Estimation of Soil Hazard Quotient of Some Identified Heavy Metals from an Abandoned Municipal Waste Disposal Site in Aba, Nigeria.

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Abstract
The soils of an abandoned waste disposal site reclaimed for commercial activities have been investigated for heavy metal concentration using an Energy Dispersive X-ray Fluorescence (EDXRF) Spectrometer. 20 samples were collected with a coring material 5 cm below the soil from five representative points (each of the points in regular grids of 50 m by 50m). The results obtained showed that the mean heavy metal concentrations were 5327.5 mg/kg, 2273.4 mg/kg, 797.1 mg/kg, 11104.7 mg/kg, 862.6 mg/kg for chromium (Cr), cobalt (Co), copper (Cu), zinc (Zn) and Lead (Pb) respectively. These results were found to be higher than the international permissible limits and the world average concentration of heavy metals in soil. All the identified heavy metals had their Hazard Quotient far greater than unity implying that the site has been heavily polluted by disposed wastes and may pose significant health risk to occupants of the site. Certain remediation processes were suggested to make the place less toxic and more accommodating for humans.
Keywords: Soil, Heavy Metal, Hazard Quotient, Waste

1. Introduction

Indiscriminate dumping of wastes in urban areas poses a health threat to the inhabitants especially, when proper discrimination of wastes (to ascertain their chemical potentials) is not done prior to disposal. Simpson (1996) opined that human health in towns and cities is strongly dependent on the status of urban soils. This is true because the qualities of food crops and underground water produced within these environments are marred if the soil quality is poor. According to Sajjad et al (2009), heavy metals' contamination is a major problem to our environment and also one of the major contaminating agents of our food supply, Lead and Cadmium being the most toxic and the most abundant metals in food. Excessive accumulation of these heavy metals in human bodies creates problems like cardiovascular, kidney, nervous and bone diseases.

Richard and Woodbury (1996) listed some of the sources that introduce metal contaminants into the solid waste stream to include; batteries, consumer electronics, ceramics, light bulbs, house dust and paint chips, lead foils such as wine bottle closures, used motor oils, plastics, and some glass and inks. They estimated that lead-acid batteries contributed 66% of the lead in municipal solid waste in the United States of America and nickel-cadmium batteries may be responsible for up to 52% of the cadmium. Okoronkwo et al (2006) stated that excessive wastes in soil may increase heavy metal concentration in the soil and underground water. Heavy metals may have harmful effects on soils, crop and human health (Nyle and Ray 1999; Smith et al., 1996). Many metals act as biological poisons even at parts per billion (ppb) levels. The toxic elements which accumulate in organic matter in soils and sediments are taken up by growing plants (Dara, 1993). Sajjad et al (2009) in their research on the health risk assessment of heavy metals for population via consumption of vegetables proffered that the risk of intake of such vegetables to human health was characterized by Hazard Quotient (HQ) and this was defined as the ratio of determined dose of heavy metal concentration to the reference dose. The population will pose no risk if the ratio is less than one and if the ratio is equal to or greater than one, then the population will experience health risk.

Aba, the industrial headquarter of Abia state, Nigeria, plays host to so many multinational and cottage industries. It is also the home of Ariara international market and so many other major markets where commercial activities such as sales of industrial chemicals and other raw materials, building and construction materials, textile materials, etc. take place. The major municipal waste disposal site in Aba was formerly located at the Bakasi junction, along Aba/Port Harcourt express high way and very close to Ariaria international market. All refuse collected from all parts of the city was finally deposited at this site. Outside the poor aesthetic feature of this great commercial city owing to indiscriminate waste dumping within the site, other major side effects resulting from the dump site included; poor odour (that oozed out from the dump site) and strong depletion of the coal tar along the express high way. As a result of the above mentioned negative impacts and more, arising from this disposal site, the government of Abia state banned every dumping of waste within the site and has since reclaimed the place for commercial activities. However, proper assessment of this reclaimed waste disposal site (to the best knowledge of the researchers) has not been carried out to ascertain the level of heavy metal concentration since most of the wastes that were indiscriminately disposed in this area would have served as sources of toxic heavy metal contaminants to the soil. This work therefore aims at investigating the concentration of heavy metals within this reclaimed waste dump site and their hazard quotient to ascertain the suitability of the place for commercial activities.

2 Materials and Methods

2.1 Sample collection and preparation

This study was carried out in August, 2009 in an abandoned waste disposal site in the Bakasi area of Aba in Osisioma Ngwa Local Government Area, Abia State, Nigeria. This site has been reclaimed for commercial activities. The sampled area was apportioned into five representative points (in regular grids of 50 m by 50m). Four soil samples were collected randomly from each representative point which amounted to 20 samples for the five representative points. The samples were collected with a coring material 5 cm below the soil surface and bagged in black nylon bags before being transported to the laboratory for analyses. The soil samples collected were crushed, ground and sieved (by using a 1.0-mm mesh screen to separate coarse particles from the needed fine grained powder). Further crushing was done with an agate motar and pestle, to a grain size of less than 125μm. Then, pellets of 19 mm diameter were prepared from the powdery soil (0.5g – 0.8g) mixed with three drops of organic liquid binder (Tolium dissolved in PVC) and pressed afterwards with a 10 tons hydraulic press. The pellets of samples were then kept in desiccators awaiting counting (to prevent samples from acquiring moisture or being contaminated).

2.2 Sample analyses

An Energy Dispersive X-ray Fluorescence (EDXRF) Spectrometer was used in this work to measure the elemental concentration of heavy metals in the samples. The detection system is a liquid nitrogen cooled lithium drifted silicon Si (Li) detector with a resolution of 170 ev for the 5.9 kev line. It basically consists of an excitation source and a detection system coupled to a computer controlled ADC card. The excitation source is an annular 25 mCi ^{109}Cd (Cadmium – 109) that emits Ag – K x-rays (22.1 keV) in which case all elements with lower characteristic excitation energies were accessible for detection in the samples. The excitation source irradiates a primary target (Mo) which serves as monochromatic x-ray source to irradiate the sample thus, generating a detectable pulse. The detector output is then pre-amplified and subjected to a multi-channel analyzer (MCA) which discriminates the pulse–heights based on their corresponding photon energies (average pulse heights). Pulse height distributions present are read out as peaks on a scale of intensity. The MCA counts how many pulses generated in each height interval which gives the intensity of corresponding energy. The irradiation of the samples was done for a period of 3000 s. While the positions of the peaks represented the photon energies which are characteristics of the elements present in the analyzed samples, the intensity of the peaks gave the concentration of elements present in the samples in fractions (C_f). The calculated concentration of elements (C_c) in mg/kg was computed using the relation;

$$C_c = C_f \times 10^6 \quad (1).$$

The soil Hazard Quotient (HQ) [the ratio of the heavy metal concentration of surveyed soil samples to reference permissible limit] was computed using the relation;

$$HQ = Cc/Cp \quad (2),$$

Where C_p = reference maximum permissible limit of heavy metal concentration.

3. Results and discussions

3.1 Discussions

The results of the heavy metal concentration and soil hazard quotient of an abandoned waste disposal site have been presented in Tables 1 and 3 respectively. The identified heavy metal concentrations measured from the surveyed site showed very strong elevation when compared with the world average as presented in Table 2. Also, the mean concentration of heavy metals from surveyed samples when compared with some standard permissible limits (listed in Table 2), indicate strong elevation. The average concentration of chromium (Cr) in the surveyed samples was 5327.5 mg/kg and this is far greater than the world's average value of 63.7 mg/kg (Kabata-Pendias, 2000). This result is greater than the maximum content of Cr (100 mg kg^{-1}) reported by Kabata-Pendias and Pendias (2000) in soil used in cultivation and also the natural background of Cr in agricultural soils in China (90 mg kg^{-1}). This result is above the risk reduction standard of 100 mg/kg as legislated for Cr (http://rules.sos.state.ga.us/docs/391/3/19/07.pdf.). This implies that this surveyed area has Cr value that poses significant risk for residential use (i.e. above risk reduction standard).

The mean concentration of Cobalt was recorded in Table 2 as 2273.4 mg/kg. This result is far greater than the world's average value of 9.6 mg/kg (Kabata-Pendias, 2000) and Netherlands permissible limit of 240 mg/kg (MOH- Ministry of Housing, Netherlands, 1994). Also, this result is above the risk reduction standard of 20 mg/kg as legislated for cobalt (http://rules.sos.state.ga.us/docs/391/3/19/07.pdf.).Toxic effects of cobalt on plants are likely to occur above soil cobalt concentrations of 40 mg kg^{-1}. Exposure to very high levels of cobalt can cause health effects. Effects on the lungs, including asthma, pneumonia, and wheezing, have been found in workers who breathed high levels of cobalt in the air (MOEE: Ontario Ministry of the Environment and Energy, 2001).

The mean concentration of Copper was recorded in Table 2 as 797.1mg/kg. This result is far greater than the world's average value of 21.6 mg/kg (Kabata-Pendias, 2000) and above the risk reduction standard of 100 mg/kg for copper (http://rules.sos.state.ga.us/docs/391/3/19/07.pdf) .The mean concentration of Zinc (Zn) was recorded in Table 2 as 11104.7 mg/kg. This result is far greater than the world's average value of 65.85 mg/kg (Kabata-Pendias, 2000) and the risk reduction standard of 100 mg/kg for Zinc (http://rules.sos.state.ga.us/docs/391/3/19/07.pdf.). Also, this result is greater than the maximum Zn value in light soil used in cultivation in India given as 100 mg kg^{-1} and the threshold natural background value of Zn in crop soils and paddy soils in China rated as ≤100 mg kg^{-1} (Kabata-Pendias and Pendias, 2000).

The mean concentration of Lead (Pb) was recorded in Table 2 as 862.6 mg/kg. This result is far greater than the world's average value of 29.8 mg/kg (Kabata-Pendias, 2000) and the risk reduction standard of 75 mg/kg for (http://rules.sos.state.ga.us/docs/391/3/19/07.pdf.). This result revealed that surveyed samples contained relatively higher amount of Pb than that of agricultural soil. Islam et al (2009) reported threshold natural background of Pb in agricultural soil in China as ≤35 mg kg^{-1} while Kabata-Pendias and Pendias (2000) reported that the maximum content of Pb was 50 mg kg^{-1} in light soils used for cultivation.

The magnitude of elevation of heavy metal concentration of these surveyed samples can be appreciated more when we look at the hazard quotients (HQ) of the various samples with relation to some international permissible standards as reported in Table 3. The computed HQ ranged from 14.01 to 53.28; 2.95 to 79.7; 15.42 to 37.01 and 1.62 to 4.31 for Cr, Cu, Zn and Pb respectively while Co had HQ of 9.47. These high HQ levels of identified heavy metals indicate high amplification values over the standard permissible limits as proposed by certain regulatory bodies such as; SEPA (1995), ECC (1986), TZS (2003), MOH- Ministry of Housing, Netherlands (1994) and imply that the population currently doing business within this reclaimed dump site may experience certain health risk since all the computed HQ's are greater than unity (which serves as control limit). Excessive accumulation of heavy metals either in the soil or ground water leads to failure of many biological functions like heart failure and polycythemia (MOEE: Ontario Ministry of the Environment and Energy, 2001). The accumulation of heavy metals in environmental samples such as plants, sediments, soils, etc is a potential risk to human health due to their transformation and their uptake by plants and subsequent introduction into the food chain.

4. Conclusion

The results obtained for the surveyed site indicate large presence of heavy metals in soil. The increase in heavy metal concentration in the soil may have resulted from excessive waste disposal that characterized this area in the past. This has the capability of polluting underground water and may have very harmful effects on soils, crop and human health. When several toxic pollutants are released into the surrounding environment, some water soluble pollutants percolate into the ground water (Kanan, 1995). This affects the quality of water and soil gets deteriorated. The consequences of massive water pollution in relation to human health are of great concern because; two thirds of many illnesses are reported to have been related to the water borne diseases through metal intoxication (Olaniya and Saxena 1977, Saprykina 1977).

It is therefore suggested that remediation processes should be carried out in the surveyed site to reduce the level of heavy metal toxicity and thus, make the place more habitable for humans. Such processes should include: Increasing the pH level of the soil since cationic metals are less soluble at higher pH levels and this makes them less available to plants and therefore less likely to be incorporated in their tissues and ingested by humans; draining wet soils since this improves soil aeration and will allow metals to oxidize, making them less soluble and less available to plants and humans.

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Table 1: Results of concentration of elements identified in the sampled area

Sampled Points	Chromium- Cr (mg/kg)	Cobalt- Co (mg/kg)	Copper-Cu (mg/kg)	Zinc- Zn (mg/kg)	Lead- Pb (mg/kg)
1	5070	1330	649	49100	2960
2	10300	4210	1030	4260	613
3	14300	3870	2590	53900	2520
4	8130	3350	1030	1370	2520
5	3140	3410	1660	42700	700
6	10300	3410	333	1330	1570
7	4460	1470	1460	22400	336
8	3980	1710	991	673	511
9	4640	1470	682	1950	189
10	2940	610	759	232	897
11	4050	1640	757	2430	215
12	2240	1730	442	258	478
13	10200	2370	352	1470	461
14	3450	2450	533	214	763
15	2870	3290	522	1970	239
16	4140	711	437	25400	501
17	3140	566	457	10200	432
18	2850	2340	399	238	375
19	3110	2390	472	1760	501
20	3240	3140	386	238	471
Mean	5327.5	2273.4	797.1	11104.7	862.6

Table 2: Comparison of concentration of elements identified in the sampled area with world average, uncontaminated soil and permissible limits (PL)

	Cr (mg/kg)	Co (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)
Sample Mean	5327.5	2273.4	797.1	11104.7	862.6
World Average [a]	63.7	9.6	21.6	65.85	29.8
Indian PL [b]	---	---	135 - 270	300 - 600	250 - 500
Uncontaminated Soil (India)[c]	5 - 3000	---	2 - 100	10 - 300	2 - 200
SEPA Limit (China)[d]	250	---	100	300	350
ECC Limit[e]	100	---	50 - 140	150 - 300	50 - 300
Tanzania PL [f]	200	---	100	---	200
Netherlands PL[g]	380	240	190	720	530

[a]Source:Kabata-Pendias (2000), [b]Source: Awashthi (2000), [c]Source: Bowen (1966), [d]SEPA (1995), [e]ECC (1986), [f] TZS (2003), [g]MOH- Ministry of Housing, Netherlands (1994),

Table 3: Computed hazard quotients (HQ) based on various permissible limits

	Cr	Co	Cu	Zn	Pb
HQ (Indian PL)	…	---	2.95	18.5	1.73
HQ (SEPA, China PL)	21.31	---	7.97	37.01	2.46
HQ (ECC PL)	53.28	---	5.7	37.01	2.88
HQ (Tanzania PL)	26.6	---	79.7	---	4.31
HQ (Netherlands PL)	14.01	9.47	4.19	15.42	1.62