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Distribution And Enrichment Of Heavy Metals In Soils From Waste Dump Sites Within Imoru And Environs, Southwest Nigeria

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Abstract

Soil samples from waste dump sites from Imoru and the towns around it were analyzed for their cadmium, chromium, copper, manganese, nickel, lead and zinc contents in order to determine the distribution and enrichment of these metals in the area. Results show the average metal content as Cd (1.18 mg/kg^{-1}), Cr (0.69 $mgkg^{-1}$), Cu (9.61 $mgkg^{-1}$), Mn (93.41 $mgkg^{-1}$), Ni (2.94 $mgkg^{-1}$), Pb (12.24 $mgkg^{-1}$) and Zn (78.82 $mgkg^{-1}$).Using Enrichment Factor (EF) the soils were classified as deficient to moderately enriched with Cd and Cr while they are deficient to minimally enriched with Cu, Mn, Ni and Zn. Calculated Geo-accumulation index (Igeo) shows the soil to be unpolluted to moderately polluted of all trace metals analyzed for. The C / P index places the soil as very slightly contaminated to slightly contaminated by Cr, Pb and Ni; severely contaminated to moderately polluted by Cd; and very slightly to severely contaminated with Cu. Generally, the average concentration of the trace metals are below international guideline values for environmental quality criteria.

Keywords: heavy metal, soil, enrichment factor (EF), geo-accumulation index (Igeo), contamination / pollution index

1. Introduction

In many cities of the developing countries, lack of proper waste disposal practices have been recognized as one of the major sources of anthropogenic pollution/contamination (Udueze, 2004). Pollutants from human and land use wastes dumped directly into the rivers in and around urban and rural centers have led to various levels of contamination and loss of the natural ecosystem in many areas (Ihenyen and Aghimien, 2002). Adaikpoh (2011) determined the contents of some trace elements in the soils within Ifon and environs and reported high mobility factor (bioavailabilty) of Cd in soils of some sites in Ifon area. This, as reported, poses a threat to the region. A common approach to determine how much the soil has been affected by heavy metal incursion is to calculate the Enrichment Factor (EF) for metal concentration above. uncontaminated background level (Huu *et al.*, 2010).

Enrichment Factor (EF)

The EF method normalizes the measured heavy metal content with respect to a reference sample such as Fe, Al or Zn (Mediolla et al., 2008). Pollution is measured as the amount or ratio of the sample metal enrichment above the concentration present in the reference station or material. The EF of a heavy metal in the soil is calculated as

EF = [Cmetal / Cnormalizer]soil / [Cmetal / Cnormalizer]control

where Cmetal and Cnormalizer are concentrations of heavy metal and normalizer respectively, both in the soil and in the control. Enrichment factor is used to differentiate between the contamination / pollution resulting from natural and anthropogenic sources as well as assessing the degree of anthropogenic influence. As the EF values increase, the contributions of the anthropogenic origin also increase (Suther, 2000). Contamination categories based on enrichment factor are as follows:

EF < 2 is deficiency to minimum enrichment

EF = 2-5 is moderate enrichment

EF = 5-20 is significant enrichment

EF = 20-40 is very high enrichment

EF > 40 is extremely high enrichment

Index of geo-accumulation (Igeo)

The degree of metal contamination or pollution in terrestrial, aquatic and marine environment can be evaluated using Index of geo-accumulation (Igeo) (Tijani and Onodera, 2009). The Igeo of a metal in the soil is calculated as thus:

$Igeo = \log_2 Cmetal / 1.5Cmetal\ (control)$

where Cmetal is the concentration of the heavy metal in the enriched sample and Cmetal (control) is the concentration of metal in the unpolluted sample or control. The factor 1.5 is introduced to minimize the effect of possible variations in the background or control values which may be attributed to lithogenic variation in the soil.

According to Huu et. al. (2010), seven contamination classes are used to define the degree of metal pollutants in soils based on the increasing value of the index of geo-accumulation as follows:

Igeo < 0 means unpolluted

$0 \leq$ Igeo <1 means unpolluted to moderately polluted

$1 \leq$ Igeo <2 means moderately polluted

$2 \leq$ Igeo <3 means moderately to strongly polluted

$3 \leq$ Igeo <4 means strongly polluted

$4 \leq$ Igeo <5 means strongly to verystrongly polluted

Igeo >5 means very strongly polluted

Contamination / Pollution Index

The contamination / Pollution index is as defined by Lacatusu, 2000.

C / P Index = Concentration of metals in soil / Target value

The target value is a reference value of metals as obtained using the standard table formulated by the Department of Petroleum Resources of Nigeria (DPR, 2002) for maximum allowable concentration of metals in the soil (Adaikpoh and Kaizer, 2012). The DPR target values considered here are: Cd (0.8 $mgkg^{-1}$); Cr (100 $mgkg^{-1}$); Cu (36 $mgkg^{-1}$); Ni (35 $mgkg^{-1}$); Pb (85 $mgkg^{-1}$); Zn (146 $mgkg^{-1}$) and Mn (437 $mgkg^{-1}$). C / P index values less than one define contamination ranges while values greater than one define pollution (Lacatusu, 2000) as thus ;

<0.1	Very Slight contamination
0.10 -0 .25	Slight contamination
0.26 - 0.50	Moderate contamination
0.51 – 0.75	Severe contamination
0 .76 – 1.00	Very severe contamination
1.1 – 2.0	Slight pollution
2.1 -4.0	Moderate pollution
4.1 – 8.0	Severe pollution
8.1 – 16.0	Very severe pollution
> 16	Excessive pollution

Soils in any area are repositories of heavy metals generated through natural processes or anthropogenetic sources. At low concentration, heavy metals in plants and animals may not be toxic (except for Lead, Mercury and Cadmium that are toxic at very low concentration). At high concentrations heavy metals become toxic and a threat to biotic systems. It is therefore very necessary to monitor the levels of heavy elements in soils within areas with fast growing population/urbanization. All indices discussed are used to determine the enrichment and contamination status of the soils in the study area. Results here will serve as baseline data for future monitoring of contamination/pollution due anthropogenic effects.

1.1 Study Area

Imoru and its environ are within the interior coastal lowland of southwestern Nigeria (Figure 1).

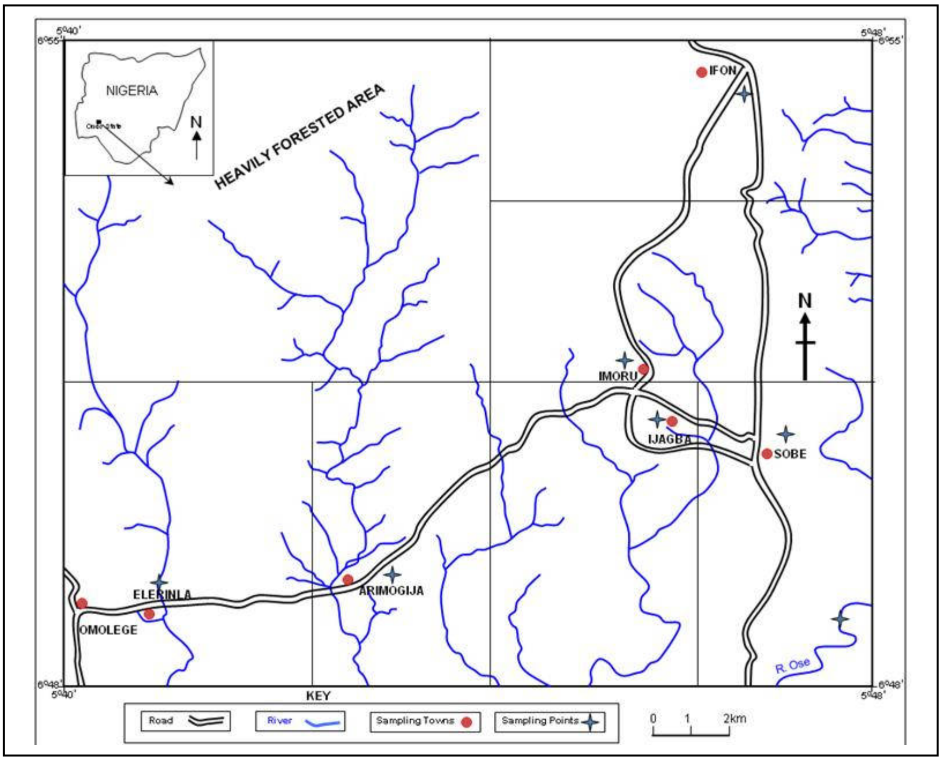

Figure 1: Map of study area and sample locations

The study area is located in the southwestern part of Ondo State in Ose local government area of Nigeria (latitude $6^0\ 50^1$ -$6^0\ 55^1$ N and longitude $5^0\ 30^1$ E - $5^0\ 45^1$ E). The area is of the tropical hinterland climate of Nigeria (Emielu, 2000). It comprises of two main distinct seasons; the dry and the wet season. Two major seasonal air masses determine the climate of the area. The moisture laden south western wind (Tropical Maritime air mass) is responsible for the several months of rainfall (April – October) while the dry northeastern wind (Tropical continental air mass) brings about the dry season (November – March), which is usually accompanied by a dry cold harmattan wind which prevails during the months of December and January (Udo, 1975). During the rainy season, up to 200m of rainfall may be experienced in the coastal areas of the south, diminishing to 150m in the hinterland. The annual mean temperature is about 27°C (Emielu, 2000). The vegetation type that prevailed in this region is the mangrove forest type and is associated with sub-equatorial rainforest which is characterized by dense vegetal growth with a mixture of palm trees, bamboo, etc.

The terrain is generally gently sloping with altitude ranging between 100 – 300m above sea level (Emielu, 2000). Drainage in the area is essentially relief controlled with low lying to high rising lateritic ridges. The main rivers (River Ose and River Owan) flow northeast – southwest.

The area has a rural community with dispersed settlement. It is sparsely populated. According to the National Population Commission results (1991), the population is about 4,063. This has increased, according to the census data of March, 2006 to 144,139. The settlement is linear along the major road where some of the inhabitants are engaged in petty trading and subsistence agriculture. The area is underdeveloped and lacks basic infrastructures such as hospitals, public water supply, regular power supply etc. Accessibility of the people to health facilities is of great concern because they lack well equipped health centers. The geology of the area is that of a sedimentary basin with sandstone being overlain by shale and laterite. It has being described by Reyment (1965), Adekoke (1977) and Adaikpoh (2011).

2. Method of study

2.1. Sampling method

Sediment samples were collected randomly from seven towns - Imoru and others around it (Table 1) at depth range of 0-30 cm, with the aid of a stainless steel iron cover and stored in black polythene bags for laboratory analysis.

2.2. Analysis Procedure

The samples were first air-dried and later thoroughly homogenized using agate mortar and pestle. The partial extraction method was applied by weighing one gram of each sample into washed glass beakers, and the samples digested by adding 20 cm^3 of aqua-region (mixture of HCl and HNO_3 at a ratio of 3:1) and 10 cm^3 of 30% of hydrogen peroxide (H_2O_2). The H_2O_2 was introduced in small proportions to avoid any possible overflowing, which may lead to loss of materials (soil) from the beaker. These samples were then covered with wash glasses and heated over hot plate to about 90^0C (near boiling point). They were then filtered hot, so as to separate the insoluble solids. These solid parts were then rinsed with hot HNO_3 after which the final dilution was made with distilled de-ionized water. All the samples were then stored in plastic containers and refrigerator until they were subjected to Atomic Absorption Spectrophotometry (AAS) method of analysis. The metals determined were Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Manganese (Mn), Nickel (Ni) and Zinc (Zn).

3. Results

The results are presented in Tables 1-4 and Figures 2-8.

Table 1. Contents of sampled metals of soils in Imoru and Environs ($mgkg^{-1}$)

Sample site/Number	**Cd**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**
Ifon (N=8)							
Mean	1.88	1.30	23.24	133.48	5.70	24.35	136.00
	±1.07	±0.63	±5.58	±28.23	±0.82	±5.44	±6.62
Lowest	<0.001	0.02	<0.001	23.12	3.76	4.86	25.22
Highest	2.30	1.56	29.66	167.44	6.43	32.48	147.36
Imoru (N=8)							
Mean	1.20	0.30	12.12	116.07	3.60	18.85	143.08
	±0.61	±0.11	±5.77	±42.61	±2.65	±9.33	±51.66
Lowest	<0.001	0.27	4.01	13.96	1.04	11.86	65.09
Highest	1.42	0.40	18.53	162.62	6.14	21.47	158.32
Sobe (N=8)							
Mean	1.63	0.90	15.60	151.04	3.90	15.60	124.80
	±0.58	±0.73	±5.11	±32.58	±2.90	±6.54	±25.67
Lowest	0.21	0.52	8.65	98.32	2.18	12.33	90.28
Highest	1.98	1.40	16.73	176.40	5.33	18.80	133.65
Ijegba (N=7)							
Mean	0.84	0.60	3.82	37.98	1,70	5.60	23.40
	±0.66	±0.44	±0.61	±5.48	±1.75	±2.53	±4.77
Lowest	0.43	0.02	2.21	23.21	1.21	4.21	20.81
Highest	1.56	0.83	3.98	48.65	1.98	11.48	31.77
Elerinla (N=7)							
Mean	1.52	0.50	4.10	68.08	2.70	11.95	40.40
	±0.32	±0.41	±0.18	±10.18	±2.18	±3.54	±6.13
Lowest	1.08	0.30	3.36	21.92	2.34	6.18	31.11
Highest	1.66	0.56	4.33	71.05	4.52	14.55	49.94
Omolege (N=8)							
Mean	0.53	0.61	4.90	64.24	1.46	4.16	38.20
	±0.48	±0.44	±3.68	±39.32	±072	±1.53	±10.50
Lowest	<0.001	0.48	1.22	15.76	1.38	2.12	36.74
Highest	0.61	0.96	8.15	78.27	1.66	4.65	51.22
Arimogija (N=8)							
Mean	0.52	0.27	2.33	68.86	1.50	5.18	41.80
	±1.27	±0.47	±0.32	±26.32	±0.77	±2.81	±8.32
Lowest	<0.001	0.08	1.62	53.43	1.08	1.65	37.41
Highest	1.86	0.64	3.48	82.50	2.40	9.37	48.20
Study Area :							
Mean (N=64)	1.18	0.69	9.61	93.41	2.94	12.24	78.82
Lowest	<0.001	0.30	1.22	13.96	1.04	1.65	20.81
Highest	2.30	1.56	29.66	176.40	6.43	32.48	158.32

Table 2. Enrichment factor of trace metals in soil sample from Ifon, Imoru, Sobe, Elerinla and Omolege waste dump sites.

Metal	Ifon	Imoru	Sobe	Elerinla	Omolege
Cd	0.64	0.47	0.49	2.96	1.09
Cr	0.61	0.16	0.38	1.87	2.42
Cu	1.73	1.04	1.03	1.78	2.25
Mn	1.00	1.00	1.00	1.00	1.00
Pb	0.03	0.02	0.02	0.01	0.005
Ni	0.002	0.001	0.001	0.001	0.0004
Zn	0.63	0.76	0.51	0.001	0.36

Table 3. Index of Geo-accumulation (Igeo) of trace metals in soil sample from Ifon, Imoru, Sobe, Elerinla and Omolege waste dump sites.

Town	Cd	Cr	Cu	Mn	Pb	Ni	Zn
Ifon	0.72	0.42	0.79	0.12	0.55	0.98	0.20
Imoru	0.21	-1.93	0.70	0.12	0.50	0.73	0.20
Sobe	0.56	-0.17	0.69	0.13	0.47	0.77	0.20
Elerinla	0.77	-2.43	0.58	0.06	0.46	0.64	0.08
Omolege	-1.17	-1.73	0.65	0.06	0.27	0.24	0.08

Table 4. Contamination / pollution (C/P) index value (Target = DPR Values)

Metal	Ifon	Imoru	Sobe	Ijegba	Elerinla	Omolege	Arimogija
Cd	2.35	1.50	2.04	1.58	1.90	0.67	0.65
Cr	0.013	0.003	0.009	0.006	0.005	0.005	0.006
Cu	0.65	0.28	0.43	0.11	0.11	1.36	0.01
Mn	0.31	0.27	0.35	0.09	0.16	0.15	0.16
Pb	0.29	0.22	0.18	0.07	0.14	0.05	0.06
Ni	0.16	0.10	0.11	0.05	0.08	0.04	0.04
Zn	0,93	0.98	0.92	0.17	0.30	0.28	0.31

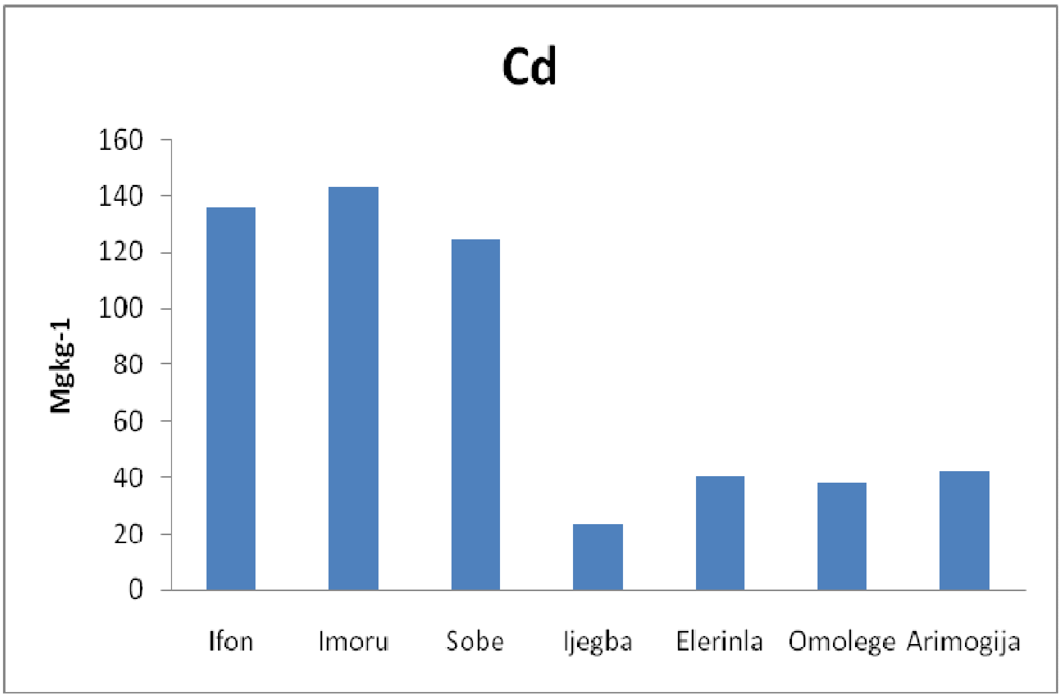

Figure 2. Mean concentration of cadmium for different towns

The average Cadmium content in the soils examined is 1.18 mg/kg^{-1} and ranges from <0.001 – 2.30 $mgkg^{-1}$ in the soil samples (Table 1). The average concentration for soils of each town is plotted in figure 2. These are within the natural limits of 0.01-3.0 mg/kg in soil as given by EC (1986) and MAFF (1992). The EF for Cd of soils from Elerinla is 2.96 (Table 2) indicating moderate enrichment while soils from other towns have EF for Cd less than 2 showing deficiency to minimum enrichment of Cd in the soil. The Igeo of Cd ranges from -1.17 in Omolege to 0.77 in Ifon (Table3), interpreted as unpolluted to moderately polluted. The C/P index ranges from 0.65 in Arimogija to 2.35 in Ifon (Table 4) indicating severe contamination to moderate pollution.

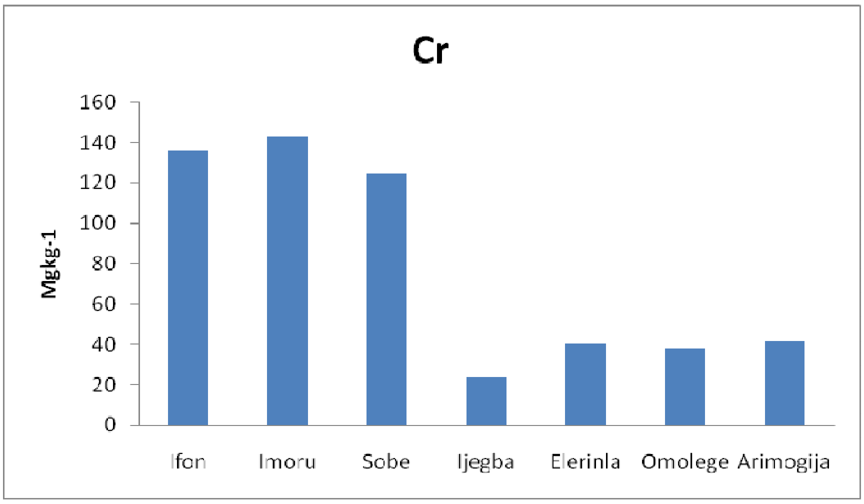

Figure 3. Mean concentration of chromium for different towns

According to Jung et al., 2006, sources of Cr in the soils could be due to waste consisting of lead-chromium batteries, coloured polythene bags, discarded plastic materials and empty paint containers. The average concentration of Cr in soils of Imoru and environ is 0.69 $mgkg^{-1}$ and ranges from 0.30 – 1.56 $mgkg^{-1}$ in the soil samples. The average for each town is plotted in figure 3. These are lower than the critical permissible level which is 50mg/kg for soil recommended for agriculture by EC (1986) and MAFF (1992). The EF range from 0.16 – 2.42 in Ifon. showing that the samples fell within the class of deficiency to minimal enrichment –

moderate enrichment. The Igeo of Cr ranges from -2.43 in Elerinla to 0.42 in Ifon (Table3), interpreted as unpolluted to moderately polluted. The contamination/pollution index obtained for Cr ranged from 0.003 – 0.013 indicative of very slight to slight contamination.

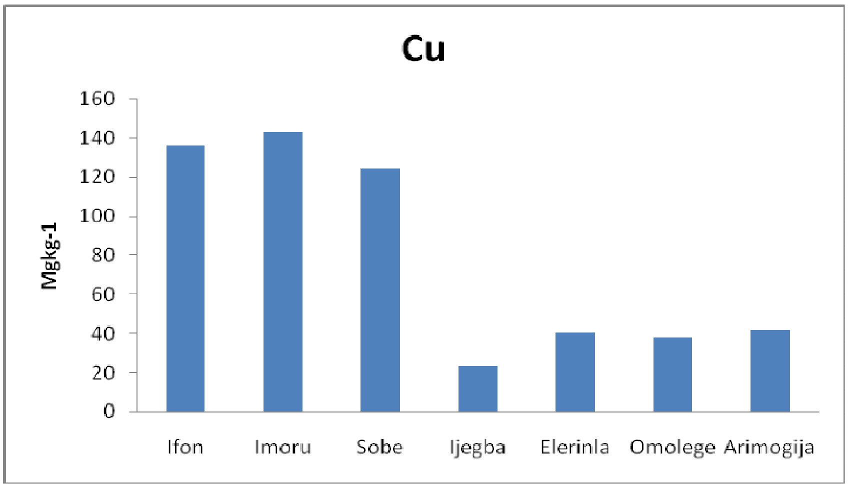

Figure 4. Mean concentration of copper for different towns

The average copper content in the soil is 9.61 $mgkg^{-1}$ and its concentration range is 1.22-29.66 (Table 2). The content for each town is as presented in figure 4. The EF of Cu ranged from 1.03 (in Sobe) to 2.25 (in Omolege) showing deficiency to minimum enrichment in the soil. The Igeo ranged from 0.58 to 0.79 interpreted as unpolluted to moderately The normal threshold value prescribed in soil is 30 $mgkg^{-1}$ and copper normally accumulates in the surface horizons (Kabata- Pendias, 2004). polluted. The C/P index ranged from 0.01 (Arimogija) – 0.65 (in Ifon) indicating very slight contamination to severe contamination. This shows that copper is of low concentration in the soil.

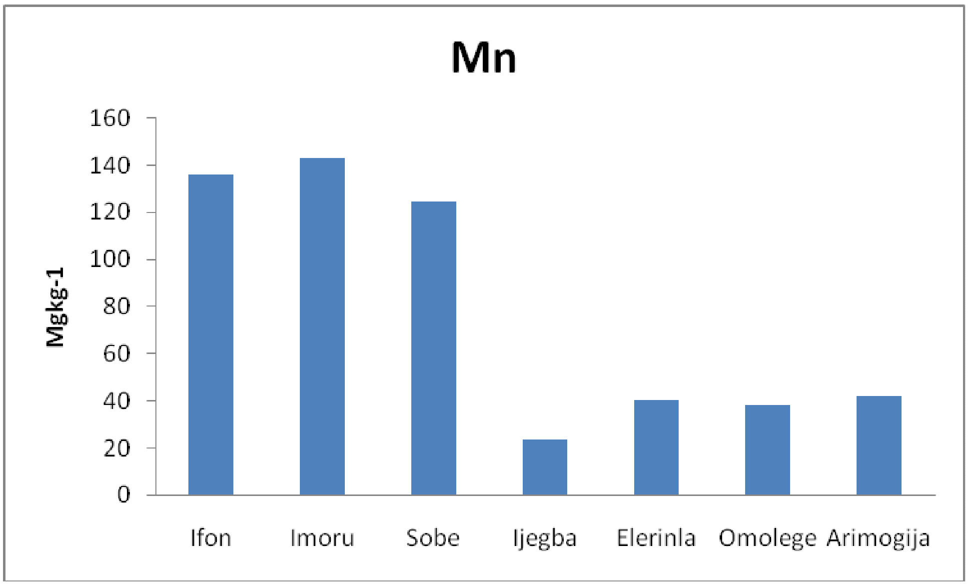

Figure 5. Mean concentration of manganese for different towns

The average concentration of Manganese in the soils is 93.41 $mgkg^{-1}$ and ranges from 13.46 – 176.40 mg/kg^{-1} (Table 2). The content in each town is present in figure 5. It has an EF of unity although indicating crustal origin and falls into the category of deficiency to minimal enrichment. The Igeo ranges from 0.06 to 0.12 translating to unpolluted to moderately polluted soil. The C/P value ranges from 0.09 in Ijegba to 0.35 in Sobe, is very slight contamination to moderate contamination.

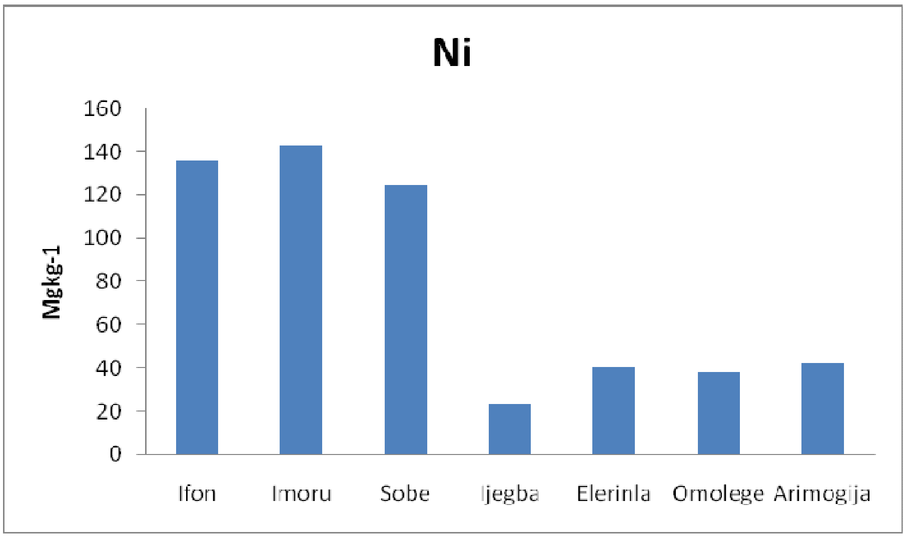

Figure 6. Mean concentration of nickel for different towns

The average concentration of Nickel in the soils is 2.94 $mgkg^{-1}$ and ranges from 1.04 – 6.43 mg/kg^{-1} (Table 1). The content in each town is ploted in figure 6. Nickel in soil is usually present in the organically bound form, which under acidic and neutral conditions increases its mobility and bio availability (Kabata – Pendias and Pendias 1999). The EF value ranges from 0.0.0004 in Omolege to 0.02 in Ifon (Table 2) which falls under the deficiency to minimal enrichment category and the C/P index ranging from 0.04 – 0.16 (very slight contamination – slight contamination). The Igeo for Nickel ranges from 0.24 – 0.98 (Table 3) showing unpolluted to moderately polluted soil.

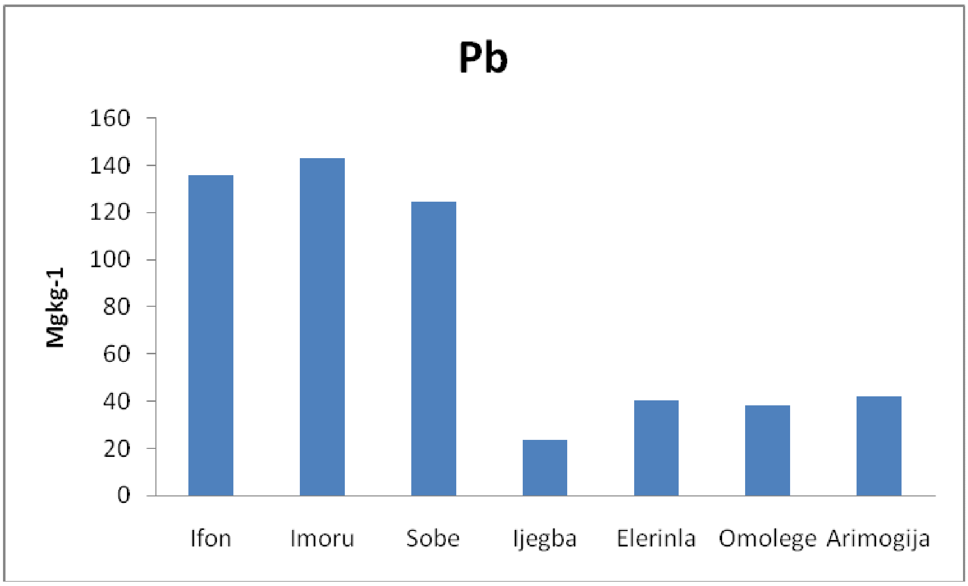

Figure 7. Mean concentration of lead for different towns

Lead in the soils of the study area could be from automobile exhaust fumes as well as dry cell batteries, sewage effluents, runoff of wastes and atmospheric depositions. The average concentration of Lead in the soils sample is 12.24 $mgkg^{-1}$ and ranges from 1.65 – 32.48 mg/kg^{-1} (Table 1). The content in each town is present in figure 7. These values are lower than EU (1986) upper limit of 300 mg/kg and the maximum tolerable levels proposed for agricultural soil, 90-400 mg/kg set by WHO (1993). The EF value ranges from 0.0.005 in Omolege to 0.03 in Ifon (Table 2) which falls under the deficiency to minimal enrichment category with the C/P index ranging from 0.05 – 0.29 (very slight contamination – moderate contamination). The Igeo for Lead ranges from 0.27 – 0.55 (Table 3) showing unpolluted to moderately polluted soil

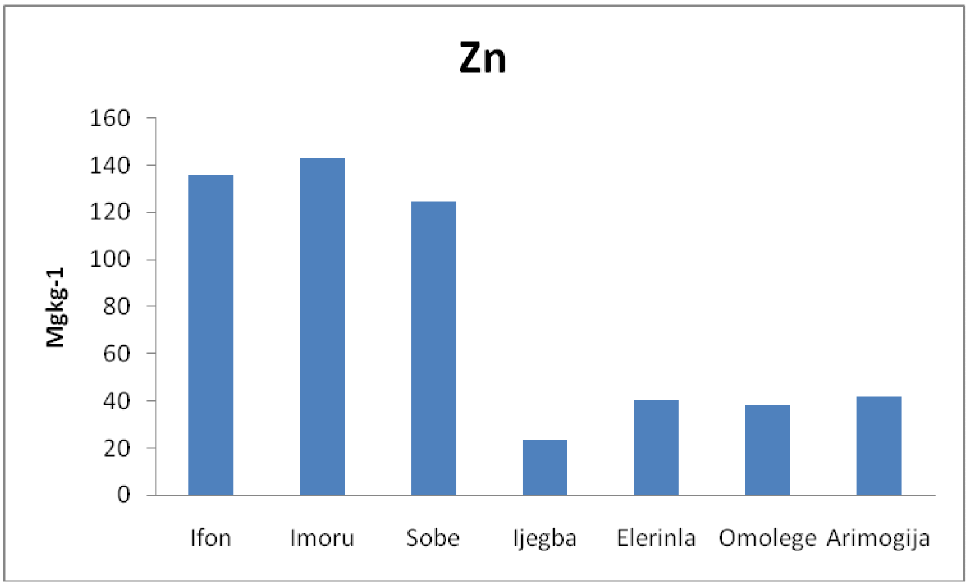

Figure 8. Mean concentration of zinc for different towns

Zinc belongs to a group of trace metals, which are essential for the growth of humans, animals and plants and are potentially dangerous for the biosphere when present in high concentrations. The average concentration of zinc in the soils sample is 78.82 $mgkg^{-1}$ and ranges from 20.81 – 158.32 mg/kg^{-1} (Table 1). The content in each town is present in figure 8. The main sources of pollution are industries and the use of liquid manure, composted materials and agrochemicals such as fertilizers and pesticides in agriculture (Gowd et al., 2010). The EF value ranges from 0.001 in Omolege and Elerinla to 0.76 in others (Table 2) which falls under the deficiency to minimal enrichment category and the Igeo ranges from 0.08 – 0.98 (Table 3) showing unpolluted to moderately polluted soil. The C/P index for zinc ranging from 0.28 in Omolege to 0.98 (moderate contamination – very severe contamination).

4. Conclusion

Soils from Imoru and environs have average metal content as Cd (1.18 mg/kg^{-1}), Cr (0.69 $mgkg^{-1}$), Cu (9.61 $mgkg^{-1}$), Mn (93.41 $mgkg^{-1}$), Ni (2.94 $mgkg^{-1}$), Pb (12.24 $mgkg^{-1}$) and Zn (78.82 $mgkg^{-1}$).Using Enrichment Factor (EF) the soils were classified as deficient to moderately enriched with Cd and Cr while they are deficient to minimally enriched with Cu, Mn, Ni and Zn. Calculated Geo-accumulation index (Igeo) shows the soil to be unpolluted to moderately polluted of all trace metals analysed. The C / P index place the soil as very slightly contaminated to slightly contaminated by Cr, Pb and Ni; severely contaminated to moderately polluted by Cd; and very slightly to severely contaminated of Cu. Generally, the average concentration of the trace metals are below international guideline values for environmental quality criteria. For those soils that were defined generally as unpolluted to moderately polluted by some metals by the Igeo, the C / P index further gave finer sub- groups (eg. very slightly contaminated to slightly contaminated levels). The concentration of Cd, Cr, Cu, Mn, Ni, Pb and Zn are all within tolerable levels hence the area can be used for agricultural and recreational purposes.

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