree Central Mosque.

Sample analysis

Both the soil and the plant materials were analyzed using Atomic Absorption Spectrophotometer. 0.5 g of plant (*Imperata cylindrica*) (2.0g of soil) was weighed into a digestion flask, 10 mL of nitric perchloric acid (2:1) was added to the sample and digested at 150°C for 1 ½ hours. 2 mL of HCl-distilled water (1:1) was added. The temperature was increased to 230°C and further digested for another 30 minutes, removed from heat and allowed to cool. It was washed into a standard 50 mL volumetric flask and made up to the mark with distilled water. The amount of heavy metals in the sample was determined by Atomic Absorption Spectrophotometer (BUCK 210 VGP). The concentration of heavy metal was extrapolated from the calibration graph prepared.

Statistical analysis

Statistical analyses such as mean, standard deviation, Pearson correlation, t-tests, plant concentration factor, and integrated pollution index using NCSS were used.

RESULTS AND DISCUSSION

Tables 1 and 2 summarize the concentration of five heavy metals respectively in 7 soil and 7 plant (*Imperata cylindrica*) samples collected in the vicinity of the steel rolling mill. All the five elements displayed presence in all the soil and plant samples used for the study.

Table 1: Heavy metal concentration in plant samples collected in the neighbourhood of a steel rolling mill

Metal	Heavy metal concentration (mg/kg)				Control sample	Accumulation factor
	Min	Max	Mean	Std		
Fe	876 (VG 6)	17305 (VG 7)	6874	6307	680	10.1
Co	38.92 (VG 1)	86.45 (VG 4)	62.2	21.2	34.68	1.79
Ni	131 (VG 5)	303 (VG 7)	213	67	1.86	115
Pb	0.05 (all except VG 7)	38.85 (VG 7)	5.59	14.7	0.05	112
Cr	223 (VG 5)	1088 (VG 7)	630	334	3.74	169

Metal levels in the plant samples collected are as shown in Table 1. The highest level correspond to Fe (VG 7), C (VG 7) followed by Ni (VG 7) and Co (VG 4). The lowest corresponds to Pb (all sites except VG 7). A close look at Table 1 shows that the variability in the range of all the metal distribution in the plant samples as compared to their means respectively is an indication of over contamination with the metal ions. The issue of over contamination is supported by the fact that most metals exceeded their critical value in the plants samples. For instance, the critical levels of Cr in plants are 5 -10 µg/g (Cicek and Koparala, 2004) and 0.06 – 18 µg/g (Shanker *et al*., 2005) indicating that the results in the investigated area runs a risk of Cr pollution in the plant samples. Mobility of cobalt element has been found to be slow in plant (Robson *et al*., 1997) and toxic level is about 0.05 µg/g (Kabata-Pendias and Piotrowska, 1984). The present level of 62.2 mg/kg is a clear indication of potential pollution. According to Onder *et al*. (2007), the acceptable Pb limit level is 3 µg/g for plant: however, the maximum Pb level in VG 7 and the mean concentration (5.59 mg/kg) for current study is an indication of over contamination. All other sites of the sampling area contained low Pb level. The decreasing order of elemental concentrations in the plants is in the order Fe>Cr> Ni> Co>Pb. The levels of these metals in the control sample were observed to be lower compared to the study area with Cr having the highest factor of accumulation (169).

The levels of these metals in soil are as shown in Table 2. The highest level correspond to Fe (SS3) and Cr (SS6) followed by Pb (SS7). The lowest levels of metal were Co (SS6) and Ni (SS6). Studies on soil have implicated these metals as reaching or exceeding toxicity levels. Bergmann (1992) has shown that the toxic levels of Cr in soil is around 2 -50 µg/g and this when compared to Cr level for this study is too high. The critical levels of Ni in soil have been investigated by many researchers (Bergmann, 1992; Madejon *et al*., 2002 ; Gune *et al*., 2004) and estimated to be in the range of 2 -50 µg/g. the present study shows Ni range to be 227- 882 mg/kg which is alarming suggesting that Ni pollution is critical in the investigated area. These metals can be carried away or blown by wind to nearby river used by man to carry out their activities. The elemental concentrations in soil samples are in the decreasing order of Fe>Cr>Pb>Ni>Co. The levels of metals in soil of study area were found to be higher compared to the control area with Co having the highest accumulation factor (5.62).

Table 2: Heavy metal concentration in soil samples (mg/kg)

Metal	Heavy metal concentration (mg/kg)				Control sample	Accumulation factor
	Min	Max	Mean	Std		
Fe	13770 (SS2)	29895 (SS3)	23,524	6610	13,908	1.69
Co	132 (SS2)	510 (SS6)	267	136	47.5	5.62
Ni	227 (SS2)	882 (SS6)	495	266	138	1.86
Pb	95.0 (SS2)	2525 (SS7)	1387	1017	0.05	1.36
Cr	753 (SS1)	2935 (SS6)	1674	827	700	2.02

The decreasing order in the quantitative trend of the metal content in both the vegetation and soil samples indicate a certain measure of similarity between the different sets of samples. This similarity is expected since heavy metals from soil enter plants primarily through the root system. The similarities in the trend suggest some level of relationship in the plants uptake of elements from soil (Bell, 1992). In an attempt to understand this relationship, the Pearson correlation coefficient, r, was used to establish the relationship between the concentrations of corresponding metals evaluated from the soil and plant samples. Tables 3 and Table 4 show the correlation coefficient between pairs of metal in soil and pairs of metal in plant and inter-element correlation between metals in soil/plant.

Table 3: Pearson correlation coefficient between (r) pairs of heavy metals in soil and pairs of metals in plant samples.

Correlation between metals	r value
Correlation in plant	Ni/Fe +0.945
	Cr/Co +0.932
	Fe/Cr +0.753
	Ni/Cr +0.877
Correlation in soil	Fe/Cr +0.857
	Co/Cr +0.857
	Pb/Co +0.821

Table 4: Inter-element correlation between soil and plant samples

Correlation between metals	r value
Ni veg/Fe soil	+ 0.259
Cr veg/Co soil	- 0.295
Fe veg/Cr soil	-0.281
Ni veg/ Cr soil	- 0.340
Pb veg/ Co soil	- 0.080

A significant correlation could be seen in Table 3 for metal pairs. This implies that these metals originate from the same polluting source. Table 4 however showed a negative correlation for metal pairs except for Ni veg./Fe soil. The negative correlation results give a strong suspicion to the fact that some elements might be assimilated through other organs of the plants other than their roots or some plants may have high affinity of assimilation of some elements directly from atmospheric deposition. Another good reason might be due to the fact that only the upper layer (a soil horizon) of soil was sampled. It is important to note that no other industrial facility exist in the study area, however, the irregular distribution of metals in samples could be due to traffic of vehicles and specially trucks, operating within the proximity of the steel rolling mill. The trucks operating around the factory include the factory's own which transport materials to be used for producing steel and trucks that transport discarded metal materials to the factory that indiscriminately around the factory. In the cause of operations of these vehicles around the steel rolling mill, metal distribution into the soil and atmosphere may come about through the spread of metal chippings on the soil and plant, exhaust fumes from vehicles and stack of the factory chimney are not left out from this pollution saga.

The soil and plant data obtained were used in explaining sources of environmental contamination of heavy metals. The plant concentration factor calculated as

Plant concentration factor (PCF) = C plant/C soil, according to Cui *et al*. (2005),
Where,
C plant is the concentration of the metal in plant
C soil is the concentration of the metal in soil.

The PCF for this study is as shown in Figure 2. The Figure explains the absorption of heavy metals in soil by plants to be in the order Cr>Ni>Fe>Co>Pb.

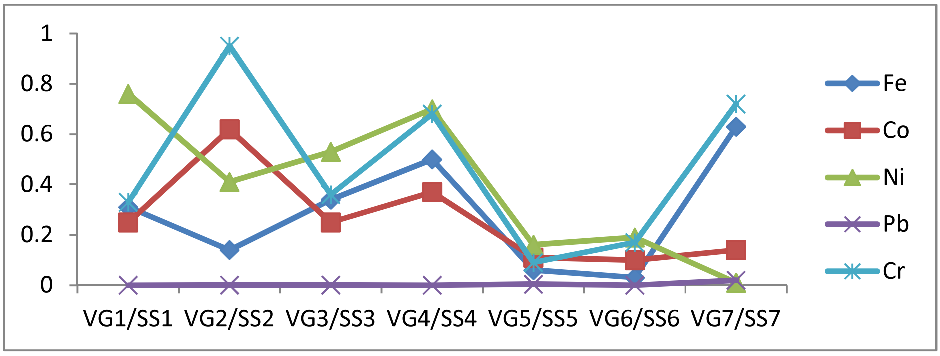

Figure 2: Plant concentration factor for metals in study area

This signifies that the plant absorbs a higher concentration of Cr from the soil compared to other metals and Pb is the least absorbed and this result agrees with Table 1.

The integrated pollution index of heavy metals in soil was calculated using IPIn = Cn/ Bn according to Chen *et al*. (2005) and Wei *et al*. (2009) as shown in Table 5.

Where Cn = concentration of element in the environment
Bn= background value according to CEPA (1995)
IPI was classified as:
IPI<1 low level of pollution; 1<IPI< 2 moderate level of pollution; 2<IPI<5 high level of pollution; IPI> 5 extreme high level of pollution (Chen *et al*., 2005; Wei *et al*., 2009).

Table 5: Integrated pollution index of soil of study area

Sampling point	Ni	Pb	Cr
SS1	4.70 (high)	0.81 (low)	3.76 (high)
SS2	4.54 (high)	0.32 (low)	4.04 (high)
SS3	8.90 (extreme high)	2.90 (high)	8.63 (extreme high)
SS4	8.44 (extreme high)	7.12 (extreme high)	7.04 (extreme high)
SS5	17.64 (extreme high)	4.69 (high)	12.2 (extreme high)
SS6	8.20 (extreme high)	8.12 (extreme high)	7.55 (extreme high)
SS7	2.75 (high)	8.42 (extreme high)	3.50 (high)

The IPI shows that Ni, Pb and Cr showed high to extreme high level of pollution except some sites where Pb was found to be low (SS1 and SS2) towards the gate of the factory and beside the fence. The IPI helps to understand the degree of pollution of each metal at a specific sit studied.

Table 6 illustrates the level of significant difference observed in the means of metals obtained for plants and soil of the study area and the control site. T-tests showed statistical significant differences in their means except lead that was not significant in plant.

Table 6: T-tests for metals in plants/soil sample and control site ($p< 0.05$)

Metal	t-test	P value	Level
	Plant		
Fe	9.1437	0.000001	Significant
Co	3.4220	0.0051	Significant
Ni	8.3468	0.000002	Significant
Pb	1.0001	0.3370	Not significant
Cr	4.3910	0.009	Significant
Soil			
Fe	3.8485	0.0023	Significant
Co	4.2580	0.011	Significant
Ni	3.5528	0.0040	Significant
Pb	3.6094	0.0036	Significant
Cr	3.1166	0.0085	Significant

RESEARCH IMPLICATIONS

The data generated can be used as base line for Environmental Impact Assessment since the industry just began operation. The soil of this industry is grossly polluted with nickel, lead and chromium which will invariably have a negative impact on nearby farmlands and river network around the vicinity. Motorists passing through this route are exposed to heavy fumes of these metals especially during production.

CONCLUSION

The identification and quantification of heavy metal sources as well as contamination status are important environmental scientific issues. Evaluation of soil and plant contamination was possible through the use of correlation analysis, plant concentration factor, integrated pollution index and t-tests. The high concentrations of the studied metals clearly indicate that the major source of pollution comes from the activities occurring in the steel rolling mill and were anthropogenic. It is advisable that future steel industries should be sited far away from the major roads where many passers-by will inhale these pollutants. The human body is of a complex structure; therefore, the accumulation of metals can cause toxic effects, which can influence different mechanisms on the body. It is therefore advisable that:

1. There is need for replacing periodic studies (every two years) on the effect that the facility of the industry will have on the environment.
2. Monthly evaluation of the health status of the factory workers
3. Monitoring by state environmental agencies so as to check their operations and to protect the environment from hazardous pollutants.

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