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Research Article

Pollution status, Bioavailability and Risk of Metal toxicity on Surface Soils of Children's Recreational Parks within Owerri Municipal, Imo State, Nigeria

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Abstract

This study was carried out to determine the risk due to heavy metals found in children parks. The concentration, distribution and bioavailability of heavy metals insoils of children parksat Owerri Municipal were then analysed because children, many young people and their escorts frequent these open city areas to play. Samples were collected from surface soils of three recreational parks: Jesus Christ Never Fails Amusement park (JNF), IHOP children's amusement park (IHOP), and FSP Recreational park(FSP). Nine soil samples were analyzed for Mn, Co, Ni, Cu and Zn. They were extracted by sequential extraction method in order to estimate mobility and bioavailability of chemical forms of these metal species in the soils. Soil samples were characterized using standard methods for determining physicochemical properties. The metal specie concentrations (in mg/kg) were determined from various sequential extracts using Perkin Elmer A Analyst 400 series Atomic Absorption Spectrometer (AAS).Results revealed that temperatures ranged from 28°C to 29°C with FSP having the highest value; the pH values ranged from 6.2 to 7.5 with exception of JNF, the parks had acidic soils; electrical conductivity ranged from 6.8 S/cm at FSP to 9.5 S/cm at JNF; the moisture content ranged from 17.83% at IHOP to 30.8% at JNF and the soil organic matter ranged from 1.27% at IHOP to 4.85% at JNF. Mean bioavailable fractions were 0.93Mn, 0.017 Co, 0.096 Cu, 0.418 Ni and 7.41 Zn mg/kg respectively. The mean values of bioavailable fractions are not high. There was low mobility of heavy metals in the park soils. The contamination assessment was then estimated using pollution index and the results showed values <1 indicating that those parks were not contaminated. Zn showed exceptionally high risk assessment code (RAC) at FSP while all metals at JNF showed low risk. However continuous deposition from atmosphere and from various human activities could lead to danger as a result of metals bioavailability, bioaccumulation and persistence in the environment.

Keywords: Assessment, Atomic absorption, Heavy metals, Health, Physicochemical, Toxicity

Introduction

Recently there is increasing awareness that heavy metals in the soil may have negative effects on human health and on the environment. This is contained in the number of articles published on soil for heavy metal bioavailability and risk assessment [1]. Soils receive a higher load of heavy metals than their rural counterparts from traffic and industrial activities. However, a large proportion of the heavy metals present in soil originate from diffuse or non-point sources such as long short-range atmospheric deposition, erosion and transportation of contaminated nearby soil and land filling of site with excavation masses. Whatever the source metal exist in various forms and so they become bioavailable to children who frequent these play ground. Play is an essential part of children growing up as most children prefer recreational parks and playgrounds and on these lay the danger of bioavailable metals.

The term bioavailability is defined as the extent to which a contaminant in a source is free for uptake. Bioavailability of a metal contaminant can be defined in terms of its absolute or relative bioavailability. For the purpose of this study bioavailability is the fraction of the metal contaminant present in the soils that can dissolve and systemic circulation from where adverse health impacts could manifest [2-4]. Metal toxicity depends on the duration and intensity of exposure and bioavailability [5]. The absorptionrate of solubilized metal from the intestinal tracts is controlled by metal oxidation state and physical forms [6]. Determination of soil pollution based on total metalconcentrations often results in overestimation of the inherent health risk [7,8]. Furthermore, Adekule, Ndahi and Owolabi reported intheir study that soil-metal sequestering properties significantly reduced the bioaccessibility ofarsenic and chromium upon ingestion [9]. Therefore, the total metal concentration in soil is notavailable for complete absorption through the gastrointestinal system and so studies involving total metal digest are clearly misleading in toxicological information [10,11].

Schwartz and Hu 2007) determined the bioavailability of metals in soil relative to the bioavailability of the solubilized species in water.Verla, Verla and Enyoh further highlighted the influence of soil properties on metal contaminants availability through a stepwise mechanism that involves accessibility (release of contaminant from soil into solution), absorption and metabolism of the contaminants [14,15].

The difference in bioavailability between the two media necessitate the introduction of a correction factor; relative bioavailability factor (RBA), which may be greater or less than 1.0while absolute bioavailability never exceeds 1.0 (100%) (USEPA, 2007). The US EPA defined relative bioavailability as "the ratio of the bioavailability of a metal in one exposure context (that is, physical chemical matrix or physical chemical form of the metal) to that in another exposure context (USEPA, 2007). In many definitions, especially those associated with pharmacology or mammalian toxicology, bioavailability of a contaminant implies the degree to which the contaminant is free to be taken up and to cause an effect at the site of action [16]. Whether or not the organism is exposed to the contaminant concentration will depend on whether it comes within close proximity of the media containing the contaminant. The organism must be in appropriate contact in order to absorb, ingest, imbibe, or inhale the contaminated material [17]. Metals of major interest in bioavailability studies, as listed by the U.S. Environmental Protection Agency (EPA), are Al, As, Be, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Sb [18]. Other metals that are presently of lesser interest to the EPA are Ag, Ba, Co, Mn, Mo, Na, Ti, V, and Zn. These metals were selected because of their potential for human exposure and increased health risk. Metals can be dispersed in soil, water, air and atmosphere by natural geochemical cycling, microbial activities and by anthropogenic processes such as smelting and burning leaded gasoline and coal. These metal fluxes must be considered in overall metal bioavailability studies. Bioaccumulation of metals by biota in surface water and by plants and animals in terrestrial environments can adversely affect humans.

Children could be perhaps the worst victims of bioavailable metals exposure due to a lot of factors militating against them, ranging from smaller body size to high childhood vulnerability. Children have the tendency to explore the environment through their pica actions. The mouthing of dirty hands and objects are done through deliberate and involuntary ingestion of soil or dust particles. Children have more susceptibility than adults to any potential negative health effects of bioavailable metal ingestion. While their smaller body mass increases the relative exposure to any given quantity contaminants, they also have a higher gastrointestinal absorption of those metals. Moreover, they are more sensitive to neurotoxic metals and organic substance intake because their nervous and digestive systems are not fully developed. The center for Disease Control and Prevention has established a blood Pb level of concern for children at 10µgd/L or above [19]. This value is also used as an international action level. The potential risks posed by soil bioavailable metal intake depend on the amount of heavy metal ingested and the bioavailability of that metal specie, which in turn depends on its concentration in exposure media, sometimes on its chemical speciation that is more or less toxic. Soil characteristics such as pH, organic matter and clay content affect the sorption strength of metals. Lowered pH increases the mobility and increases the metal content because more attractive binding sites are provided Levy Barbarickk [20,21]. Siemerand Sommersl, 1992, Citeau and Lamy2003). Soil ingestion and soil bioavailable metal exposure are also dependent on the time spent at the play park and its location. Bioavailability depends on metal species, dust organic content and particle sizes [22]. The incorporation of site-specific bioavailability into the risk assessment process may help to reduce the uncertainty in determining contaminant risk and to better understand the sources and nature of the pollution. However, the knowledge of total concentration of bioavailable metal and soil characteristics is important for safety policy formulation and awareness in children's commercial amusement parks [23].

Few research works have been reported on heavy metals in soils of children's playground in Owerri city. These include physicochemical characterization of playgrounds soils of public schools in Owerri metropolis, Imo state Verlaet al. 2015a), A preliminary survey of heavy metals concentrations in children playground within Owerri metropolis, Imo state (Verlaet al. 2015b) and other similar works but none has been studied on bioavailable metals in soils of children's amusement parks in Owerri municipal [1,24]. In addition, attempt at remediation of bioavailable metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, environmental and associated health risks of these metals [25]. There is therefore need for a continuous monitoring of level of heavy metal in the area in order to keep a check on the environment and to provide data for future research works. The aim of this research is to determine the distribution of heavy metals and their bioavailability from soils of children's parks in Owerri municipal of Imo state and to compare the soil bioavailable metal concentrations withregulatory standard values permitted by the Nigerian environmental guideline as well as international standards [26, 27]. The objectives set to achieve this aim include: to establish the distribution and variability in concentrations of bioavailable metals for soils in children's amusement parks of Owerri municipal of Imo state, to investigate the dispersion of the bioavailable metal concentrations in the surface soil at depth of 0-5cm, to assess the level and extent of contamination by comparing the results obtained with Nigerian environmental soil guidelines as well as international soil standards and also using soil contamination indices to identify any need for urgent remediation, to evaluate health risk of these bioavailable metals on children.

The commercial amusement parks sampled in this study were chosen from different landuse areas in Owerri municipal of Imo state. Soil collected at city center and commercial district with high traffic emissions may contain elevated bioavailable metal content than soils collected from amusement parks located at residential areas with low traffic emission and commercial activities [28]. Three commercial amusement parks were sampled and analyzed for the bioavailable metals (Co, Cu, Mn, Ni, and Zn).

The significance of this study is to provide Owerri city planners and recreational parks operators with soil geochemical and physicochemical data that can be used in policy formulation. To improve the sustainable management of identified risks associated with the parks and safeguard the health of city dwellers, especially the children that frequently use the parks.In this study, heavy metals are limited to Mn, Co, Ni, Zn, and Cu.

Materials and Methodology

Study Area

The study is limited to Owerri municipal in Imo state, taking Jesus Christ Never Fails (JNF), IHOP and FSP children's recreational parks as sites for assessing bioavailable metals. Owerri is the capital of Imo state, set in the south eastern region of Nigeria. Owerri generally consists of three Local Government Area including Owerri municipal, Owerri north and Owerri west. It is located between latitude 5°45'N and 5°20'N and longitude 6°45'E and 7°05'E. It lies within the tropical rainforest zone of West Africa. The monthly temperature is highest in February with a value 30.1°c, while the lowest is 26.7°c recorded around August. Owerri is inhabited by Igbos and mostly Christians. Owerri municipal is one of the Local Government Area in Imo state, Nigeria. It has an area of 58km2. Owerri municipal council, formally the headquarters of the old Owerri Local Government Area (comprising present day Owerri municipal, Owerri north, Owerri west and NgorOkpala L.G.A) became municipal council in 15thDecember, 1996. Routes to Owerri municipal are Okigwe road, Onitsha road, Port Harcourt road, Aba road and Umuahiaroad. The population of Oweri as at last published national population census conducted in Nigeria in the year 2006 was 400,000 [29].

Soil Sample Collection

Three different sample sites were selected and three samples collected per site within Oweri municipal of Imo state. Soil samples at 0-5 cm depths were collected using a hand-held auger in the month of June during rainy season. A 'W' shaped line was drawn in a 2x2m surface along which samples were taken from five different sampling points. The soil samples were pooled together, treated by conning and quartering to obtain a composite sample.

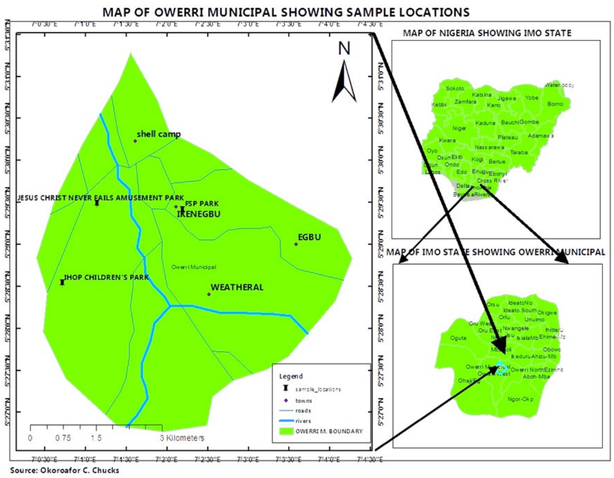


Figure 3.1: Map ofOwerri municipal showing sampling points

Sampling Preparation

The soil samples were sun/air-dried for 24 hours (care was taken to prevent contamination from laboratory dusts). The dried soil samples were sieved in a 2mm laboratory sieve in order to remove the larger grits and dirt before being homogenized with mortar and pestle. The samples were kept in a stainless steel container prior to analysis. All laboratory glass wares and plastic wares were first washed with high grade laboratory soap, and rinsed with deionized water and soaked in Nitric acid (overnight).

Physicochemical analysis

The soil physicochemical analysis was determined according to methods of [30]. The temperature was determined using the Soil Gardner's Thermometer by inserting the probe into the soil at depth of 3-6cm for 6 minutes and readings were taken. The electrical conductivity was measured after calibration with KCl using HANNA HI8733 EC METER in S/cm. 50 g of the air-dried soil sample was carefully weighed into a beaker and 100ml of distilled water was added. It was then shaking vigorously to allow separation of the soil sample and allowed to stand. The EC probe was then introduced into the soil-water suspension for 60seconds and readings were taken. The pH was determined using JENWAY 3510pH METER which was calibrated using buffer 4 and buffer 7 by dissolving one capsule each in 100ml of distilled water respectively. The pH was determined also with the same method used for the EC measurement. The moisture contentwas determined using the gravimetric method.10g of the soil was placed in an oven at 105oC for 2 hours until all the water was driven off. The difference in weight is the amount of moisture in the soil. The moisture in the soil is calculated using the formula below.

% Moisture Content = wet weight - dry weight/ dry weight x 100…….. (1)

The soil organic matter (SOM) was determined using the weight Loss on Ignition (LOI) method. From the moisture content determination, the entire oven-dried test soil sample was placed into the muffle furnace at 440oC for more than 8 hours [31]. The calculations were done as differences in weight of the initial drysoil to the final soil weight after cooling from the furnace.

Sequential Extraction Procedure

Water Soluble Fractions (F1): 1g of the air dried soil sample was mixed with 10ml of distilled water with continuous agitation for 1 hour.

Exchangeable Phase (F2): The residue in (F1) above is shaken at room temperature with 16ml of 1M $Mg(NO_3)_2$ at pH 7.0 for 1 hour.

Carbonate-Bound (F3): the residue from exchangeable fraction was extracted with 8ml of 1M CH_3COONH_4 (adjusted with Acetic acid to pH 5.0) for 5 hours.

Fe-Mn Oxides-Bound (F4): The residue from F3 was extracted with 0.04M NH_2OH. HCl in 25% (v/v) Acetic acid at 96°C with occasional agitation for 6 hours.

Oxidized Phase (bound to organic matter) (F5): Residue from F4 above +10ml of 8.8M H_2O_2 + 6ml of 0.02M HNO_3 was shaken for 5 hours at 98°C. 10ml of 3.5M CH_3COONH_4 was added as an extracting agent.

Crystalline Phase (Residual) (F6): The residual from F5 was dried and digested in a conical flask with 10ml of 7M HNO_3 on a hot plate for 6 hours. 1ml of 2M HNO_3 was added after evaporation and the residue after dissolution was diluted to 10ml then washed with 10ml deionized water [32-34].

The heavy metals were analyzed in six different fractions. Metal species in Fractions 1, 2, and 3 were considered bioavailable (BIOA), metal fractions 4 and 5 were considered non-bioavailable (NBIOA) whilemetal species in fraction 6 was the residual fraction (Res). After successive extraction and rigorous shaking, the metal fractions were determined using Perkin Elmer A Analyst400 Series Atomic Absorption Spectrophotometer (AAS) in mg/kg.

Statistical and Chemometricanalysis

Data was reported as mean of triplicate analysis and analyzed using SPSS, version 18 of the statistical package for social sciences for standard deviations were appropriate. Co-efficient of variation (CV%) was used to categorise variability of RAC in the recreational grounds for the two seasons. Variability was ranked as follows: little variation (CV % < 20), moderate variation (CV % = 20 – 50) and high variation (CV % > 50) according to Mbah and Anikwe (2011).

The pollution level by a given heavy metal was evaluated with the single pollution index (PLI). Values of PLI of each metal was calculated from the contamination factors (CF) which is the ratio between the metal concentration (Ci) in a soil sample and its reference value (Si):

$$CF = \frac{Ci}{Si} \quad \text{..........................(1)}$$

$$PLI = (CF_1 X CF_2 X CF_3 \ldots CF_n)^{1/n} \quad \text{......... (2)}$$

The Si values for Mn, Co, Ni, Cu and Zn were based on the Standard Regulatory Limits (SRL), which are summarized asMn, 25 mg/kg; Co ,8 mg/kg; Ni, 40mg/kg; Cu, 30mg/kg; Zn, 90mg/according to Verla et al.2016, USEPA [35,36]. The overall pollution status (Basta, Ryan and Chaney 2005) of the surface soils by the heavy metals was assessed by the Nemerowpollution index (PIN) [37]:

$$P_s = \sqrt{\frac{P_{ave}^2 + P_{max}^2}{2}} \quad \text{.................. (3)}$$

whereP$_{ave}$was the average pollution index; Pmaxwas the maximum value of the pollution index.The possible relationship of heavy metals in the surface soils were identified with correlation. Correlation graphs were used to investigate the associations among the measured heavy metals and physicochemical properties of the soil. Mean, standard deviation and graph were also used to show the variations of the bioavailable metals.

According to Luo, Yu andLi 2012, Mobility factors (MF) for various swimming pools were calculated by summing the metal species in F1, F2 and F3 as the most mobile specie and then expressing its fraction to the total sum of fractions as a percentage.

$$MF = \frac{(F1+F2+F3)}{(F1+F2+F3+F4+F5+F6)} \times 100 \quad \text{............. (4)}$$

Risk assessment code was taken to be an interpretation of mobility factors expressed as percentage. It was assumed that the most mobile fractions for each metal are the ones that will find their way into children who make use of these recreational grounds. Therefore the percentage at which they are mobile is assumed to represent the percentage at which they could potentially be harmful [38,39].

Results and Discussion

Table 1: Physicochemical properties of the soil samples

Parameter	Samples during dry season					Samples during rainy season				
	FSP	IHOP	JNF	Mean	SD	FSP	IHOP	JNF	Mean	SD
Temp. (OC)	29	28	28	28.33	0.54	26	26	25	25.78	0.50
pH	6.2	6.4	7.5	6.7	0.02	6.2	6.3	6.43	6.31	0.04
EC (S/cm)	6.8	7.7	9.5	8	1.0	6.7	7.4	6.8	6.97	1.0
Moisture (%)	20.9	17.83	30.8	23.18	1.50	28.5	29.2	29.5	29.07	1.20
OM (%)	1.92	1.27	4.85	2.68	0.04	1.97	1.72	2.6	2.10	0.03

*EC- electrical conductivity, OM- organic matter, SD- standard deviation

Physicochemical characteristics of the investigated children's park soils are shown in table 1. Play park soils showed temperatures ranging from 28oC to 29oC with FSP parkhaving highest value (table 1).Soil temperatures are significant in their influence on soil characteristics. High temperature reduces growth of microorganism, and has been associated with soil acidity.Mean soil temperature was within acceptable range for Nigerian soils.

Bioavailability considers the most soluble fractions of metal species in soil to be responsible for the risk. Increasing values of EC of soil (which could be due to presence of soluble metal species) will lead to increasing bioavailability. Therefore increase in EC values are undesirable and portents high risk of metals for the soil. The children's park soil showed that electrical conductivities (EC) also differed significantly among the three parks ($p < 0.05$). EC varied widely ranging from 6.8 S/cm at FSP to 9.5 S/cm at JNF park. EC values indicate ionic concentration of soils. The EC level is a good indication of the amount of nutrient available in the soil. It is observed that JNF park showed an out layer with EC of 9.5 S/cm. EC of soil is classified as: non saline <2; moderately saline 2-8; very saline 8-above; extremely saline >16 [40]. From result of the study, the EC was classified as very saline since the mean for the children parks is 8.0 S/cm.

The moisture percentage in the investigated children's park soils ranged from IHOP Park (17.83%) to JNF park (30.3%). The high values of the moisture could be due to the persistent rainfall during the time of the study. High soil moisture has been linked to larger soil particles and leaching processes [41]. Moisture has been known to reduce dust while organic matter is effective in trapping moisture. Therefore high moisture content of the children parks is advantageous to children as this reduces chance of ingestion or inhalation of particles hence reducing chances of metal toxicity risk.

Soil organic matter (SOM) content not only determined the nutritional status, but also affected the migration of heavy metals. Organic matter affects both the physical properties of the soil and its overall health. The percentage organic matter for the three parks ranged from (1.27%) at IHOP park to (4.85%) at JNF park. The result is similar to result obtained in other areas of Imo state [41]. Organic matter is known to form complex with heavy metals, which is of advantage to children as it also reduces chances of inhalation and ingestion [42].

Table 2: Heavy metal fractions (mg/Kg) of soils of recreational parks

	Metal Species in various Samples during dry season														
	IHOP Park					FSP Park					JNF Park				
Specie	Mn	Co	Ni	Zn	Cu	Mn	Co	Ni	Zn	Cu	Mn	Co	Ni	Zn	Cu
F1	0.282	0.026	0.034	0.875	0.081	0.001	0.000	0.017	0.099	0.012	0.000	0.000	0.026	0.745	0.051
F2	0.588	0.029	0.063	3.483	0.355	0.871	0.000	0.037	9.705	0.306	0.378	0.000	0.028	3.449	0.266
F3	0.627	0.000	0.022	0.721	0.080	0.043	0.000	0.062	2.033	0.041	0.000	0.000	0.037	1.106	0.062
F4	0.608	0.000	0.064	0.772	0.115	0.139	0.000	0.094	1.994	0.112	0.043	0.000	0.092	1.079	0.118
F5	0.564	0.003	0.016	1.684	0.084	0.701	0.000	0.000	0.763	0.033	0.259	0.000	0.052	1.458	0.071
F6	0.512	0.077	0.262	3.758	0.434	1.076	0.013	0.373	5.119	0.643	0.620	0.089	0.489	6.492	0.893
Sum	3.181	0.135	0.46	11.29	1.149	2.83	0.013	0.583	19.71	1.147	1.3	0.089	0.724	14.33	1.461
RAC (%)	47.1	40.7	25.8	44.9	44.9	32.3	0	19.9	60	31.2	29.07	0	12.6	37	25.9
Metal Species in various Samples during rainy season															
F1	0.270	0.105	0.118	0.600	0.098	0.071	0.000	0.072	0.095	0.091	0.105	0.068	0.042	1.251	0.245
F2	0.510	0.002	0.042	2.811	0.452	0.671	0.000	0.165	8.228	0.548	0.221	0.017	0.172	2.428	0.308
F3	0.551	0.065	0.017	0.427	0.087	0.645	0.000	0.153	1.856	0.780	0.108	0.082	0.584	1.800	0.271
F4	0.600	0.017	0.132	0.282	0.205	0.350	0.000	0.107	0.998	1.179	0.289	0.015	0.292	1.046	0.198
F5	0.668	0.053	0.002	0.884	0.172	0.978	0.000	0.016	0.870	0.087	0.197	0.085	0.825	1.907	0.427
F6	0.620	0.018	0.079	2.896	0.490	2.006	0.036	0.292	4.587	0.585	0.869	0.297	1.045	6.744	0.992
Sum	3.22	0.26	0.39	7.9	1.50	4.72	0.04	0.81	16.63	3.27	1.79	0.56	2.96	15.18	2.44
RAC (%)	24	41	41.02	43.18	36.7	16.68	00	29.25	50.04	19.45	18.21	15.17	7.23	24.23	226.6
CV (%)	64.97	0.7	45.50	3.90	20.09	63.78	00	38.04	18.97	46.56	45.93	200	54.16	41.71	159

Sum: summation, RAC: Risk assessment code, CV- Coefficient of variability

It was essential to estimate the pollution degree of soil according to various metals. Pollution loads Index (PLI) of Mn, Co, Ni, Cu and Zn in soils together with mean values are plotted in figure 1, the degree of pollution in five different points and between the heavy metals can be drawn.

Cu at IHOP showed the PLI of 0.18 while zinc showed generally highest PLI at all parks. Despite these, all PLI were below1 (fig 3) indicating that there was no danger arising from multi-element contamination in the near future. The contamination level maybe classified based on their intensities on a scale of ranging from 1 to 5 (0=none, 1=medium, 2=moderate, 3=strong, 4=strongly polluted, 5=very strongly polluted). The overall pollution status of the surface soils from this study showed JNF (0.039 x 10-1) <FSP (0.968 x 10-1)<IHOP (1.288 x 10-1). The overall pollution status indicates the total pollution of the individual pollution indexes referred to as Pollution index (PIN). The result obtained from this study signifies that the top soils from the three children's parks are not contaminated with heavy metals, which could be due to proper management of these parks. However, cobalt level (0) is particularly absent in FSP park and JNF park. The children parks are however safe in terms of heavy metals, owing to the fact that the soils from these parks are not contaminated.

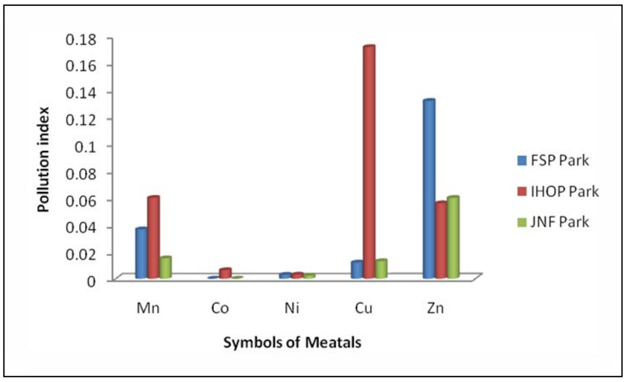
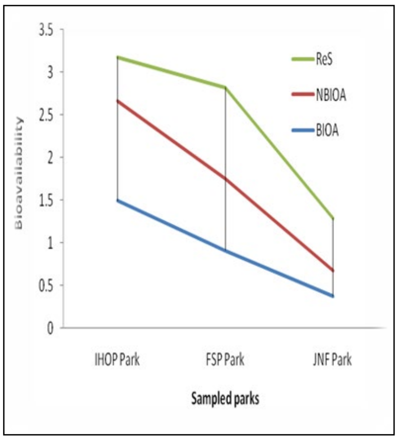
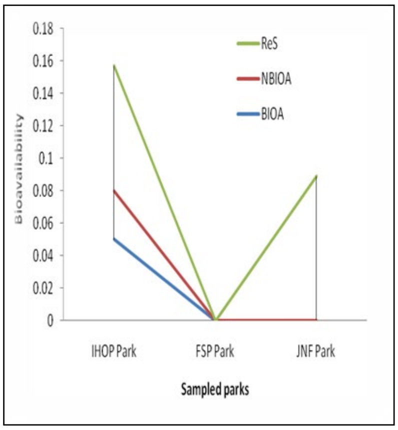


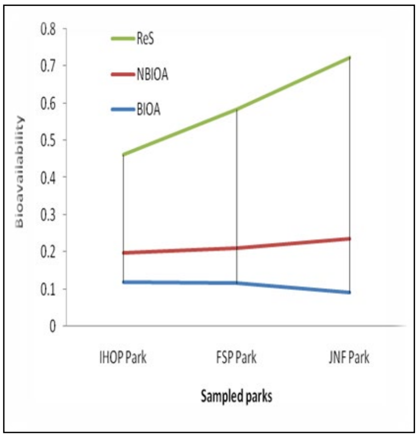
Figure 1: Barchart comparing pollution indices of recreational grounds



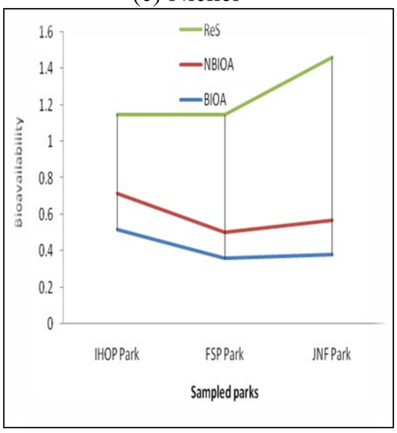
(a) Manganesse



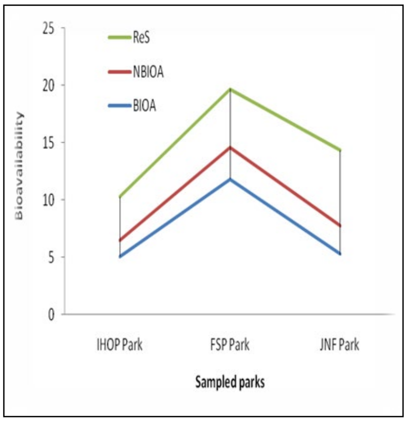
(b) Cobalt



(c) Nickel



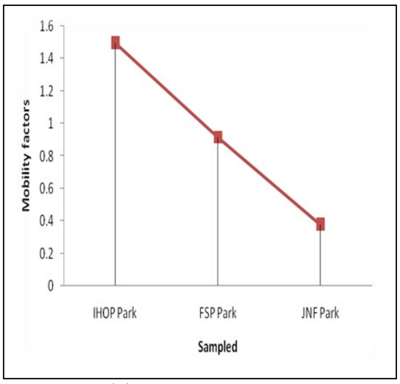
(d) Copper



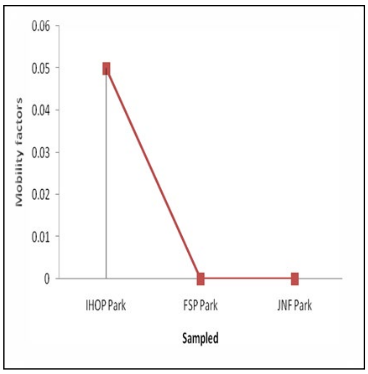
(e) Zinc

Figures 2a-2e: Bioavailable fractions, Non-Bioavailable fractions and Residual fraction (mg/kg) of soils of three recreational Parks

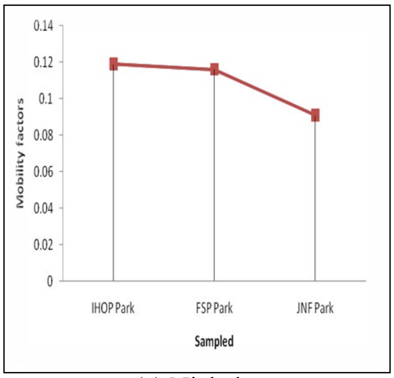
The heavy metal concentration fractions were presented in table 1 with FSP park having both the highest concentration of Zn (19.713mg/kg) and lowest concentration of Co (0.00mg/kg). Heavy metal concentrations in different parks showed significant variations. The order of abundance of the analyzed metals at the three sampling sites was Zn >Mn> Cu> Ni> Co. The soil at FSP Park has more mobile Zn compared to other two children's parks (fig. 2). However, the trend may be correlated with the soil properties that influence heavy metal availability. The relationship between heavy metals and the soil properties didn't obey exponential distributions. In statistics, a perfect negative correlation is represented by value -1.00, while 0.00 indicates no correlation and a +1.00 indicates positive correlation. There was a negative correlation between the soil properties and bioavailability of metals from the three children parks as shown in figures 2. Therefore, it could be said that the mobility of heavy metals in these children parks are not totally dependent on the physical and chemical properties of the soil.



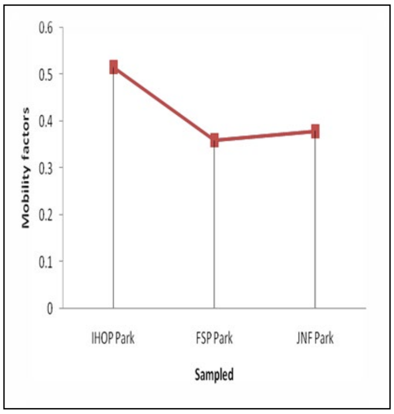
(a) Manganesse



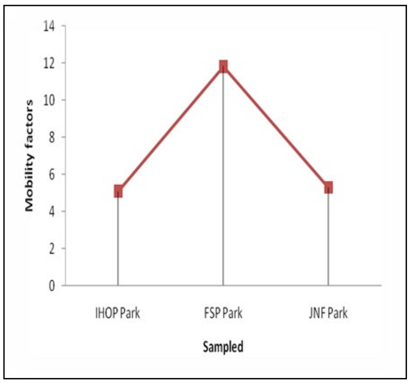
(b) Cobalt



(c) Nickel



(d) Copper



(e) Zinc

Figure 3a-e: Mobility factors of various metals at different parks

Mobility factor was generally highest at IHOP park and lowest at JNF park in all the recreational parks except FSP. When MF was ranked for the metals analyzed, the decreasing order was Zn >Mn> Cu > Ni > Co. Considering the individual parks, a general view of fig 2 reveals the following trends in mobility factors of metals:
Mn: IHOP > FSP > JNF; Co: IHOP > FSP & JNF; Ni: IHOP > FSP > JNF; Co: IHOP > JNF > FSP; Zn: FSP > JNF > IHOP. These trends of metal mobility of soils of children's recreational parks reveal that Mn and Ni had similar behavior. This is could be a reflection of their chemical behavior. While Zn showed an entirely contrasting trend, it could be said that all recreational grounds could have significant mobile fractions. This is however confirmed by the RAC.

Risk assessment code (RAC) revealed that metals generally had low to intermediate risk. Zinc (60%) was an exception at followed by Mn (47.1 %) at IHOP while Zn and Cu were 44.9% at same IHOP [43]. Diattaand Grzebisz, reported much less risk of Zn contamination in recreational parks in Poland. Results her are generally in agreement with expected values as most recreational parks in Nigeria not well taken care of, leaving deposited dust from various source to enrich the parks with metals. Risk of Co was zero at FSP and JFP but at IHOP, Co showed intermediate risk of 40.7%. Though most metals showed low risk there could be danger if preventive measures are absent.

Seasonal variation: The dry season showed higher metal concentrations than the rainy season. Pollution indices and bioavailability of metals followed similar trend as the metal concentrations. Variability was than categorized for RAC and results showed that Ni (00) had no variability between seasons Co (0.7) had little variability amongst all metals and recreational parks. At IHOP, Cu showed medium variability while Mn and Ni showed high variability. At FSP park Mn again showed high variability. At JNF park variability of RAC was generally higher than those of IHOP and FSP. It is therefore advisable that children visit these parks often in the rainy season than in the dry season [44-50].

Conclusion

The metal concentrations in the children's play park soils studied is characteristic of unpolluted soils with levels less than acceptable limits for recreational parks. However, the pollution index is <1 based on Standard Regulatory Limits (SRL) which signifies that the top soils from the three children's recreational parks are not contaminated with heavy metals. This could be due to proper management of these parks. However RAC revealed that metals generally pose no risk except for Zn, Cu and Mn but dry season values where higher for most metals. It could be advised that children frequent these parks in the rainy season than the dry season. Although there were low concentrations of bioavailable metals in the surface soils of recreational parks studied, maintaining ground cover and playing facilities will however provide a margin of safety from exposure to heavy metals by children playing in the parks.

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