METAL CONTAMINATION AT DUMP SITES IN MAKURDI, NIGERIA

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ABSTRACT

This study has focused on the investigation of metal contamination by refuse dumps in Makurdi, Nigeria. Soil samples were collected from 17 dump sites and also from a forest to serve as control. Samples were pretreated, digested by aqua regia and the resulting solution analyzed for Fe, Zn, Cu, Pb and Cd using atomic absorption spectrophotometer (AAS). Result shows that the range of iron was 120-440ppm; zinc 100-260ppm; copper 16-201ppm; lead 10-115ppm and cadmium 2-30ppm ; in soil from refuse dump sites while forest soil has a range of 120 - 300ppm for iron, 25-150ppm for zinc, 20-50ppm for copper, 7-31ppm for lead and 0.5 - 3.5ppm for cadmium. The significant difference between result obtained for refuse dump sites and the forest soil indicates that refuse dump sites most probably represent point sources of metal contamination to nearby environment. This study also examined metal mobility with 0.1M HCl solution. Result shows that extraction rates (mobility) were in the order Zn>Cd>Cu>Pd>Fe which may be due to differences in geochemical behaviour of metals in the soil. Finally the concept of pollution index (PI) of soils was applied to determine the extent of multi-element contamination caused by refuse dumps.

KeyWords: Extraction rate, Makurdi, metal contamination, pollution index, refuse dumps.

INTRODUCTION

Since the biogeochemical behavior of heavy metals is very complex, only those metals, which are also, valuable micronutrients (Fe, Mn, Zn, Cu, B, Mo and Cl) were given extensive attention in the past. In recent years, however, increasing attention has been on toxic heavy metals, which have been recognized as great potential health hazard (Page and Bingham, 1973).

A survey of heavy metals indicates that they have accumulated in various media in some localized area of human activities as compared to areas that have remained under virgin condition (Smith, 1989). This anomalous accumulation seems to derive from industrial and waste disposal dumps (Chon et al., 1997); accidental spillage (Tiller, 1992); agricultural activities (Wong, 1996); auto-traffic (Lau, 1994); mining and smelting (Hammer, 1998) as well as the geology of the area (Thornton and Plant, 1980).

A typical refuse dump in Nigeria comprises plastics, garbage, tins, motor machine parts, rags and textiles, wood, dry-cell batteries, papers, raw sewage (including urine and excreta), ash etc. The frequent burning of the garbage on the dump sites tends to get rid of the organic materials leaving the ash, which is richer in metal content. All these materials contain some heavy metals, which could be released in the environment through such process as precipitation, oxidation, and corrosion. Once released, the heavy metals could be leached into the soil where they may be

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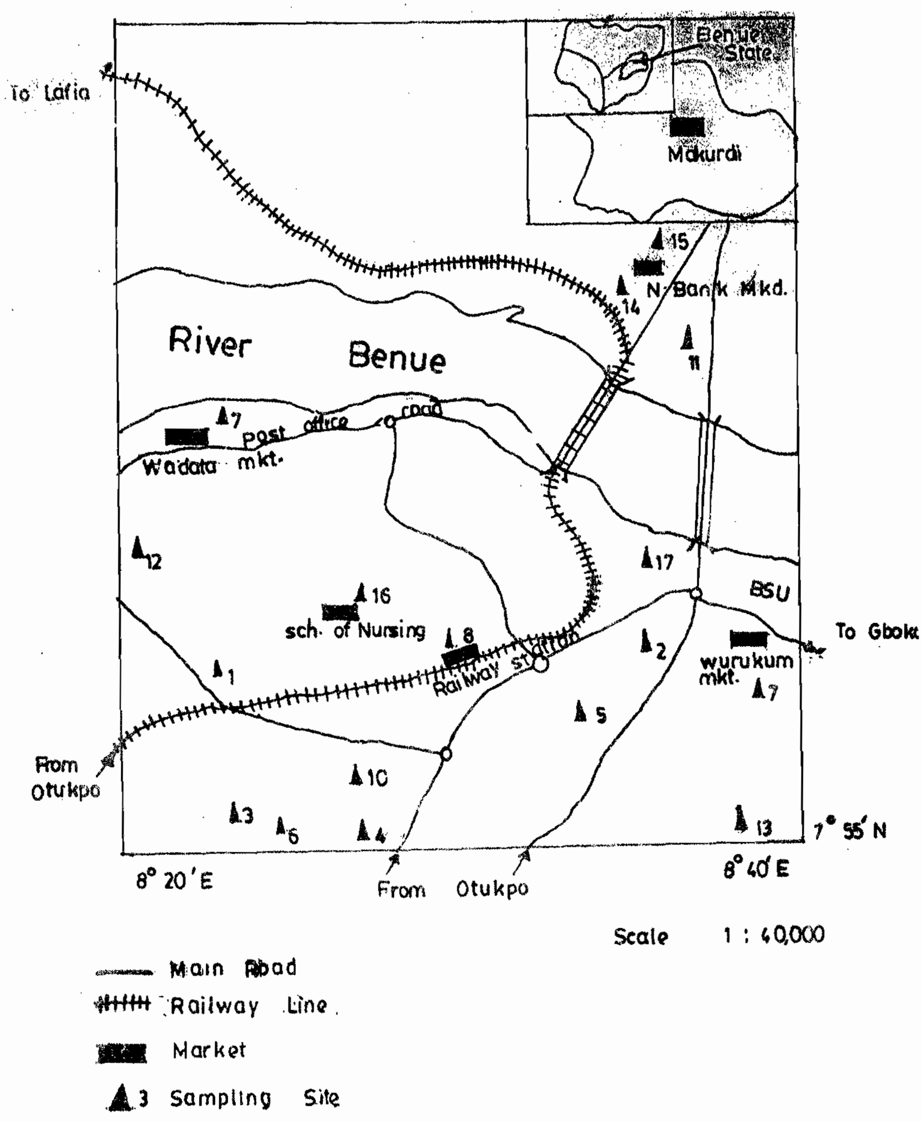

Fig. 1 Sampling Location of refuse lump sites in Makurdi, Nigeria. Insert: Location map of study area.

absorbed by growing plants or make their way into the drainage system thereby heightening the potential for their introduction into food chains and subsequent increased dietary exposure to consumers thereby causing health risks (Smith, 1996). One striking feature of these heavy metals on the biosphere is that their effects are cumulative or assiduous. Thus by the time the effect becomes manifest, a lot of harm, which is often irreversible has been done.

Table 1: The Mean and Range[a] concentrations (ppm) of analysed metals in refuse dump soils and forest soils together with the ranges of their mean abundance[b] commonly found in soils.

S. No.	LOCATION	N	Fe	Zn	Cu	Pl	Cd
1	Railway By-pass	3	256 (150-310)[a]	128 (120-136)	87 (60-101)	32 (20-40)	21 (18-30)
2	Ageshi	3	225 (140-390)	162 (126-211)	191 (91-201)	23 (19-31)	10 (7-15)
3	Nr Shan Hotels	3	296 (170-400)	220 (180-260)	42 (16-60)	34 (20-50)	18 (13-27)
4	B.Division	2	300 (200-400)	120 (110-130)	103 (100-106)	81 (47-115)	8 (7-9)
5	Wurukum NKST CH.	5	265 (200-360)	196 (110-230)	40 (32-50)	73 (60-80)	9 (5-15)
6	Idye	4	241 (201-280)	182 (121-201)	26 (18-40)	26 (17-31)	13 (10-23)
7	Wurukum Market	5	198 (190-251)	173 (57-260)	89 (60-100)	46 (36-56)	16 (13-20)
8	Railway Station	3	272 (120-307)	200 (133-231)	76 (20-100)	84 (38-102)	7 (3-15)
9	Wadata Market	3	260 (200-300)	215 (200-230)	104 (89-196)	35 (10-60)	5 (2-10)
10	High level Market	4	279 (250-300)	164 (140-180)	36 (30-60)	15 (10-20)	6 (5-8)
11	Kaltungu	3	251	157	23	104	8

			(200-300)	(140-180)	(20-30)	(60-115)	(4-12)
12	Modern Market	5	299 (250-350)	125 (100-150)	73 (60-85)	30 (12-49)	4 (2-6)
13	Logo 1	3	277 (230-300)	173 (150-190)	56 (40-70)	31 (19-50)	3 (2-4)
14	North Bank Market	5	236 (220-240)	160 (140-180)	93 (73-129)	28 (20-40)	10 (5-20)
15	Lafia park	3	264 (230-300)	108 (120-170)	87 (69-101)	31 (24-60)	14 (10-20)
16	Off Balewa Crst.	2	130 (120-140)	201 (148-254)	74 (48-100)	42 (28-54)	2 (2-2)
17	Head Bridge	4	234 (230-250)	198 (190-200)	140 (120-160)	52 (40-70)	6 (4-10)
18	Forest	10	171 (120-300)	85 (25-150)	34 (20-50)	20 (7-31)	2 (0.5-3)
19	World average abundances of soil[b]	-	1-2.1%	36-100	20-50	17-30	0.1-0.5

N = Number of samples

a = range values in parenthesis

b = cited from Rose et al (1979).

The objectives of this study are therefore to investigate the extent and degree of metal contamination of surface soil in refuse dump sites in Makurdi, Nigeria and to determine the mobility (extraction rate) of some heavy metals in the wastes.

MATERIAL AND METHODS

Surface soils were sampled in and around 17 refuse dumps in Makurdi, Nigeria while control samples was collected from a forest about 10km from Makurdi (Fig.1). The samples were dried at room temperature for 72 hrs and sieved through 80-mesh nylon sieves in to plastic bottles. 0.5g of each sample was weighed into a beaker and digested with aqua-regia (1:3 mixture of concentrated HNO_3 and HCl; vol: vol) and leached with 5ml of concentrated 6M HCl into already calibrated test tube, and made up to 10ml mark with deionised water. Concentrations of Fe, Zn, Cu, Pb and Cd were determined by using atomic absorption spectrophotometer (ASS Buck Model 210). In order to examine the potential mobility of heavy metals, partial extraction by 0.1M HCl a scheme modified from Davidson et al., (1994) was applied to the soil samples from refuse dumps. The resulting solution was subsequently analysed for Fe, Zn, Cu, Pb and Cd also using AAS.

RESULTS AND DISCUSION

The result of the heavy metal analyses of the soil sample is presented in table 1. They are statistical summary showing the mean and range of the values for the analysed heavy metals for each of the sampled location showing in figure 1 together with the range of world mean abundances (Rose et al., 1979) for each metal in soils.

The content of iron, which ranged between 120-400ppm at the dump sites, was not much different from range values of 120-300pp, obtained from forest soil. In addition, these are within the range of world mean abundances of iron given by Rose et al., 1979). These values most probably reflect the general abundances of iron in all environmental system (Cox, 1995). On the other hand, the values for Zn, Cu, Pb and Cd with ranges of 100-260ppm, 16-201ppm, 10-115ppm and 2-30ppm respectively for refuse dumps were higher than values of 25-150ppm, 20-50 ppm, 7-31 ppm and 0.5- 3.2ppm respectively obtained from forest soils. In addition, their concentrations in soil from refuse dumps were also higher than the ranges for world mean abundances in soil compiled by Rose et al., (1979). This implies that the surface soils at and within refuse dumps in Makurdi are contaminated in Zn, Cu, Pb, and Cd. These metals are obviously sourced from materials, such as scraps, garbage and ash, from the dump sites. The processes of oxidation and corrosion tend to decompose the materials and to release metals. The metals are then leached into the soils during heavy precipitation (Chon, et al., 1997). The variations in metals contents with dump sites could be attributed to variation in composition of materials at the dump sites and to the degree and extent to which the refuse is affected by processes of decomposition outlined above.

Soils sampled at refuse dump sites were extracted by 0.1M HCl and analysed for Fe, Zn, Cu, Pb and Cd (Table 2a) and the extraction rate of metals (metal concentration in soil extracted by 0.1M HCl divide by those extracted by aqua-regia x 100%) were computed. The results are presented in table 2b. High extraction rates are associated with ease of solubility and therefore, high mobility (Davidson, et al., 1994).

The extraction rates of the metals (Table 2b) follow the sequence; Zn>Cd>Cu>Pb>Fe. Zinc and Cd had relatively high extraction rates and ranged from 15.6-40% and 10.0-33.3% respectively. Cu had moderate extraction rates and ranged from 5 – 12%. While Pb and Fe showed low extraction rates with ranges of between 0.8-6% and 0.7-3% respectively. This implies that Zn, Cd and Cu are easily dispersed hydromorphically unlike Pb and Fe, which reflects differences in the solubility of the metals in the oxidizing environment. Cox (1995) revealed that

TABLE 2a. Mean concentrations (ppm) of analysed metals measured in solution after leaching with 0.1M HCl.

S.No	Location	N	Fe	Zn	Cu	PL	Cd
1	Railway By-pass	3	6	33	9	1	4
2	Ageshi	3	4	41	15	1	3
3	Nr Shan Hotels	3	9	64	3	1	3
4	B.Div.	2	3	31	10	8	2
5	Wurukum NKST C.	5	3	51	5	7	9
6	Idye	4	4	51	3	0.4	2
7	Wurukum Market	5	4	36	9	1	5
8	Railway Station	3	4	60	7	2	0.7
9	Wadata Market	3	4	49	7	0,4	0.7
10	H-Level Market	4	4	66	3	0.1	2
11	Kaltungu	3	4	36	2	8	2
12	Modern Market	5	5	27	5	0.4	0.6
13	Logo 1	3	6	22	7	0.6	0.4
14	N. Bank Market	5	2	29	9	2	2.5
15	Lafia Park	3	2	20	7	1	3
16	Off-Bal. Crst.	2	2	80	4	2	0.6
17	Head Bridge	4	3	41	7	1.0	1.0

Table 2b. Extraction rates (%) of analysed metals in soils from refuse dumps in the study area and pollution index (PI) values of the metals for each sampled dump site.

S.No	Location	Fe	Zn	Cu	Pb	Cd	PI
		Extraction rates of metals (%)					
1	Railway By-pass	2.3	26.0	10.0	3.0	20.0	2.20
2	Ageshi	1.7	25.0	8.0	4.0	20.0	1.42
3	Nr. Shan Hotel	3.0	29.0	7.0	8.0	19.0	1.54
4	B. Div	0.9	25.5	10.0	1.0	25.0	1.23
5	Wurukum Nkst ch.	1.2	26.2	12.0	1.0	25.0	1.20
6	Idye	1.8	28.1	13.0	1.5	16.0	1.28
7	Wurukum Market	2.1	21.0	10.0	2.0	30.8	1.73
8	Railway Station	1.5	30.0	9.0	2.0	10.6	1.14
9	Wadata Market	1.6	22.8	7.0	1.2	14.0	0.86
10	Highlevel Market	1.5	40.0	8.0	0.9	33.3	0.76
11	Kaltungu	1.5	23.1	7.0	0.8	25.0	1.12
12	Modern Market	1.7	15.6	8.0	1.2	21.3	0.61
13	Logo 1	1.9	17.8	10.0	2.0	10.0	0.69
14	Northbank Market	0.8	18.3	11.0	6.0	20.0	1.27
15	Lafia Park	0.7	13.4	8.0	4.0	15.7	1.47
16	OffBalewa crst	1.4	39.8	5.0	5.0	30.2	0.63
17	Head Bridge	1.2	20.6	5.0	1.6	16.7	1.15

oxidation of Zn, Cd and Cu releases their soluble ions (Zn^{2+}, Cd^{2+} and Cu^{2+}). However oxidization of Pb gives the Pb^{2+} ion which form insoluble oxide mineral such as carbonates and sulphates. While Fe tends to oxidize from the ferrous (Fe^{2+}) to the ferric (Fe^{3+}) state to form the extremely stable ferric oxidize as soon as it is exposed to air (Levinson, 1974). This means that the hydrogeochemical dispersion of metals in the surface environment depends largely upon the compounds formed by oxidation. Thus Zn, Cd and Cu, which form either soluble carbonates or sulphates upon oxidation, are mobile. While Pb, which form insoluble carbonates and sulphates, and Fe, which form insoluble ferric oxides, are stable as outlined above.

The implication for the relatively high extraction rates for Zn, Cd, and Cu is that these metal contaminants could be leached or mobilized from the refuse dumps both down-stream and down-slope in to soil, streams and ground water during heavy precipitation causing further dispersion of the pollutants. In addition, the pollutants could be bioavailable to crops grown on soil within the refuse dumps.

Metals contamination in the soil is associated with a cocktail of contaminants rather than a single metal. Thus the concept of pollution index (PI) is commonly employed to identify multi-element contamination resulting in increased overall toxicity (Jung, 1995, Chon, et al., 1997). In this study the PI of soils was computed by the average ratio of element concentrations of soil sampled to tolerate levels of soils for plant growth suggested by Kloke (1979). The modified equation is as follows

$$PI = \left[\left\{ \frac{(Cd)}{3} + \frac{(Cu)}{100} + \frac{(Pb)}{100} + \frac{(Zn)}{300} \right\} / 4 \right] \text{------ (1)}$$

When the PI values exceed 1.00 the soil could be contaminated by anthropogenic inputs. As shown in table 2b, most of the soils at refuse dump sites have PI values>1.0 due to the leaching of metals from refuse dumps into the soil system. This implies that most soils within dump sites in Makurdi are not good for crop production. The dump sites with low PI (<1.0) values are new sites which are yet to release enhanced levels of metals into the soils.

CONCLUSION.

An environmental geochemical survey around 17 refuse dump sites in Makurdi, Nigeria revealed that soils from the dump sites contain relatively high concentrations of Zn, Cu, Pb, and Cd as compared to values from forest soils and the world average abundances in soil. The sources of these metals is from decomposition by burning, oxidation and corrosion of various materials in the refuse dumps.

The extraction of metals from contaminated soils from refuse dumps with 0.1M HCl revealed high extraction rates for Zn, Cd and Cu but low extraction rates for Pb and Fe, which reflect their geochemical characteristics in the surface environment. In addition, the concept of pollution index (PI) was employed to assess the extent and degree of multi-element contamination of refuse dumps sites. The high PI values obtained imply that soils within dump sites are not good for the production of food crops. It is recommended that refuse at dump sites should be land filled to prevent further contamination. The drainage system within dump sites should be investigated for possible metal contamination. Food crops should not be grown on soils within refuse dumps until appropriate remedial measure is taken.

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