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Archives of Analytical and Bioanalytical Separation Techniques

GAVIN PUBLISHERS

Wirnkor VA and Ngozi VE. Arch Anal Bioanal Sep Tech: AABST-106.

## Research Article

DOI: 10.29011/AABST-106. 100006

# Body Levels of Heavy Metals in Children from Public Schools within Owerri Municipal, Imo State Nigeria

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**Citation:** Wirnkor VA, Ngozi VE (2018) Body Levels of Heavy Metals in Children from Public Schools within Owerri Municipal, Imo State Nigeria. Arch Anal Bioanal Sep Tech: AABST-106. DOI: 10.29011/AABST-106. 100006

**Received Date:** 03 May, 2018; **Accepted Date:** 17 July, 2018; **Published Date:** 25 July, 2018

## Abstract

Despite children's special vulnerability, exposure to heavy metals through playgrounds soils has been overlooked in most third world countries primarily due to lack of information. In a two-year study within Owerri municipality, 4134 children from 9 public schools were physical examined and 99 children subjected to heavy metal test using Quantum Magnetic Resonance Analyzer, Model QMRA 918. A total of 45 soil samples from school playgrounds were digested with nitric acid and hydrochloric acid and metal concentrations determined using An Analyst 400 Perkin Elmer AAS. Heavy metals concentrations in children were compared within each school, amongst school playgrounds and with upper limit of normal concentration in children. Children at Housing Estate Owerri had low concentration of metals whereas mean values of manganese and copper were higher than upper limit of normal concentration in both years. In terms of mean metal concentration in children's body, metals ranking followed the trend: Ni (4.67 mg/Kg) > Co (4.08 mg/Kg) > Zn (1.55 mg/Kg) > Mn (1.31 mg/Kg) > Cu (1.28 mg/Kg). Manganese, cobalt and zinc showed a week negative correlation whereas copper and nickel had a week positive correlation. Heavy metals in some children were found to be slightly higher than upper limit of normal concentration while most metal concentrations were lower than required for healthy living. There was a general decrease in metal concentration from 2012 to 2013. Children at public schools within the municipality could be at risk due to elevated concentrations of manganese, cobalt and copper. Therefore, there is the need for playgrounds to be periodically monitored and mitigation put in place to reduce increasing concentrations of these heavy metals.

**Keywords:** Children; Exposure; Normal concentrations; Toxic metals

## Introduction

Tiny amounts of metallic elements are necessary for good health in humans and other mammals yet may be injurious in excess [1,2]. The importance of metals in body metabolism cannot be over emphasized. However, both deficiency and excess of these metals produce undesirable effects [3-5]. Metals are ubiquitous in nature and so elevated amounts in soils are often linked to anthropogenic sources. Children's nervous and digestive system are still developing and so are susceptible to metal and organic substance intake. Children have the propensity to explore the world through their mouth [6]. They are exposed to heavy metals via absorption through skin, food, ingestion of treated materials e.g. 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. Reviewed literatures reveal that children's play grounds could be a veritable source of metal enrichment in the bodies of children [3,7-9]. Few studies have investigated children's playgrounds in Nigeria. 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 children and their playgrounds [10]. These playgrounds represent places where urban children spent most of their time when outdoor but are assessable to everyone at all times [9]. conducted a risk-based exposure of children to trace metals in playgrounds in urban Madrid concluded that ingestion of substrate particles was the highest contributor to the overall figure of heavy metals risk followed by dermal adsorption. Inhalation of resuspended particles through the mouth and nose was almost negligible when compared to the other exposure pathways. African children are more likely to perform pica activities than their counterparts elsewhere as a result of hunger, poor parental attention, warm climate that encourages outdoor activities, poor environment and non-regulated play at playgrounds amongst other reasons. All these factors generally support the existence of a huge gap of knowledge about children playgrounds especially Nigeria and Owerri municipal in particular. Therefore, the importance of this work, the first of its kind as far as could be established cannot be overemphasized.

## Materials and Methods

**Study area:** The study area is Imo State, southeast Nigeria, bounded by Latitudes $4^0 40^1$ and $8^0 15^1$ N and longitudes $6^0 40^1$ and $8^0 15^1$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 Igbo land. Its population density ranks fourth as of 2006 census [11].

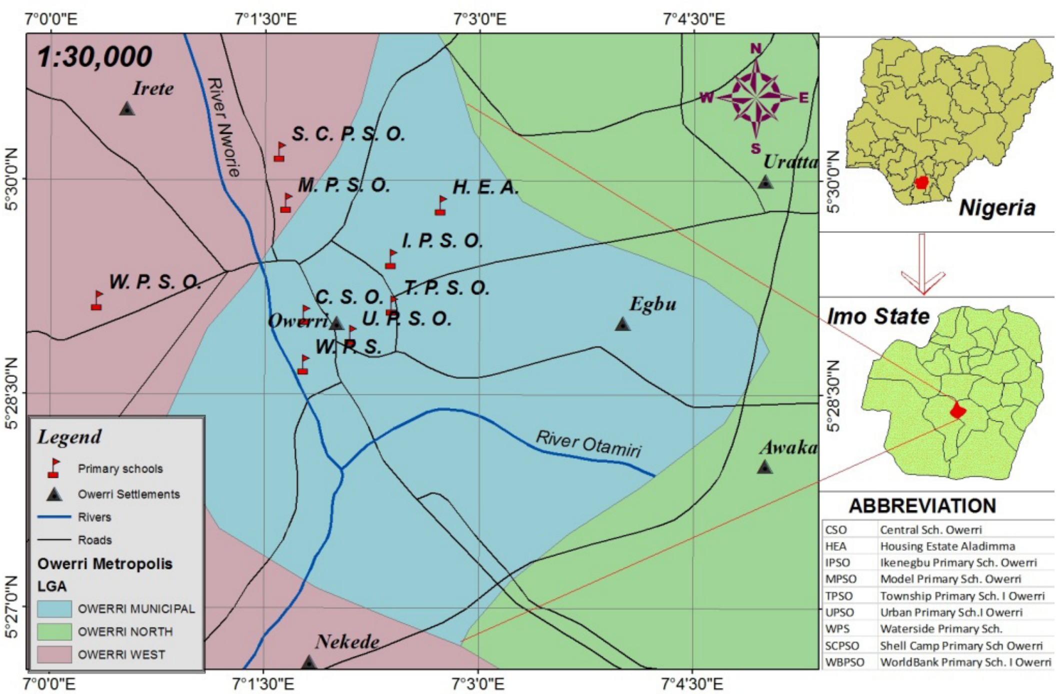


**Figure1:** Map of Owerri Metropolis showing, names, the sample locations.

This area is under heavy traffic all year round since it is home to the biggest and modern market and the seat of state government. There are no industries but connecting roads to neighboring states pass through the municipality thereby increasing traffic volume. In addition heavy construction of roads, hotels and estates can be observed by a visitor all year round. The study area falls within the most affected area in the pollution map of Nigeria [11].

### Demography

**Body Concentrations of Heavy Metal in Children (BCHMC):** All children between 4 to 12 years selected for testing were first examined physically using the parameters listed as typical symptoms of high levels of heavy metals in children compile from literature. Teachers from participating schools' teachers were also asked to complete a short questionnaire designed to identify children with possible symptoms of metal exposure. Children with 4/9 positive results were considered as cases for testing and thus were tested in situ using QRMA instrument.

**Procedure for Quantum Resonance Magnetic Analyzer:** After installing the software in PC, the USB drive was connected to PC. The metal stick line to instrument was handed to a child and then the software opened (Plate 1). The start testing option was chosen and in 1 minute, the instruments auto-showed the test results of all five metals in mg/Kg units.


**Plate 1:** Quantum Bio-electric Sensor.

### Ethical considerations

Permission was obtained from school principles and parents consent was sought children accepted willingly to take part in the study before start of data collection. Study approval was also obtained from relevant government bodies. The names of the schools that participated in the study including their locations were kept open during data analysis and compilation of the final report.

### Determination of heavy metals in playground soils

**Soil sample collection and treatment:** Soil samples at 0-5 cm depths were collected in the months of June and September (rainy season), in January and March (dry season), of 2012, 2013 and in February (dry season). At each sampling site, a “W” shaped line was drawn on a 2 x 2 m surface along which samples were collected from five points into previously treated polythene containers using a perforated container to allow water to drain for rainy season samples. These samples were sun/air dried for two days, and then oven dried at 50$^o$C for 2 days; ground in acid-washed porcelain mortar with pestle. The samples were sieved through a 2 mm sieve in order to normalize variations in grain size distributions. The samples were stored in polythene containers with caps for further analysis.

**Determination of total heavy metal:** The total heavy metal in all 45 soil samples were determined by first digesting with nitric acid and hydrochloric then manganese, cobalt, nickel, copper and zinc concentrations were determined using An Analyst Perkin Elmer 400 Atomic Absorption Spectrometer. Quantification was carried out using appropriate calibration curves prepared in the same acid matrix with standard metal solutions for atomic absorption spectrophotometer.

## Results and Discussion

Considering the upper limit of normal concentration of metals in children (ULNCC) to be 0.88 mg/kg, 5.73 mg/kg, 5.53 mg/kg, 0.75 mg/kg and 1.99 mg/kg for Mn, Co, Ni, Cu and Zn respectively, the measured body levels of heavy metals (BLHMs) in children were selected and expressed as percentages of children with heavy metals above normal range (Table 2). While schools, WBP and WSP had 4% of children heavy metal level above normal range. The low percent children with metal above normal range estimated for WBP and WSP could be attributed to the fact that the schools were newly opened, and so the soil have not been impacted by anthropogenic activities. Schools UPS and CSO had highest values of 17.6 and 16% respectively. Schools UPS and CSO are at commercial centers and surrounded by petrol stations and heavy traffic all year round. Atmospheric deposition and commercial activities could be responsible for the abnormal rise in body levels of heavy metals in children at the two schools. On the other hand, no case was recorded for schools HEO and MNO. Mostert, 2009 suggested that play grounds within commercial centers are likely to have children with elevated blood lead levels. This may be the case with schools UPS and CSO in which children showed elevated concentrations of body metals. (Table 2) equally shows the mean values of body heavy metals in children. Out of 4134 children screened using symptoms compile from literature, 183 were found with body levels of heavy metal above normal range in children. Eleven children were taken from each school where then subject to testing by QMRA instrument. Considering individual schools the total percent of children with metal levels above ULNCC was 65.4%. This value is cannot be overlooked.

| S/No | School playground Codes | Land use | No of Children on role | Cases of heavy metals above normal range | Percent children with metal above normal range |
|---|---|---|---|---|---|
| 1. | HEO | R | 470 | 00 | 00 |
| 2. | MNO | R | 1260 | 00 | 00 |
| 3. | SCP | GRA | 326 | 17 | 5.2 |
| 4. | CSO | Busy high way | 241 | 39 | 16 |
| 5. | TSO | Busy high way | 276 | 35 | 12 |

| | | | | | |
|---|---|---|---|---|---|
| 6. | WSP | NP | 579 | 25 | 4.3 |
| 7. | WBP | R/CC | 387 | 16 | 4.1 |
| 8. | IKS | NP | 470 | 29 | 6.2 |
| 9. | UPS | NP | 125 | 22 | 17.6 |
| R: residential area; GRA: government residential area; R/CC: Residential/ commercial area; NP: Nigeria police station | | | | | |

**Table 1:** List of schools land use and cases of metals above normal range.

## Heavy Metal in Children's Body in 2012

(Figures 1 to 9 shows) bar charts of metal concentration in children's body in 2012. Metal concentrations in children at HOE were plotted as each metal in all children (Figure 1) showed that Nickel was highest for all children and highest amongst all five metals followed by Cobalt. At HOE the depressing order of metal concentration in children was Ni > Co > Zn > Cu > Mn. Figure 2 shows that an overall total concentration of cobalt was slightly higher than Ni. Again, Mn was the least amongst all five metals in children at MNO. The decreasing order of metal in children for MNO was Co > Ni > Zn > Cu > Mn. Figure 3 again shows Nickel to top the list amongst five metals in children's bodies at CSO and was closely followed by Cobalt. The order of decreasing metal concentration in children's body at CSO was Ni > Co > Zn > Cu > Mn. Figure 4 shows bar chart of metals concentration in children's bodies at SCP. Results are much similar to those in CSO above. However, copper was the lowest metal for children at CSO. The order of decreasing metal concentration here was Ni > Co > Zn > Mn > Cu. (Figure 5) shows metals in mg/kg concentrated in children's body for TSO. Result shows that Mn was the least as have been seen in children of other playgrounds. Here the decreasing order of metals was Ni > Co > Zn > Cu > Mn (Figure 6). Shows that Nickel was the highest metal in children as WSP while Mn the lowest. However, the concentration of Mn and Zinc were much elevated in than WSP. The order of decreasing concentration of metals in children at WSP was Ni > Co > Zn > Mn > Cu (Figure 7). Shows that Ni was highest followed by cobalt and Zn while copper was lowest at WBP. Decreasing order of metals concentration was Ni > Co > Zn > Mn > Cu (Figure 8). Shows similar bar charts for metals concentration in children at IKS Nickel again was highest while copper was lowest. The decreasing order was Ni > Co > Zn > Mn > Cu. At UPS metal concentration in children was in the decreasing order of Ni > Co > Zn > Mn > Cu.

Copper was lowest in children's body at SCP, WBP and UPS while Magnesium was lowest in children's body at HOE, MNO, CSO, TSO and WSP.

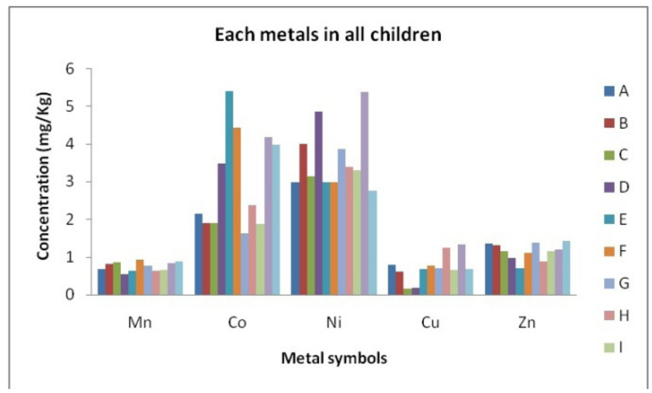


**Figure 1:** HM concentration in children at HEO.

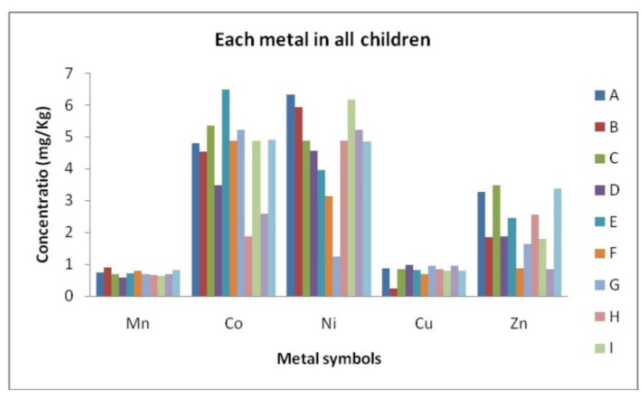


**Figure 2:** HM concentration in children at MNO.

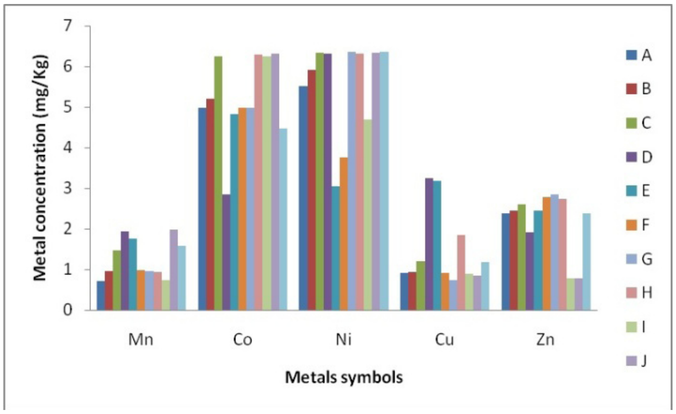


**Figure 3:** HM concentration in children at CSO.

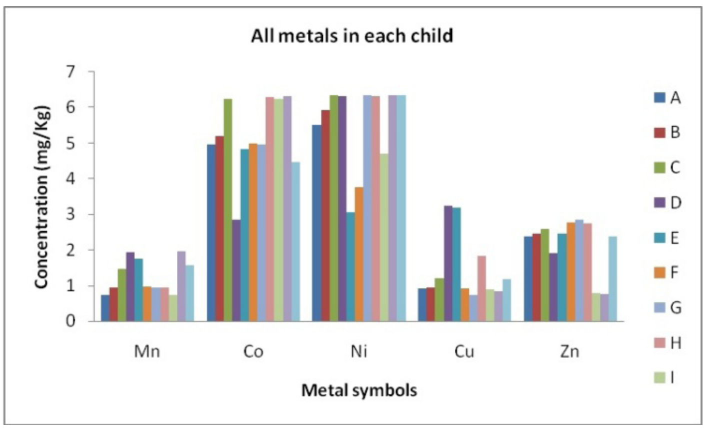


**Figure 4:** HM concentration in children at SCP.

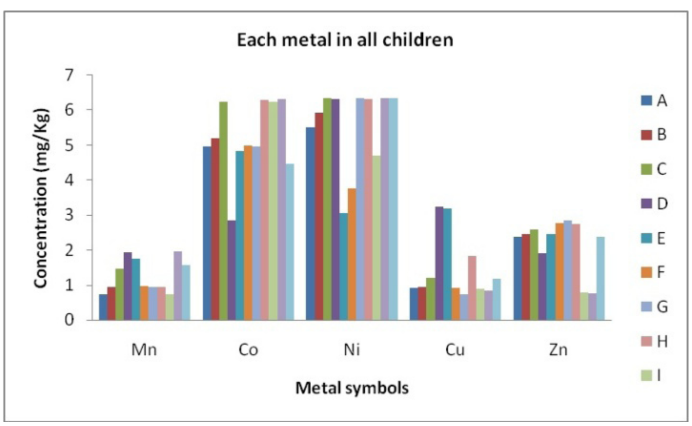


**Figure 5:** HM concentration in children at TSO.

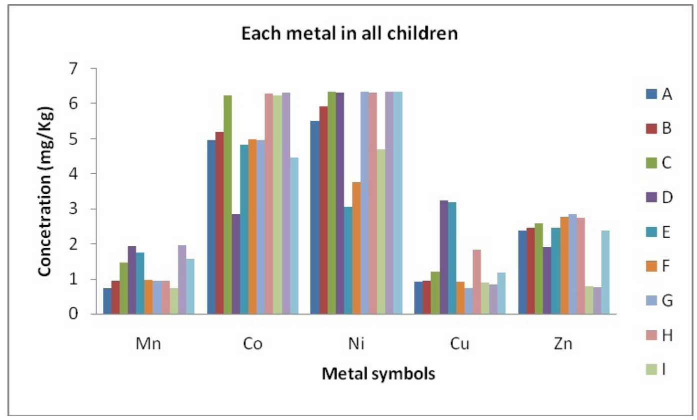


**Figure 6:** HM concentration in children at WSP.

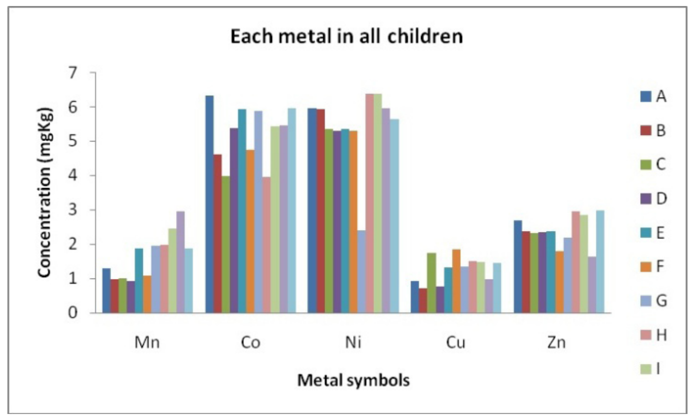


**Figure 7:** HM concentration in children at WBP.

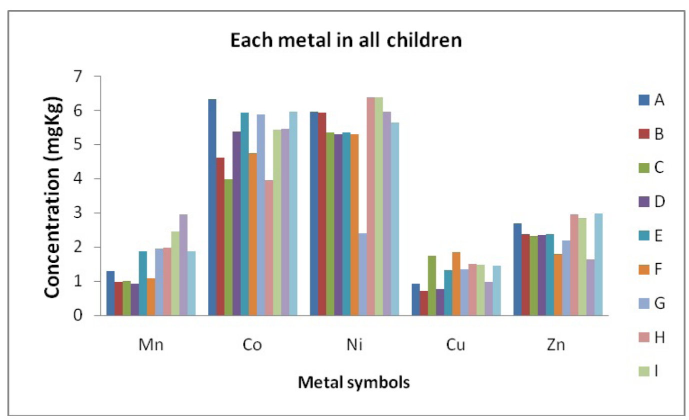


**Figure 8:** HM concentration in children at IKS.

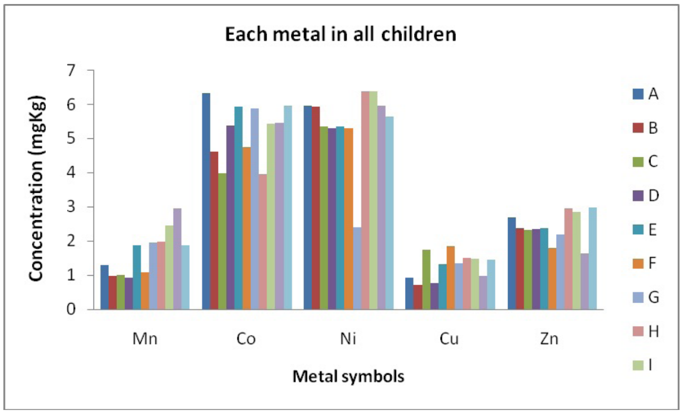


**Figure 9:** Heavy metals concentration in children at UPS.

## Heavy Metal in Children's Body in 2013

The concentrations of heavy metals in children's body were plotted against each child for HEO (Figure 10). The bar chart shows that Nickel was the highest metal except child F, G and L where cobalt was highest. Copper was the lowest metal in the body of children where child C had the lowest concentration of copper. The decreasing of metals in children was Ni > Co > Zn > Mn > Cu (Figure 11). Shows that Nickel was highest in five children while cobalt followed as highest in four children the order of decreasing concentration for metals in children at MNO was Ni > Co > Zn > Mn > Cu (Figure 12). Shows that nickel was highest overall and child B had the high concentration whereas in child C and E nickel compared well with cobalt. The concentration of metals in children at SCP for 2013 showed the decreasing order Ni > Co > Zn > Mn > Cu (Figure 13). Shows the concentration of metal in children at CSO in 2013 as expected, Ni topped the chart followed by cobalt. The decreasing order was Ni > Co > Zn > Mn > Cu (figure 14). In the concentrations of metals in children's body at TSO are shown in the bar chart. Nickel was highest overall and highest for child A, B, G, H, J, K while cobalt was highest for child C and D. The order of decreasing concentration for TSO children was Ni > Co > Zn > Mn > Cu (Figure 15). Shows that metal concentration in children could be ranked in decreasing order out WSP as follows: Ni > Co > Zn > Mn > Cu in child D and E copper was highest than other metals except Nickel (Figure 16). Shows that Nickel was highest followed closely by cobalt. The decreasing order of metal concentration in children at WBP was Ni > Co > Zn > Mn > Cu. At IKS (figure 17) it was deduced that the decreasing order was Ni > Co > Zn > Mn > Cu. Values of Ni and Zn were generally high at IKS.

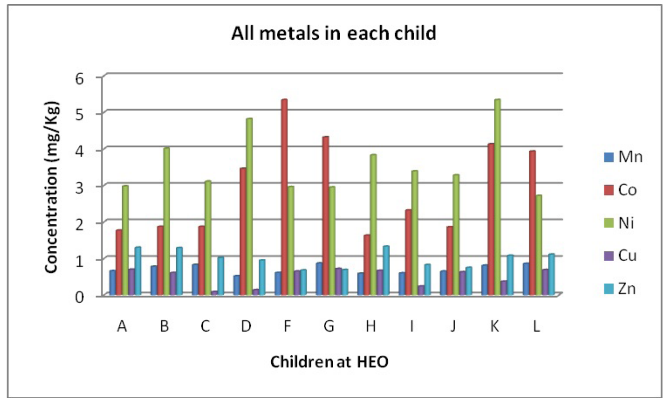


**Figure 10:** HM concentration in children at HOE.

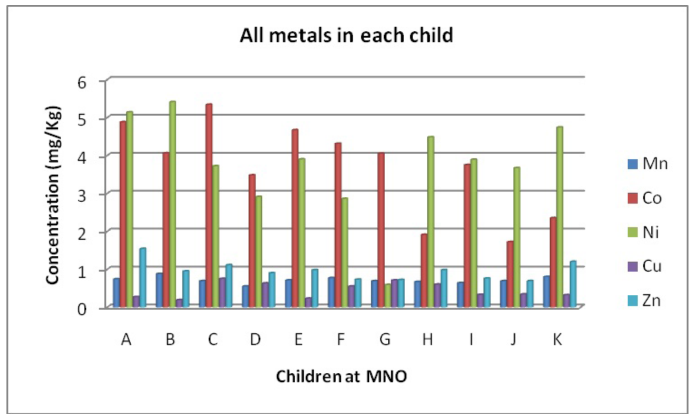


**Figure 11:** HM concentration in children at MNO.

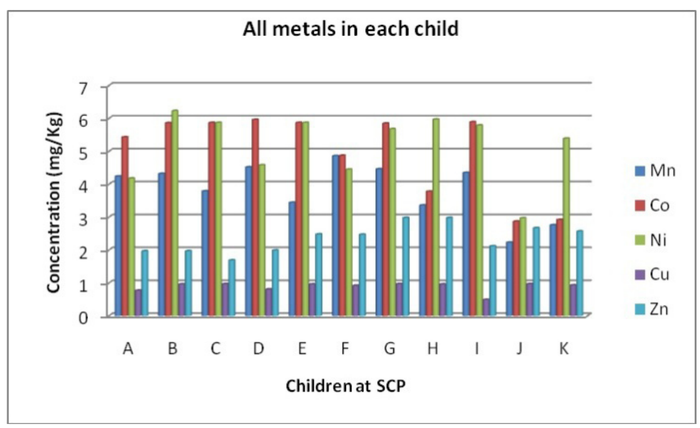


**Figure 12:** HM concentration in children at SCP.

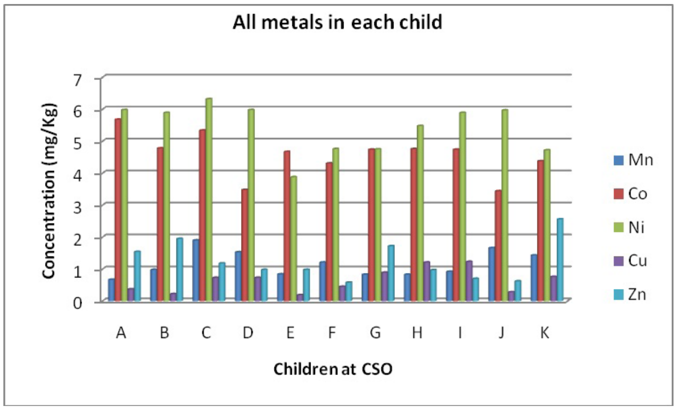


**Figure 13:** HM concentration in children at CSO.

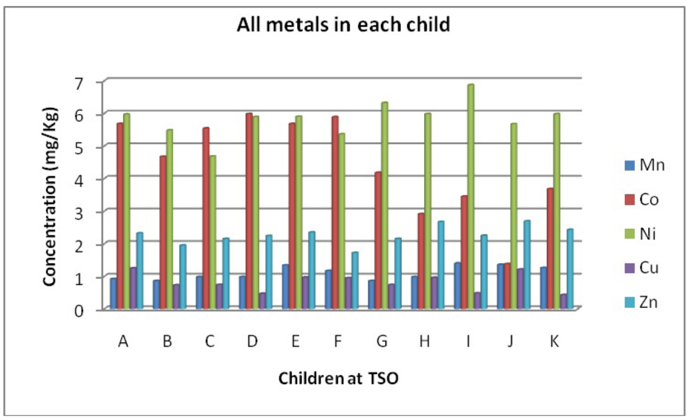


**Figure 14:** HM concentration in children at TSO.

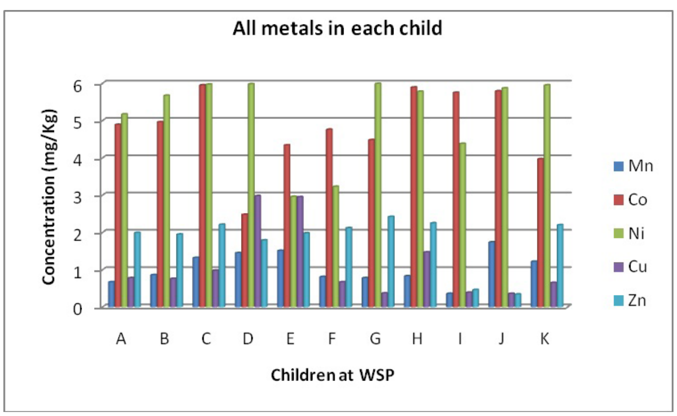


**Figure 15:** HM concentration in children at WSP.

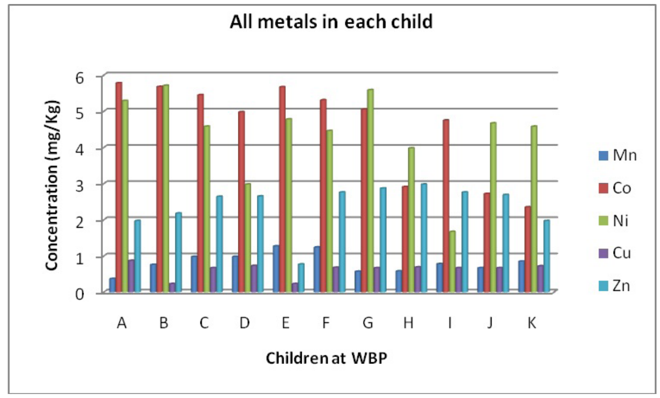


**Figure 16:** HM concentration in children at WBP.

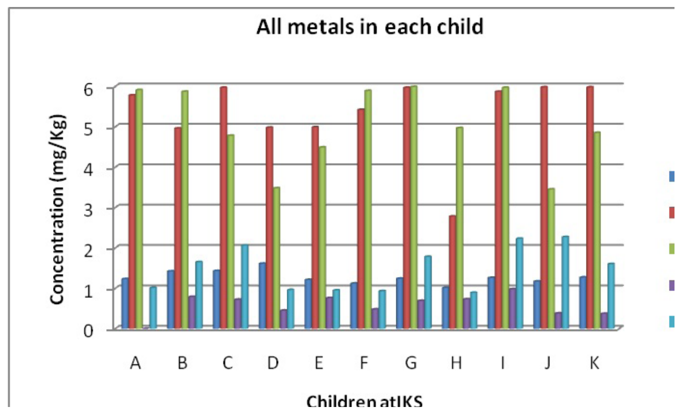


**Figure 17:** HM concentration in children at IKS.

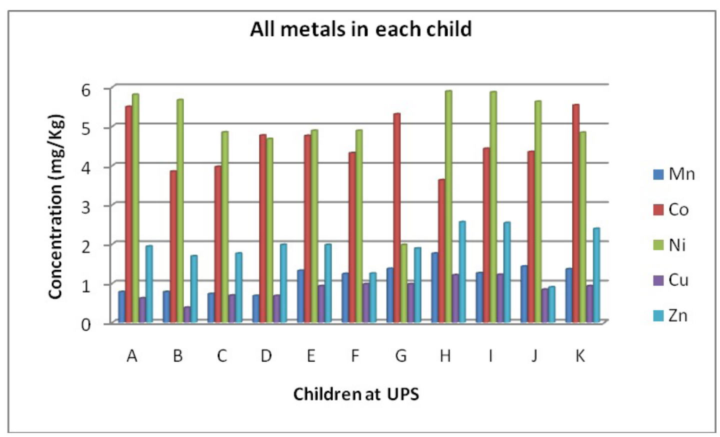


**Figure 18:** HM concentration in children at UPS.

The concentration of metals at UPS show that nickel was highest as usual followed by zinc. Copper and magnesium values here were higher than for many playgrounds. Mean values of heavy metals in children for March, 2012 and Feb-March 2013 have been summarized in (table 5).

Manganese ranging from 0.71 mg/Kg for HEO to 3.94 mg/Kg for CSO with an average value of 1.59 mg/Kg, cobalt had a ranged from 3.58 mg/Kg for HEO to 6.23 mg/Kg for TSO; copper ranged from 0.50 mg/Kg for HEO to 1.23 mg/Kg for IKS and Zinc ranged from 1 mg/Kg for HEO to 2.67 mg/Kg for CSO. It was observed that children at playground HEO had lowest content in their bodies amongst all others. From the average metal concentration in children's bodies during Feb – March, 2013 those playgrounds could be ranked in order of decreasing concentration as follows CSO>IKS>TSO>UPS>WSP>WBP>SCP>MNO>HEO. Ranking metals in decreasing order of average concentration in children gives Ni > Co > Zn > Mn > Cu. Ni (5.18 mg/Kg) > Co (4.18 mg/Kg) > Zn (2.18 mg/Kg) > Mn (1.59 mg/Kg) > Cu (1.02 mg/Kg): Feb – March, 2013. Results of analysis summarized in (table 5). For Feb-March, 2013 for body concentrations of heavy metals in children's body indicate that Magnesium ranged from 0.81 mg/Kg at TSO to 2.39 mg/Kg at WBP. Ranking children at various playgrounds in order of decreasing body metal concentration was observed as follows:

SCP>WSP>IKS>UPS>TSO>CSO>WBP>MNO>HEO

Considering average metal concentration in children's body, the ranking of metals was observed to follow the trend: Ni (4.67 mg/Kg) > Co (4.08 mg/Kg) > Zinc (1.55 mg/Kg) > Mn (1.31 mg/Kg) > Cu (1.28 mg/kg) compared with Upper Limit of Normal Concentration in Children's body's (ULNCC).

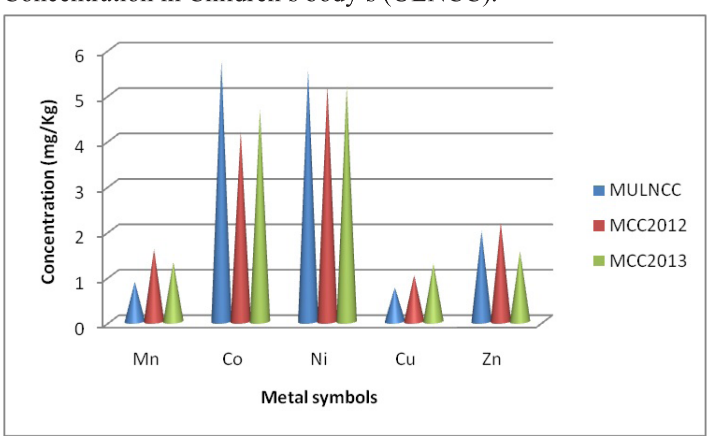


**Figure 19:** Average metal in children and upper limit of normal concentration in children's body's (ULNCC).

Figure 19 compares the average metal concentration in children's body for 2012 and 2013 with the upper limit of metal concentration in children according to QMRA model 918.The bar chart shows that magnesium was higher in both 2012 and 2013 than the ULNCC. As pointed out by WHO 1981; Needleman, 1987 and Newman, 2008, excess magnesium in children may be linked to low IQ and low growth amongst other factors such as carbohydrate and lipid metabolism associated problems. Average cobalt concentration for 2012 and 2013 in children of all playground public schools studied were lower than ULNCC of 5.73 mg/Kg even though figure 19 shows that Cobalt during 2013 was higher than for 2012, values were significant (P > 0). With increasing commercial activities, burning of refuse and other anthropogenic activities Cobalt concentrations may likely reach upper limits within a near future. Average Nickel concentrations in 2012 and 2013 in children's body at all nine playgrounds were 5.18 mg/Kg and 4.67 mg/Kg respectively. These values were slightly lower than ULNCC. Average Copper concentrations in Children's body for 2012 and 2013 were higher than nickel limit of normal concentration in children of 0. 1 mg/Kg. Figure 19 equally Shows that Nickel content in Children within public schools in the municipality compared well for 2012 and 2013. Average Zinc concentration in children was higher than for 2013. However, the ULNCC of 1.99 mg/Kg was higher than average Zinc concentration in 2013. The value for average Zinc concentration in Children in 2012 of 2.18 mg/Kg is likely a problem for the children.

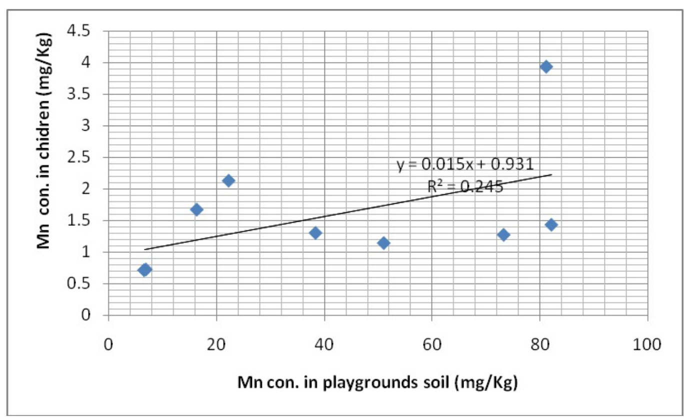


**Figure 20:** Mn in children soil against Mn.

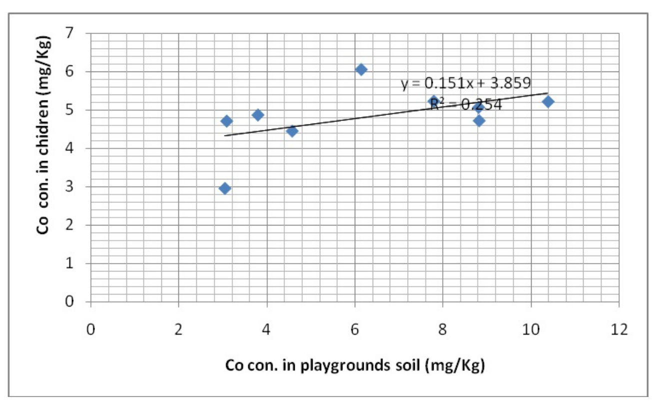


**Figure 21:** Con in soil against cobalt in children.

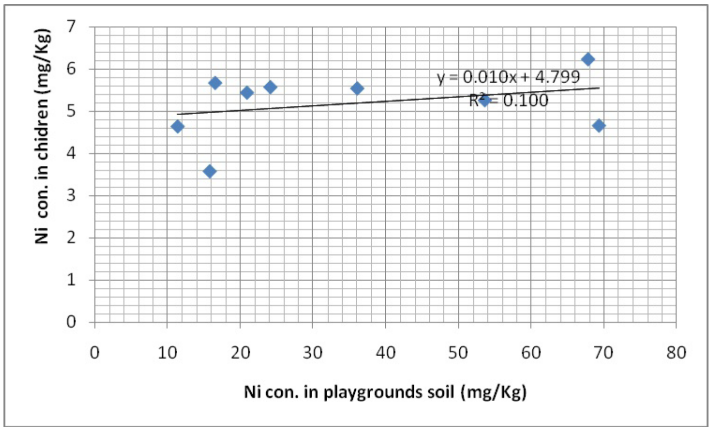


**Figure 22:** Ni in soil against nickel in children.

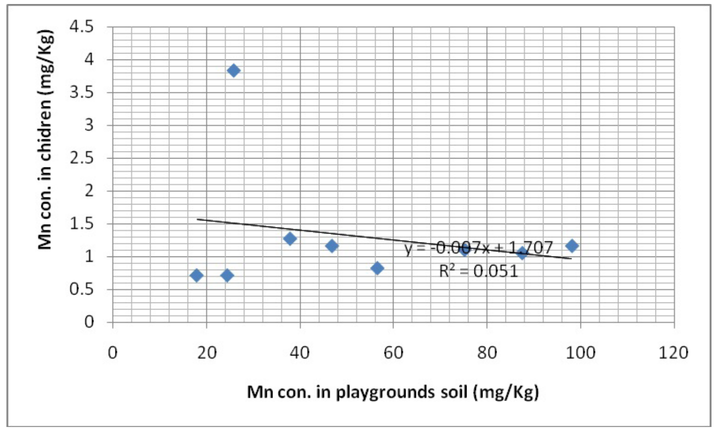


**Figure 25:** Mn in soil against manganese in children.

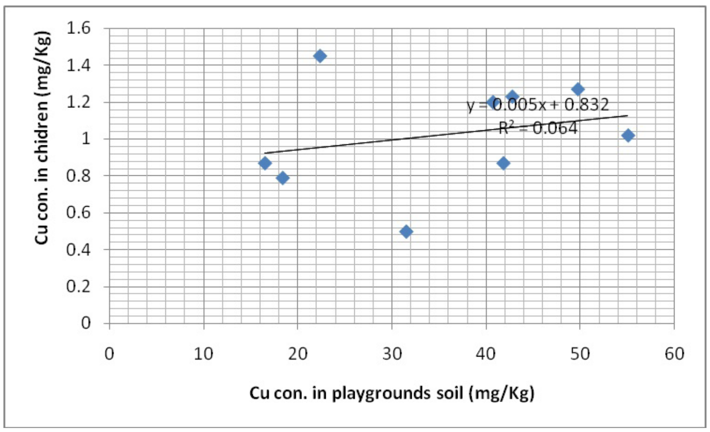


**Figure 23:** Cu in soil against copper in children.

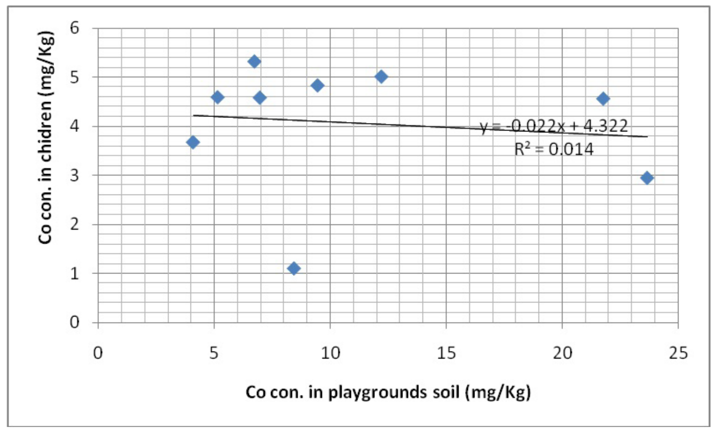


**Figure 26:** Con in soil against cobalt in children.

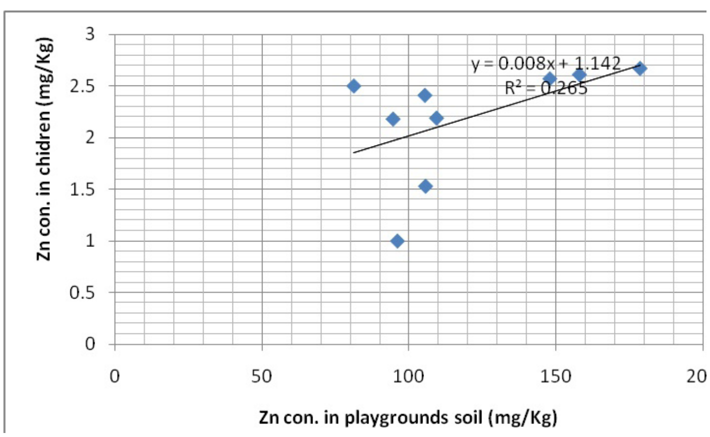


**Figure 24:** Zn in soil against zinc in children.

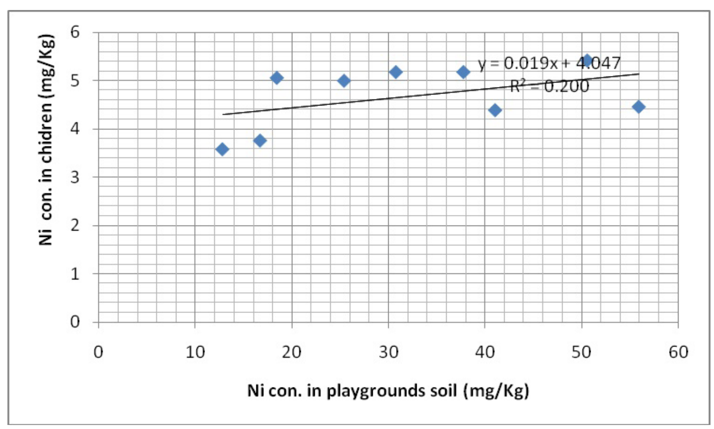


**Figure 27:** Ni in soil against nickel in children.

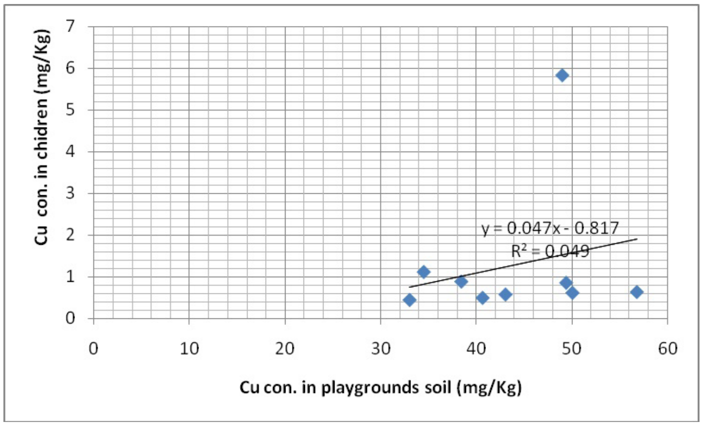


**Figure 28:** Cu in soil against copper in children.

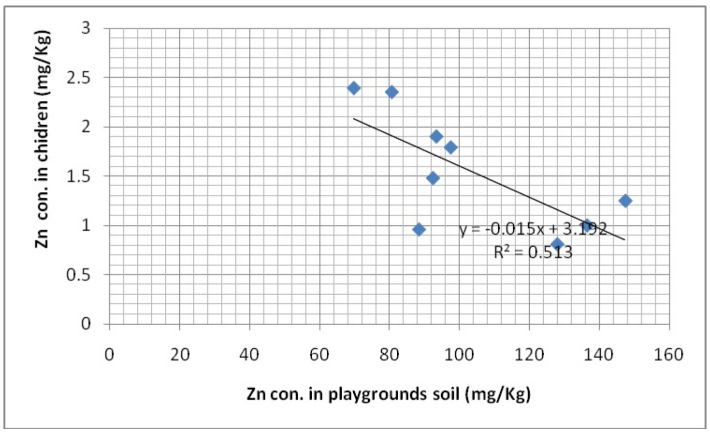


**Figure 29:** Zn in soil against zinc in children.

In order to find out the extent to which metal concentrations in playgrounds soil relate to metals concentration in children figures 20 to 29 were plotted. Result showed that all five metals concentrations in children correlated with metals concentrations in playground soils. However, Mn, Co and Zn had weak negative correlation in 2013 whereas all others had weak positive correlations with the highest being zinc ($R^2 = 0.264$) in 2012. The weak correlation could be so because uptake of metals into children's body could occur not only from ingestion of soil during play but through foods, fruits and from playing with toys for instance [7]. 2013 determined nickel concentrations of 1.76 mg/Kg in pineapple (*Ananas cosmosus*) and 2.65 mg/Kg in beans (*Phaseolus vulgaris*) which is one of the common fruits in Owerri municipality. Until the current investigation, data on metal levels in children and surface soil of children's playground from the area under study were scarce. Therefore, current results should be of a special interest as reference values in future evaluations of the playground soils, which we deemed very necessary.

## Conclusions

From the analysis and examination of data in this work the following conclusions were made in most of the nine playgrounds, all children had Ni as the highest metal concentration while Cu and Mn were the lowest in some cases. Children in playgrounds of public schools within Owerri municipality could be at risk of Mn, Cu and Zn toxicity problems. Even at MNO where the trend in metal was radically different, Zn was still the third metal in all children. Three trends were observed in metal concentration in the year 2012, dominated by Ni>Co>Zn>Mn>Cu, where as all playgrounds showed same trend in 2013 Ni>Co>Zn>Mn>Cu. Even though they were all weak correlations, metals concentrations in soil had either a positive or a negative correlation with metal concentrations in children.

## Recommendation

As a way of monitoring the influence of playgrounds on children's body level of heavy metals this study underlines the need for replicating periodic studies. More detail work is required such that urine and even blood samples be used to ascertain the actual situation as concerns heavy metals levels in children.

## Competing interests

The authors' confirms that there is no conflict of interest regarding the submitted manuscript.

## Authors' contributions

E N collected prepared the consent letter and meet the head teachers and parents, she also studied the use of the MRA analyzer and helped perform the analytical determinations, acquired and analyzed data and contributed to the writing of the manuscript and revision. AW organized the experimental setting, supervised the work and wrote the manuscript.

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