Assessment of metal levels of some refuse dump soils in Ghana

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Abstract

Concentration levels of tin (Sn), antimony (Sb), titanium (Ti), bismuth (Bi) and thallium (Tl) were assessed in refuse dump and background soils in urban (Accra and Kumasi) and rural (Sataso) communities in Ghana using a ThermoFinnigan Element 2 high resolution inductively coupled plasma mass spectrometric (HR-ICP-MS) instrument. Concentrations of the metals were lower than known normal mineral soil levels, however, based on the Igeo scale the refuse dump soils from Accra and Kumasi (urban communities) were 'Moderate to strongly polluted' with Sn and Sb while that from Sataso a rural community was classified as 'Moderately polluted' with Sn and Sb. The refuse dump soils from the urban communities were 'Unpolluted to moderately polluted' with Ti and that from the rural community was classified as 'Practically unpolluted' with Ti. All the refuse dump soils were, 'Practically unpolluted' with Bi and Tl. Differences in the pollution levels may probably be assigned to differences in population and activities in the communities.

Keywords: metals; refuse dump soil; background soil; Igeo scale; pollution level

1. Introduction

Refuse dump sites are common scenes in both urban and rural communities in most developing countries. These sites have become attractive spots for farming in urban and peri-urban communities as a result of their high nutrient concentrations.

Waste materials deposited in these dump sites have between 50 – 90% of organic materials which include raw kitchen waste generated in the preparation and consumption of food, such as food leftovers, rotten fruit, vegetables, leaves, crop residues, animal excreta and bones [1,2]. Though, large amounts of the waste comprise of organic materials, there could be considerable proportions of plastic, paper, metal rubbish and batteries which are known to be real sources of hazardous metals [3,4]. The wastes often contain metals in various forms and at different contamination levels. These metals can cause damaging effects even at very low concentrations; they tend to accumulate in the food chain and in the body. Exposure to these metals may lead to several human diseases such as development retardation or malformation, kidney damage, cancer, abortion, effect on intelligence and behaviour, and even death in some cases of exposure to very high concentrations [5,6].

Soils in their normal state have small amounts of hazardous metals [7-10], however, excessive amounts from sources such as, the use of agro-chemicals, industrial waste deposition, atmospheric precipitation and refuse dumping, are detrimental and can sterilize the soil [11].

Globally, soils are under increasing pressure from rising populations, the intensification of agriculture and contamination, and therefore studies geared towards the assessment of soil metal levels which contribute to contamination of the environment is imperative.

The most important metals with regards to potential hazards and the occurrence in contaminated soils are As, Cd, Cr, Hg, Pb, and Zn [12] therefore, most studies have been done on such metals. However, if the other metals considered to be less toxic to man are unchecked, soil contamination can reach levels which would pose risk to humans and the wider environment.

It is upon these premises that the current study was carried out to assess the levels of tin, antimony, titanium, bismuth and thallium in refuse dump soils in some urban and rural communities in Ghana.

2. Materials and methods

2.1. Publication Output

Background and refuse dump soils were collected in May, 2008 from three locations, Accra (≈ longitude 0°25'W and latitude 5°56'N) the largest city and the capital of Ghana, Kumasi (≈ longitude 1°55'W and latitude 6°54'N) the second largest city in Ghana and Sataso (≈ longitude 1°30'W and latitude 7°25'N) a village in the Ashanti region of Ghana. The soil samples were picked at 0 – 15 cm depth with a soil auger. At each of the dumpsites ten representative soil cores were picked at 2 m intervals randomly and placed in poly-bags. The background soils were picked more than 500m away from the refuse dumps in areas observed to have no records of refuse dumping in the same manner as described above. The samples were shade dried and crushed in a porcelain mortar to pass through a 2 mm mesh and placed in drug poly-bags of size 7 cm × 10 cm, labeled and sealed. These prepared samples were sent to Norway for the analyses of tin (Sn), antimony (Sb), titanium (Ti), bismuth (Bi) and thallium (Tl).

2.2. Sample Preparation and Analyses of Metals

The soil samples were ground into fine powder. To each of the accurately weighed 0.3 g portion of the soil samples was added 3.0 cm^3 concentrated HNO_3 and 0.1 cm^3 internal standard solution containing 1.0 mg/dm^3 of Rh, Ir, Ga, and Y. The samples were digested in a Milestone UltraClave High Performance Microwave Reactor (Shelton, USA) system and diluted to 70 cm^3 with deionized water (18.2 MΩ cm). External calibration was made with acid-matrix matched multi-elemental standard solutions. These processes were carried out at the Norwegian Institute of life Sciences, Department of Plant and Environmental Science, Å s.

The samples were analysed at the National Institute of Occupational Health, NIOH, Oslo, Norway to determine the metal levels using a Thermo Finnigan Element 2 (Bremen, Germany) high resolution inductively coupled plasma mass spectrometric (HR-ICP-MS) instrument.

2.3. Data Analysis

The data were subjected to analysis of variance (ANOVA) and LSD ($P \leq 0.05$) for the separation of means using the MSTAT-C statistical software [13].

The degree of metal enrichment of the refuse dump soils were assessed using the Metal Ratio MR [7] and the Geo-accumulation Index, Igeo [8].

$$\text{Metal Ratio (MR)} = \frac{\text{Concentration of metal in the refuse soil sample}}{\text{Concentration of metal in the background soil}}$$

$$\text{Geo-accumulation Index (Igeo)} = \ln (C_n/1.5 \times B_n)$$

where: C_n = measured concentration of metal in the refuse dump soil (µg/g); B_n = background value of heavy metal (µg/g); and 1.5 = background matrix correction factor.

3. Results and Discussions

3.1. Metal Concentration in Soils

Table 1 indicates the mean concentrations of tin (Sn), antimony (Sb), titanium (Ti), bismuth (Bi) and thallium (Tl) sampled from background and refuse dump soils from Accra, Kumasi and Sataso in Ghana.

The concentrations (0.782, 0.713, and 0.129 µg/g from Accra, Kumasi and Sataso respectively) of tin (Sn) from the refuse dump soils are significantly higher than their respective background soil values (0.068, 0.063, and 0.031 µg/g from Accra, Kumasi and Sataso respectively). Refuse dumps are recipients of waste substances, made up of materials such as, paints, bottles, glass, batteries, tyres, metal cans and containers, ashes and medical wastes which are sources of metals [4] and this might have resulted in the observed trend. Sn concentrations from both the background and the refuse dump soils are, however, below the normal Sn concentrations in soils of between 1 and 200 µg/g [9].

Antimony (Sb) concentrations (0.060, 0.025, and 0.021 µg/g from Accra, Kumasi and Sataso respectively) in the refuse dump soils are significantly higher than their corresponding background values (0.002, 0.001, and 0.004 µg/g from Accra, Kumasi and Sataso respectively). The same reason pertaining to Sn for the differences observed between the refuse dump soils and their background values could be assigned to Sb also. The concentrations of the metal from the background and the refuse dump soils are below the normal range of 0.2 – 10 µg/g in soils [9].

A range of between 100 and 1000 µg/g of Titanium (Ti) is generally found in soils [14]. Both the recorded background values (0.030, 0.029, and 0.042 µg/g from Accra, Kumasi and Sataso respectively) and the refuse dump soil values (0.058, 0.045, and 0.043 µg/g from Accra, Kumasi and Sataso respectively) are below the range generally found in soils. The refuse dump soils have higher Ti values than their corresponding background values, following the same trend as Sn and Sb. However, the background soil value and the refuse dump soil value for Ti are not significantly different.

Bismuth (Bi) has a concentration of 1 µg/g in soils [10] with the world's average concentration being 0.20 µg/g [15]. The concentrations of Bi from the background soils (0.134, 0.102, and 0.062 µg/g from Accra, Kumasi and Sataso respectively) and the refuse dump soils (0.092, 0.088, and 0.054 µg/g from Accra, Kumasi, and Sataso respectively) are below the world's average level. The background values are higher than the values from the refuse dump soils, however, with the exception of the Accra values the rest of the values are not significantly different, which shows that the waste materials may not have or have trace amount of bismuth in them.

Similar to Bi the background values (0.100, 0.092, and 0.090 µg/g from Accra, Kumasi, and Sataso respectively) of Tl are higher than the refuse dump soil values (0.091, 0.068, and 0.050 µg/g from Accra, Kumasi and Sataso respectively). With the exception of the Accra values, the differences between the background and the refuse dump soil values are significant. Thallium is naturally found in soil at levels from 0.3 to 0.7 ppm [16]. The values of Tl in the samples are below the range found in soils. The change in pattern for Bi and TI as compared to the trends observed for the other metals, probably indicates that the metals might have been depleted by some processes not identified in the study.

Within the metals, differences are found between the background values and also between the refuse dump soil values, which might be due to differences in parent materials of the soils and differences in waste materials in the communities respectively.

Most of the metal values are below the normal ranges in soil which is in line with the observation of Stewart et al. [14] where extracted metals have been found to be lower than the total mineral metal concentrations.

Table 1. Metal levels of background and refuse dump soils from some communities in Ghana

Source of soil		Metal				
		Sn	Sb	Ti	Bi	Tl
Accra	Background soil	0.068 d	0.002 c	0.030 bc	0.134 a	0.100 a
	Refuse dump soil	0.782 a	0.060 a	0.058 a	0.092 b	0.091 a
Kumasi	Background soil	0.063 d	0.001 c	0.029 c	0.102 b	0.092 a
	Refuse dump soil	0.713 b	0.025 b	0.045 ab	0.088 b	0.068 bc
Sataso	Background soil	0.031 e	0.004 c	0.042 abc	0.062 c	0.090 ab
	Refuse dump soil	0.129 c	0.012 bc	0.043 abc	0.054 c	0.050 c
LSD		0.012	0.017	0.018	0.015	0.022

Figures in the columns followed by the same letter(s) are not significantly different ($P \leq 0.05$)

3.2. Metal Ratio and Geo-Accumulation Index

The Metal Ratio and Geo-accumulation Index measure the degree of enrichment of the metals in the refuse dump soils.

The Metal Ratio (MR) (Table 2) which is the ratio of metal concentration in the refuse dump soil to its concentration in the background soil shows that the refuse dump soils have ratios of Sn, Sb, and Ti to be > 1, while Bi and Tl have ratios of < 1. The refuse dump soils are therefore polluted with Sn, Sb, and Ti, but are not or little polluted with Bi and Tl.

Table 2. Metal Ratio (MR)

Source of soil	Metal				
	Sn	Sb	Ti	Bi	Tl
Accra	11.50	30.00	1.93	0.69	0.91
Kumasi	11.32	25.00	1.55	0.86	0.74
Sataso	4.16	5.25	1.02	0.87	0.56

The extent of the pollution is measured by the Geo-accumulation Index (Igeo) (Table 3).

The Igeo has a scale consisting of seven grades (0 − 6) ranging from practically unpolluted to very strongly polluted [8]. Based upon the Igeo scale the refuse dump soils from Accra and Kumasi (urban communities) may be classified as 'Moderate to strongly polluted' with Sn and Sb while the refuse dump soil from Sataso a rural community is classified as 'Moderately polluted' with Sn and Sb. The refuse dump soils from the urban communities are 'Unpolluted to moderately polluted' with Ti while the refuse dump soil from the rural community is classified as 'Practically unpolluted' with Ti. The low population and industrial activities in Sataso, a rural area, may be the reasons behind the lower levels of metals in its refuse dump soil as compared to those in the urban communities.

The refuse dump soils from all the three community are found to be 'Practically unpolluted' with Bi and Tl.

Table 3. Geo-accumulation Index (Igeo)

Source of soil	Metal				
	Sn	Sb	Ti	Bi	Tl
Accra	2.04	3.00	0.25	- 0.78	- 0.50
Kumasi	2.02	2.81	0.03	- 0.55	- 0.71
Sataso	1.02	1.25	- 0.38	- 0.54	- 0.99

4. Conclusions

The study revealed that the refuse dump soils from the urban communities (Accra and Kumasi) and the rural community (Sataso) are polluted with Sn, Sb, and Ti. The pollution level is higher in the urban communities than in the rural community. The refuse dump soils are, however, not polluted with Bi and Tl. Though the Igeo scale indicates pollution of some metals in the refuse dump soils, the absolute concentrations of the metals are even lower than normal ranges in world soils.

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