Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **5(11),** 1-8, November **(2015)** *Res. J. Chem. Sci.*

A preliminary survey of Heavy metals concentrations in Children playground within Owerri Metropolis, Imo State, Nigeria

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Available online at: www.isca.in, www.isca.me
Received 5th September 2015, revised 15th October 2015, accepted 12th November 2015

Abstract

Pollution of children's playgrounds by heavy metals from various anthropogenic sources has received little attention despite the fact that Nigeria recently recorded the worst heavy metals disaster involving children. In this study eight heavy metal concentrations in a total of thirty six soil samples collected from nine playgrounds in south eastern Nigeria were investigated using the A Analyst 400 Perkin Elmer. Results of maximum metal concentrations revealed the trend; Zn (168.74 mg/Kg) > Ni (94.48 mg/Kg) > Cu (76.89 mg/Kg) > Cr (27.23 mg/Kg) > Co (13.21mg/Kg) > Pb (6.52 mg/Kg) > Mn (8.86 mg/Kg) > Cd (0.93mg/Kg). Though highest, Zn concentrations were only 1.01% to 2.4% of Queensland threshold and WHO standards values and so metal concentrations were considered low. Therefore based on the present results public school playgrounds within Owerri municipal do not pose a serious pollution threat. However the accumulation of these metals in school playgrounds could result to contamination and pollution problems in the long run.

Keywords: Pollution, public school, threshold, maximum, heavy metals, survey.

Introduction

Heavy metals are among the more serious pollutants in the human environment because of toxicity, persistence and bioaccumulation characteristics[1,2]. Elevated concentrations of these metals in children have been linked to human activities[3,4]. Generally the environmental quality of urban soil is closely related to human health and so people are becoming more concerned about the potential pollution of soil around them.

Few studies exist on children play grounds within Nigeria; however no studies have documented the presence of heavy metals in children's playgrounds within Imo state whereas volumes of studies exist on heavy metals in children playgrounds in most developed countries[5-7].

Heavy metal is a general collective term which applies to the group of metals and metalloids with an atomic density greater than 4 g/cm^3 [8]. The term, Potential Toxic Elements (PTEs), has been used for this group of metals therefore to avoid inconsistencies the term trace metals is preferred when referring to metals of low natural concentrations. Equally the term heavy metal is still the most used and recognized term, and is therefore used throughout this survey. Heavy metals have been implicated in the upsurge of liver and kidney diseases, and is believed to be responsible for a high proportion of mortality caused by kidney and liver morbidity[9-11], pains in bones, mutagenic, carcinogenic and teratogenic effects[12], neurological disorders, especially in the fetus and in children which can lead to behavioral changes and impaired performance in IQ tests[13].

Heavy metals occur naturally in the earth's crust, in soils and rocks with a subsequent range of natural background concentrations in soils, sediments, waters and in organisms. Human activities are the majorly responsible for higher concentrations of the metals relative to the normal background values. The most important anthropogenic releases of heavy metals to the environment come from metalliferous mining and smelting, agricultural materials (pesticides and fertilizers), irrigation and application of sewage water and sludge, fossil fuel combustion and metallurgical industries[14,15]. Heavy metals will tend to accumulate in the environment and can be transported from one environment compartment to another[16,17].

Whether the source of heavy metals is natural or anthropogenic, the concentrations in children playgrounds constitute a potential hazard due to their bioaccumulative characteristics and consequent toxicity. The extent of adsorption depends on the metal, the absorbent, the physico-chemical characteristics of the environment (e.g. pH, water hardness and redox potential) and the concentrations of other metals and complex chemicals present in the soil. Direct uptake from the surroundings across the body wall, from respiration and from food is also responsible for accumulation of heavy metals in organisms[18]. The free ion is the most bioavailable form and often the best indicator of toxicity. There are exceptions, such as the well known case of mercury, where the organic form, (methylmercury) is more toxic than the inorganic ion. Metals could exert toxic effects by generally interfering with biochemical reactions in the organism. Typical responses include inhibition of growth, suppression of oxygen consumption and impairment of reproduction and tissue repair[19].

Literature reveals that children's play grounds have been studied elsewhere[20.] Few studies have investigated children's playgrounds in Nigeria[21]. It is regrettable that no research existed on children's play grounds in Imo state as at the time of this research. However public schools presented themselves as appropriate targets for assessing heavy metal content of surface soils.

A child's nervous and digestive systems are still developing and so are susceptible to intake. Children have the propensity to explore the world through their mouth. They are exposed to heavy metals via absorption through skin, food, ingestion of treated materials such as wood, contaminated soil and inhaling of contaminated air. Infant and children are particularly susceptible to neuron-toxicological damage from metal exposure throughout their ongoing intellectual development. Many factors aggravate metal toxicity particularly in children[22,23].

Therefore there is need to establish measures to deal with toxicity that may arise from gradual accumulation of heavy metals in children's body as a result of metal concentrations in playgrounds. Comprehensive information about these metals is of primary importance to detect unusual concentrations, predict outbreaks and formulate preventive measures[24]. To obtain such information there is the need to constantly monitor the concentrations of theses metals. The Focus of this study was to examine the levels of some of these heavy metals in surface soils of selected playgrounds within Owerri municipal with a view to comparing such baseline data with World health organization standards and standards elsewhere. This perhaps the first study in this regards and so could be a reference for further research.

Material and Methods

Study area: The study area is Owerri municipal in Imo State, southeast Nigeria, bounded by latitudes 4^{o}40^1 and 8^{o}15^1 N and longitudes 6^{o}40^1 and 8^{o}15^{1}E. It lies within the humid tropics. Owerri municipal is one of the three local government areas (LGAs) that make up Owerri city, the capital of Imo state of Nigeria set in the heart of the Igboland. A greater proportion of the land surface of Imo State is of flat topography. The climate of Imo State is typically humid tropics characterized by 9 months of rainfall (rainy season) and 3 months of dryness (dry season)[26]. Rainfall distribution is bimodal and averages about 2500 mm per annum, while the mean annual temperature ranges from 28 to 37°C[27]. The State has rainforest vegetation characterized by multiple tree species. Economic activities are majorly buying and selling while there are no industries involved in large scale production except few printing presses.

Sampling: Nine different sampling sites were chosen from public school's playgrounds along major roads connecting Owerri metropolis in Imo state as follows: Surface soil or dust samples at 0-5 cm depth were collected in the months of November and January (dry season) 2012 and March to August (rainy season), of 2013. At each sampling site, a 'W' shaped line was drawn on a 2 x 2m surface along which samples were collected from five points into previously treated polythene containers. Using a perforated container to allow water to drain from the rainy season soils samples were sundried for two days, then oven dried at 50^{o}C for12 days and grind in acid-washed porcelain mortar with pestle. The soil samples were pooled together, treated to coning and quartering to obtain a small laboratory sample[28]. The samples were sieved through a 200 µm sieve in order to normalize variations in grain size distributions and then stored in polythene containers with caps for further analysis[29].

Determination of heavy metals: 1 gram of the soil samples were digested in Pyrex glassware using 20 mls of 4N HNO_3 acid at 90^o C for 6hrs. The mixture were then filtered into a 25mls standard volumetric flask and made up to the mark with deionized water[30,31.] The total heavy metal concentration in the soil samples was determined by the use of the aanalyst 400 Perkin Elmer absorption spectrophotometer. Quantification was carried out using appropriate calibration curves prepared in the same acid matrix with standard metal solutions for atomic absorption spectrophotometer[32].

Statistical Analysis: Data obtained from this study were analyzed using the statistical package for social sciences (SPSS) version 18.0 for windows. Metal concentrations were mean of triplicate analysis. Co-efficient of variations (CV %) were used to determine the variation in heavy metal content within playgrounds. Variability was categorized as little variation (CV % < 20), moderate variation (CV % = 20 – 50) and high variation (CV % > 50).

Results and Discussion

Table-1 shows the various calibration curve equations, detection limits (3x standard deviation of the baseline noise/sensitivity) of the analytical techniques for each element and their regression values. All regression values R^2 were above 0.9 showing good fit, even though R^2 for Mn was lowest. This could be explained by the volatile nature of the metal[33].

Table-2 shows the heavy metals, their concentrations and some statistical parameters of the data obtained in the present study. Metal concentrations revealed the following decreasing order: Zn > Ni > Cu > Cr > Co > Pb > Mn > Cd. The mean, maximum and minimum values of metals concentrations showed that zinc was at the apex while cadmium was at the bottom. Though cupper had highest standard deviation (23.72), cadmium showed highest variability. Variability was observed to follow the trend: little variation for nickel (5%), moderate variation for lead (48%) and zinc (35%) while high variations includes Cd (355%),Co (109%), Cu (89%) and Mn (70%)

Geochemical associations: Apart from anthropogenic consideration, many elements are geochemically correlated[34]. Two geochemical associations would include such suites as Cr – Co – Ni – Cu (ultraformic) and Cu – Pb – Zn – Cd – Ni (black shale). Figures-1 and 2 represent these geochemical suites. Metals in the ultra formic had generally low concentrations except for nickel at WBP and TSO and CSO while manganese was the lowest for all playgrounds.

The black shale suite (figure-2) metals showed a more even distribution across playgrounds. Zinc was the most prominent metal for all schools with black shale as the prominent geochemical suit.

The contents of Zn, Cu and Pb are higher for black shale compared with other metals. Probably this is due to vicinity of playgrounds such as car service, garden fertilizing activities, application of Zn and Cu plant protection agrochemicals and fossil fuels for domestic use. According to the present studies, average Cd, Cu, and Zn concentrations in the surface soils are very similar amongst themselves.

Comparison with literature data also revealed that our data for metals in playground soils of Owerri municipality are much lower than those presented in Czech Republic[35] and Italy[36], indicating that soils of children playgrounds within the municipality are not contaminated by heavy metals.

Comparing heavy metals concentrations with QTV: The occurrence and concentration of heavy metals in playgrounds of nine public schools located within the Owerri Municipal area in comparison with QTVs are shown on figures 3 to 10. World Health Organization (WHO) threshold values / Queensland threshold values (QTV) and background values (BkV)[37], for metals in children playgrounds and other standard found in literature were equally compared with data from the present study.

However metals concentrations at all playgrounds were dwarfed by Queensland threshold values.

Schools, CSO and TSO had elevated metal concentrations when compared to background values. The two schools are located within commercial centers and surrounded by petrol stations and heavy traffic.

Table-1
Standard curves and regression values

Metal	Equation of Curve	R^2	Detection limits µg/l
Mn	Y = 0.0388X	0.9873	0.002
Co	Y = 0.0294X	0.9998	0.05
Ni	Y = 0.0486X	0.9997	0.002
Cu	Y = 0.0239X	0.9960	0.002
Zn	Y = 0.0374X	0.9955	0.001
Cr	Y = 0.0224X	0.9833	0. 04
Cd	Y = 0.0423X	0.9975	0.002
Pb	Y = 0.0274X	0.9981	0.002

Table-2
Heavy metal concentration (mg/Kg) of surface soil and statistical data some for children playground

Metal	HEO	MNO	SCP	CSO	TSO	WSP	WBP	IKS	UPS	Mean	Max.	Min.	SDV	CV(%)
Cr	11.03	7.93	10.28	16.24	27.23	3.88	12.58	18.35	7.69	12.80	27.23	3.88	7.2	56
Mn	4.62	3.25	3.41	3.52	0.73	2.19	6.43	8.89	0.74	3.75	8.89	0.73	2.64	70
`Co	2.48	2.87	0.77	10.97	10.28	13.21	0.69	0.78	0.75	4.76	13.21	0.69	5.17	109
Ni	2.18	4.84	8.23	40.25	51.28	7.29	61.53	4.73	2.49	20.31	61.53	2.18	18.09	5
Cu	25.23	14.17	28.15	26.4	11.57	14.28	16.62	25.76	76.82	26.56	76.82	11.57	23.72	89
Zn	51.16	36.15	32.34	168.7	75.88	48.37	50.56	50.48	47.39	62.34	168.7	32.34	21.58	35
Cd	0.69	0.41	0.62	1.45	1.13	0.88	0.31	0.63	0.73	0.76	1.45	0.31	2.70	335
Pb	5.89	7.13	6.89	6.82	4.66	4.81	7.19	6.47	4.55	6.05	7.19	4.55	2.92	48

HEO: Housing Estate Nursery Primary School, MNO: Model Nursery, SCP: Shell camp Nursery/Primary School, CSO: Central School, TSO: Township school, WSP: Water side Primary, WBP: World Bank Nursery /Primary School, IKS: Ikenegbu Primary School and UPS: Urban nursery/primary school; (QTV): Queensland threshold values; BkV: background values.

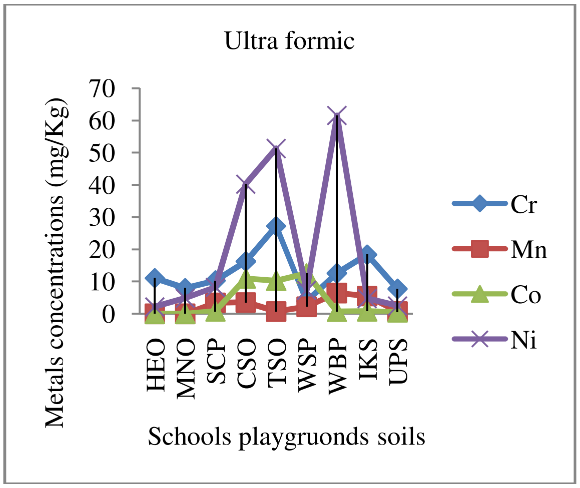

Figure-1
Ultraformic geochemical association's suites

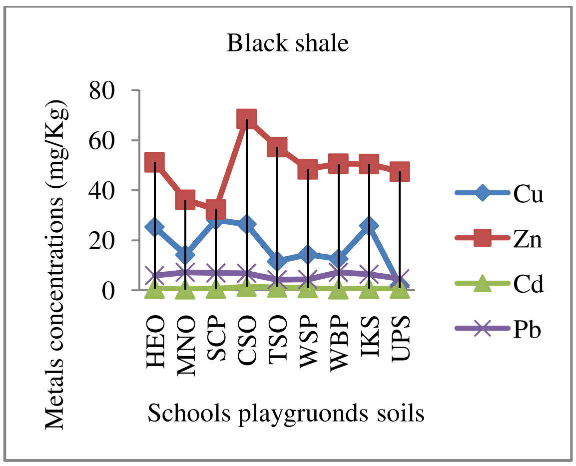

Figure-2
Black shale geochemical association's suite

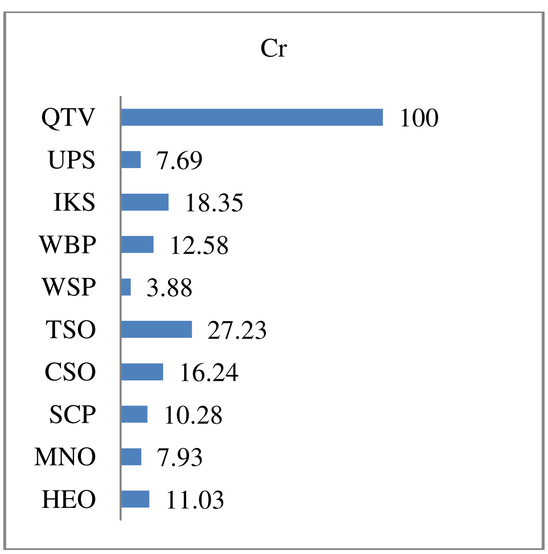

Figure-3
QTV and Chromium concentrations (mg/Kg)

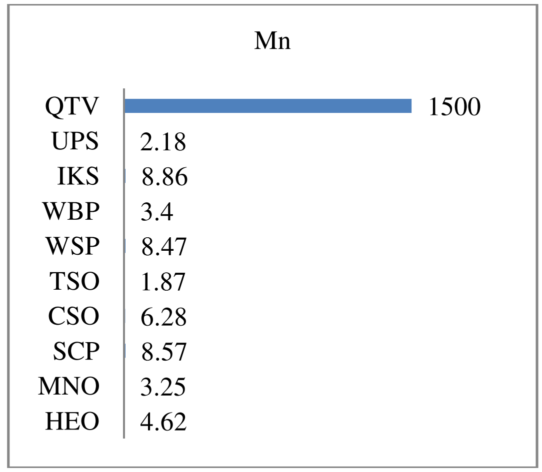

Figure-4
QTV and Manganese concentrations (mg/Kg)

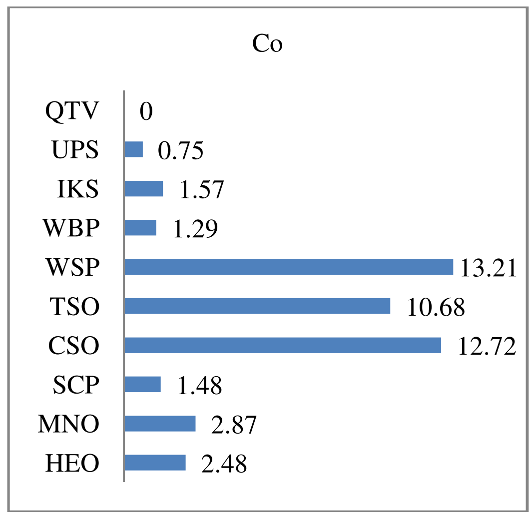

Figure-5
QTV and Cobalt concentrations (mg/Kg)

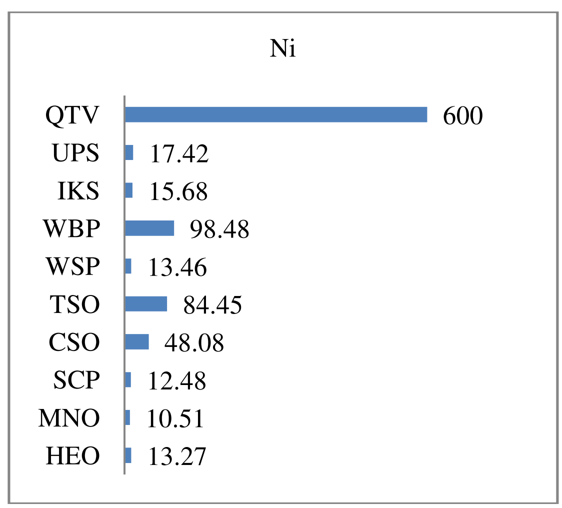

Figure-6
QTV and nickel concentrations (mg/Kg)

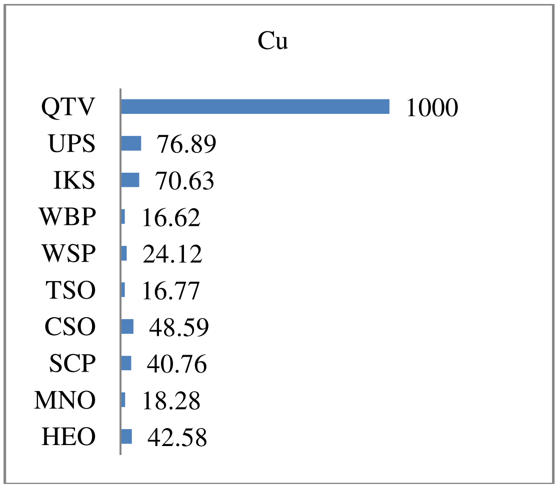

Figure-7
QTV and Copper concentrations (mg/Kg)

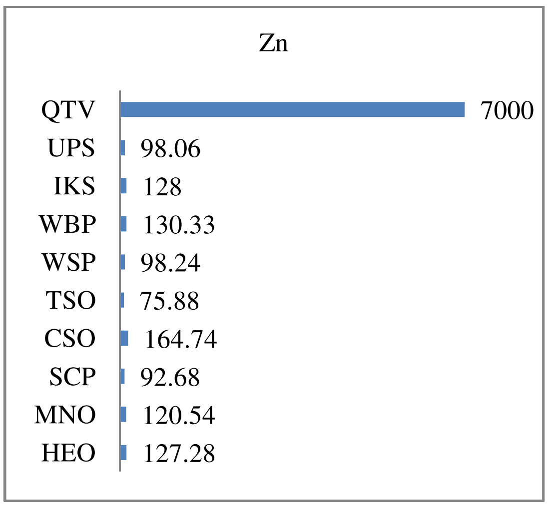

Figure-8
QTV and Zinc concentrations (mg/Kg)

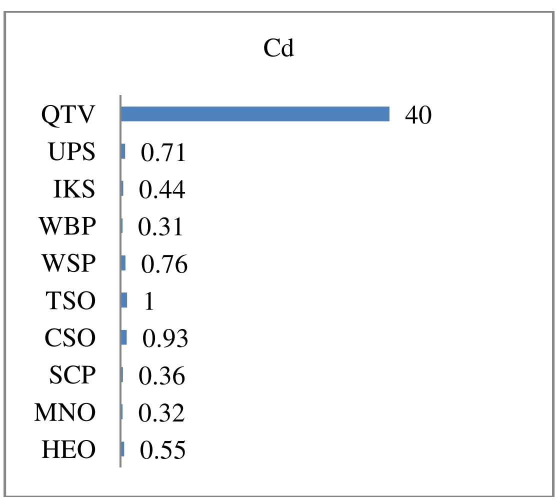

Figure-9
QTV and Cadmiun concentrations (mg/Kg)

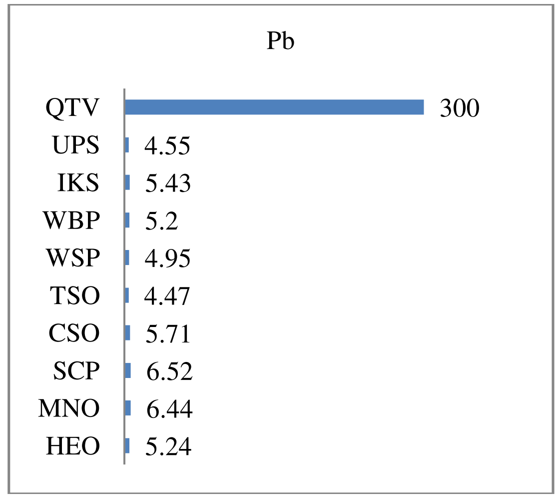

Figure-10
QTV and Lead concentrations (mg/Kg)

Chromium: Chromium concentration (27.23g/Kg) at TSO though abnormally high compared to other playgrounds was only 27.23% of QTV while WSP had lowest chromium concentration (3.88%). Chromium showed higher concentrations than background value (15mg/Kg) at CSO, TSO and IKS. Compared to baseline value (10-15mg/Kg) reported [38], playgrounds WSP, MNO and UPS were bellow the range. Chromium finds use in pigments, leather tanning, and wood preservative, component of corrosion resistant steel. No doubts playground soils had low chromium content probably due to lack of industries in Owerri.

Manganese: Manganese concentration (8.86mg/Kg) at IKS was only 0.6% of QTV despite being highest for all nine playgrounds. WSP showed highest cobalt concentration (13.21mg/Kg) while UPS was lowest with cobalt concentrations of (0.75mg/Kg). Manganese was virtually insignificant compared to background value metallic Manganese slowly dissolves in acids while the finely divided metal is pyrophoric in air. Mn is used in animal feed, fertilizer glass ceramics WHO[39], used in the Clay blocks for road construction; petrol additives have been known to contain Mn. Many commercial bleaching processes use $KMNO_4$ such as in bleaching of cotton, jute fibres and beeswax due to the strong oxidizing power of manganese. Mn is also used in the commercial supply of batteries in the so called MNO_2 – Zn dry battery (the super ion battery). Mn is one of the abundant elements in the earth's crust, surprisingly it is insignificant in playground soils of Owerri municipality. Mn in classroom dust in Lagos metropolis was undetectable[40]. Though ubiquitous in the environment, Mn could remain undetected due the form in which it exists especially when in silicates. Manganese was virtually insignificant compared to background value. Metallic manganese slowly dissolves in acid while the finely divided metal is pyrophoric in air. Manganese is used in animal feed, fertilizers, glass, ceramics[41], used in the clay blocks for road construction, petrol additives have been known to contain manganese. Many commercial bleaching process use

$KMnO_4$ such as in bleaching of cotton, jute fiber bee wax due to the strong oxidizing power of manganese. Manganese is also used in the commercial supply of batteries

Cobalt: Notice that no standard value existed for cobalt and so fig. 5 shows that cobalt was highest at WSP and lowest at UPS. The background value of 8 mg/Kg for cobalt was realized in all nine playgrounds in Owerri Municipality where highest cobalt concentration was 13.21mg/Kg at WSP. Cobalt is usually in high demand used as a pigment of decorating glasses and enamels. It has recently been used as an effective solar collector due to its high solar absorbance and low in emittance. Cobalt has 26 known radioactive isotopes but only ^{57}Co and ^{59}Co are of commercial importance.

Nickel: Like cobalt, nickel is slowly attached by dilute mineral acids. The bulk metal is oxidized by air or steam at high temperatures. According to SPDC guidelines nickel usually occur in the environment in low concentrations. Soil usually contains 4 – 80 ppm while the SPDC guidelines for Nigeria soils 10 – 120 µg/g playground soils. Diesel oil, residual oil tobacco smoke, catalyst and rusting steel are some possible sources of Ni in the playgrounds studied especially those located at the city centres such as WBP, TSO and CSO.

Copper: Copper ranged from WBP (16.62 mg/Kg) to UPS (76.89 mg/Kg) which were only 1.7% and 7.7% of QTV respectively. Copper is the only first row d-block elements with a stable oxidation state. In spite its essential nature to life, Cu is as toxic as Lead even in low concentrations. The SPDC 2004 range of 5 – 50 µg/g fitted well for all most playgrounds except for UPS and IKS playgrounds whose values where still below the 100 µg/g for soils of Western Nigeria as reported[42].

Zinc: Zinc had the highest concentration of heavy metals studied in this survey. Zinc values ranged from TSO (75.88 mg/Kg) to CSO (168.74 mg/Kg) but these where only 1.01% to 2.4% of QTV respectively. Zinc is widely used in modern society to coat or galvanize iron to prevent corrosion. Particles release from vehicle tires and brakes linings are major sources of zinc in urban area[43]. Zinc is less toxic to man. Zinc values vary widely in nature but baseline data range from 50 – 100mg/kg. Playground soils for HEO, MNO, CSO, and WSP showed higher zinc concentrations than background range. According to the background value of 90 mg/kg [44], were not exceeded only by playground TSO with Zn 75.88mg/kg. Corroding Zinc roofs could have contributed to high values of zinc in playground within Owerri Municipality.

Cadmium: Cadmium concentrations were lowest for all playgrounds studied and values ranged from WBP (0.31 mg/Kg) to TSO (1.0 mg/Kg) representing a 0.78% to 2.5% of QTV respectively. All playgrounds had cadmium concentrations below the SPDC 2004, 0.7 µg/g standard value, whereas playgrounds CSO, TSO and WSP and UPS were within the range. The rest of playgrounds were below the range. Possible cadmium sources include pipes, tobacco smoke, burning of plastics automobile wastes. Thus this study showed no danger of cadmium pollution.

Lead: Lead was lowest at UPS (4.55 mg/Kg) and highest at SCP (6.52 mg/Kg); these lead concentrations were only 1.51% and 2.2% of QTV. It is probable that play grounds within commercial centers are likely to have elevated heavy metal levels; this may have been the case with schools UPS and CSO.

Several Pb compounds are components of pigments in the paint industry. It is also used in explosives, insecticides and ceramics and glass plumbing fixtures and rubber products. Lead background level of 30 mg/kg was never attained by any one school playground in Owerri Municipal. However, lead has been banned by many countries, and this may account for reduced concentrations in soils. All playgrounds had lead values above the critical concentration of European Union of 3.5 µg/g. Other possible sources of Pb in playgrounds of Owerri municipal could include auto exhaust, airborne lead fallout and battery.

Generally the range of values for all metals was low for all playgrounds. This could be explained by considering the land use at the vicinity of such playgrounds. In some play grounds it was observed that dumping of waste was a common practice. For instance waste ink and from artist studios and printers workshops were found on CSO playground. This could account for elevated metals such as Pb, Cr, Co since these metals are components of printer's ink [45].

Conclusion

Soil heavy metals were comparable to values reported by other workers and background values, suggesting that soils have not been polluted. Cd, Zn and Co showed slightly elevated concentrations above background values for some playgrounds suggesting that human activities have not impacted playground soils. The concentrations of all metals determined were far below QTVs standards. However the accumulation of these metals in soil playgrounds is a call for concern with regards to the health of our children. Further investigation is deemed necessary to study the sites that may require urgent attention. Periodic studies are recommended in other to procure enough data for this sensitive issue. In conclusion, playground soils metals in this study may not constitute pollution by heavy metals but contamination is certainly on an increase.

Acknowledgement

This work is part of PhD thesis in the Department of Pure and Industrial Chemistry, University of Port Harcourt. We thank members of the Research in Analytical Chemistry and Environment Pollution Studies (RACEPS). We express deep gratitude to the Director; Spring Board Laboratory, Awka for the use of certain scientific instruments, and Engineer Clement of Federal Environmental Laboratory, Imo state.

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