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Assessment of Health Risk of Pollutants in Surface Soil And Road Dust From E-Waste Recycling/Dismantling Areas in Lagos

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Abstract- 12 soil and dust samples were collected from the e-waste recycling and dismantling locations in Lagos with a view to assess the health risk associated with these study sites. The digestion of the soil and dust samples was carried out using aqua regia prior to the determination of heavy metal by MP-AES. The e-waste soils were the most contaminated with higher concentration of trace metals compared to the road side soils and indoor dust. Lawanson and Alaba e-waste soils had the highest concentration of Cu (4147.71µg/g and 1820.30 µg/g) respectively; lowest concentration of Cu was from Westminister e-waste soil (32.61µg/g). Agbara Morogbo e-waste soil had the highest concentration of Cd-(662.47µg/g), Pb-(791.03µg/g) and As-(258.75µg/g). The lowest concentration of Cd-(22.46µg/g) and Pb-(54.73µg/g) was from Alaba e-waste soil. Lawanson road side soil was the most contaminated with trace metals (As-74.31µg/g; Cd-254.89µg/g; Cu-2263.84µg/g; Pb-312.67µg/g) compared to other road side locations. Lawanson indoor dust was the most polluted dust with Pb and Westminister indoor dust contain the highest level of Cd (126.71 µg/g). The highest and lowest As levels (58.76µg/g and 0.87µg/g) were from Alaba and Agbara Morogbo indoor dust respectively. Agbara Morogbo indoor dust had the highest concentration (910.98µg/g) of Cu. Tessier's sequential extraction method was used to determine the degree of pollution and partition the trace elements in the most contamination soil (Lawanson e-waste and road side soils). The health risk assessment of the heavy metals in Lawanson soil and dust predicted that children are of higher risk of serious health problems than adults in the future.

Keywords— Microwave plasma-atomic emission spectrometer (MP-AES), Westminister, e-waste, soil, dust, Lawanson, Alaba, Agbara Morogbo, heavy metal.

I. INTRODUCTION

The extensive use of electric and electronic equipment (EEE) for everyday needs in a wide range of applications has led to the production of large volumes of electronic waste (e-waste) all around the globe. E-Waste is chemically and physically distinct from other forms of municipal or industrial waste; it contain intricate blends of plastics and chemicals, which when not properly and carefully handled can be dangerous to people and the environment (16).

The composition of e-waste is very diverse and differs in products across different categories. It contains more than 1000 different substances, which fall under 'hazardous' and 'non-hazardous' categories. The presence of elements like lead, mercury, arsenic, cadmium, selenium and hexavalent chromium and flame retardants beyond threshold quantities in e-waste classifies them as hazardous waste (19).

Recycling can recover valuable components and base materials, especially Cu and precious metals. However, due to lack of facilities, high labour costs, and strict environmental regulations, rich countries tend not to recycle e-wastes. Instead, it is either landfilled, or exported from rich countries to poor countries, where it may be recycled using primitive techniques and little regard for worker safety and environmental protection (8).

Studies have revealed that heavy metals present in the soil not only diminish the productivities and qualities of crops but also threaten the safety of ecosystem and human health (26). Plants can absorb these metals from soil by their roots, transport them upwards to their shoots, and finally accumulate them inside their tissues. Different plant species have large variation in terms ofmetal accumulation ability (17, 18). In addition, direct foliar uptake of heavy metals from the atmosphere can also take place during plant growth (6).

Oral ingestion of contaminated food has been proved to be an important pathway for the transfer of heavy metals from the environment to human bodies. Studies on the accumulation of heavy metals from rice, and organic pollutants from vegetables grown around uncontrolled e-waste recycling sites have shown high levels of Pb, Cd, organic pollutants such as polybrominated biphenyls (PBBs), Polybrominated diphenylethers (PBDEs), and Polychlorinated bipheny (PCBs) in these local food samples (10, 33).

Indoor dust around e-waste sites can give information about the level, distribution, and fate of contaminants present in the environmental surface. The composition of settled dust which is similar to atmospheric suspended particulates can be an indicator of pollutants such as heavy metal contamination in the atmosphere (3, 28). The level of heavy metal concentration may be evaluated from the level of dust deposition per unit area and metal concentrations in the deposit (15).

Two recent studies carried out in Guiyu, China have demonstrated elevated body loadings of heavy metals (14) and persistent toxic substances (7) in children and e-waste workers, respectively. Although there are insufficient data on the impact e-waste environmental assessment in the Africa region, a recent study in Nigeria has demonstrated high concentrations of heavy metals such as copper, nickel, zinc and lead in soils far in excess of European Union limits at e-waste dump sites in Lagos, Benin, and Aba cities in Nigeria (24).

Nigeria is presently undergoing rapid development in information and communication technology (ICT) with very important part of ICT users relying on used equipment from developed countries, particularly from Europe and North America due to the poor economic status of many Nigerians. It was estimated and established that about 400,000 units of second-hand desktop computers (PCs or CRTs) are imported into Nigeria every month (21).

II. EXPERIMENTAL

Sample collection and preparation

Top soil samples and dust samples were collected from four different dismantling and recycling e-waste sites in Lagos. These sites with their abbreviation include Lawanson site (LS), Alaba Market site (AS), Agbara Morogbo site (AMS) and Westminister site (WS). Three samples were taken from each of the site and these include the E-waste soil sample (ES), road side soil sample (RS) and indoor dust sample (DS). Soil from farmland soil (FS) was sampled and taken as control. The four metals studied were copper, arsenic, lead and cadmium. Each of the samples was air dried at room temperature by spreading on polyethylene sheet in the laboratory for about two weeks. The air-dried soils were passed through a stainless-steel sieve with a 2mm mesh size in order to remove stones and other particles larger than 2mm.

The samples with particle size less than 2mm were stored in sealed glass containers for subsequent analysis of physiochemical parameters such pH, conductivity, cation exchange capacity; determination of trace metal concentration and sequential extraction of the metals.

pH and Conductivity

20g of soil sample and 1g of dust were weighed and dissolved in 0.1M KCl solution. The pH and conductivity of each sample solution was determined using HQ440D pH/mV Multi-Meter (HACH).

Determination of Cation Exchange capacity of soil and dust

2 g each of soil and dust samples were weighed and 10 ml of 0.5M Magnesium acetate (pH 7.0) was added and the mixture was shaken for 5 min, this was to saturate the soil and dust with magnesium. The solution was centrifuged for 5 min and the supernatant discarded. This was repeated three times, giving a total of four treatments. 10 ml of a 0.25 M magnesium chloride was then added and shaken for 1 min, centrifuged for 5 min and supernatant discarded. 10 ml of 1:2 water: acetone was added and shaken for 1 min, centrifuged for 5 min and supernatant discarded. 10 ml of 0.5M sodium chloride was added to the soil, shaken for 1 min, centrifuged for 5 min and the supernatant liquid kept in a clean 250ml conical flask. This was repeated three times, the saved supernatant was the magnesium test solution. 10 ml buffer solution of ammonium chloride-

ammonium hydroxide added to the solution in the conical flask, 10 drops of erichrome black T, 5 drops of methyl red and 10 drops of 10% sodium cyanide were also added. The solution was then titrated with 0.025 M EDTA in which the colour of the solution changed from red orange to deep grey which indicate the end point. The volume of the EDTA used was recorded to the nearest 0.01 ml (2).

Sample Digestion and Analysis

1 g of soil and dust sample was weighed into 500ml Kjeldahl flask and 12ml of aqua regia (i.e 3:1) was added. This was made into a suspension and placed on a hot plate to boil gently for about 2 hours. The digestion was completed when the solution turns light in colour. The flask was removed and content allowed to cool. The mixture was filtered through Whatmann 42 filter paper into 50 ml standard flask. The filtrate was diluted to mark using distilled water. Agilent 4100 Microwave Plasma-Atomic emission spectrometer was used to determine the trace metals (Pb, Cu, As, and Cd) in the sample solution at their various wavelength.

Sequential Extraction of metals (29)

(i) Exchangeable Fraction: The sediment was extracted at room temperature for 1 h with 8 mL of either magnesium chloride solution (1M MgCl,, pH 7.0) or sodium acetate solution (1M NaOAc, pH 8.2) with continuous agitation.

(ii) Bound to Carbonates: The residue from (i) was leached at room temperature with 8 mL of 1 M NaOAc adjusted to pH 5.0 with acetic acid (HOAc). Continuous agitation was maintained and the time necessary for complete extraction was evaluated.

(iii) Bound to Fe-Mn Oxides: The residue from (ii) was extracted with 20 mL of either 0.3 M Na2S204+ 0.175 M Na-citrate + 0.025 M H-citrate, or 0.04 M NH2OH-HCl in 25% (v/v) HOAc. The latter experiment,s were performed at 96±3°c with occasional agitation and the time needed for complete dissolution of the free iron oxides was evaluated.

(iv) Bound to Organic Matter: To the residue from (iii) were added 3 mL of 0.02 M HN03 and 5 mL of 30% H2O2 adjusted to pH 2 with HNO3 and the mixture was heated to 85± 2 °C for 2 h with occasional agitation. A second 3-mL aliquot of 30% H2O2 (pH 2 with HNO3) was then added and the sample was heated again to 65±2°c for 3 h with intermittent agitation. After cooling, 5 mL of 3.2 M NH4OAc in 20% (v/v) HNO3 was added and the sample was diluted to 20 mL and agitated continuously for 30 min.

(v) Residual: The residue from (iv) was digested with aqua regia for total metal analysis.

Health Risk Assessment

The average daily dose (ADD) (mg/kg/day) of a pollutant that can be contacted via soil/road dust through ingestion (ADD ingest), absorbed through the skin (ADD dermal) and inhalation (ADD inhale) as pathways can be calculated using the below equation (30):

$$\text{ADD Ingest} = \frac{\text{C x InR x EF x ED x CF}}{\text{BW x AT}}$$

$$\text{ADD Dermal} = \frac{\text{C x SA x AF x ABS x EF x ED x CF}}{\text{BW x AT}}$$

$$\text{ADD Inhale} = \frac{\text{C x InR x EF x ED}}{\text{PEF x BW x AT}}$$

C- Mean heavy metal concentration (Mg/kg)
InR- Dust ingestion rate (100mg/day for adults and 200mg/day for children)
EF- Exposure frequency 260working days/yr
ED- Exposure duration (6yrs for children; 24yrs for adults)
BW- Average body weight (60kg for adult;15kg for children)
AT- Average time (ED x 260days)
CF- Conversion factor (1 x 10-6kg/mg)
SA- Surface area of the skin that contact the soil (cm2) Adults-3300cm2 Children- 2800cm2
AF- Soil Skin adherence factor for soil (0.2mg/cm2)
ABS- Dermal absorption factor 0.001
Inhale R- Inhalation rate (m3/day) 20m3/day for both adults and children
PEF-Particle emission factor (1.36x109m3/kg)

A hazard quotient (HQ) for non-cancer risk was calculated to make the comparison with the health guideline and was determined by the relation: HQ= ADD/RfD. The reference dose (RfD) in the above equation is the estimates of daily exposure below which adverse non-cancer health effects are unlikely. If the $HQ<1$, then noncancerous effects are unlikely. If the $HQ \geq 1$, then adverse health effects might be possible.

III. RESULTS AND DISCUSSION

pH, conductivity and CEC

The pH results of the e-waste and road side soil samples from all the sampling sites was between 7.31-8.67 which is weakly alkaline. The alkaline nature of the soil may be as a result of natural background of the soil. This pH results were in agreement with the observations of Ofudje et al., 2014 (23). The conductivity of the e-waste and road side soils ranged between 709-4450μs/cm. The pH of the dust samples was between 7.10-7.93 which is neutral to weakly alkaline. The conductivity of the dust sample is between 9410-15320μs/cm indicating more of free ions in the dust than the soil samples.

The CEC results in Table 1- (E-waste-Soil samples) and Table 2- (Road soil samples) were lower than the CEC level of a normal fertile soils is due to the high level of heavy metals present forming complex with the exchangeable base elements (Na, Mg, Ca and K) in the soils. This effect may be due to ligand competition of heavy metal cation (4).

Sample	pH	Cond.(µs/cm)	CEC (meq/100g)
LES	7.79	1014	5.38
AMES	8.4	2840	4.13
AES	8.08	2380	4.22
WES	8.24	2810	3.75
Control	6.33	2013	15.5

Table 1: Physiochemical results for e-waste soil

Table 2: Physiochemical results for road side soil

Sample	pH	Conduc.µs/cm	CEC (meq/100g)
LRS	8.25	709	3.88
AMRS	8.67	1521	4.38
ARS	8.55	3520	2.13
WRS	7.31	4450	2.88

Sample	pH	Cond.(µs/cm)	CEC (meq/100g)
LD	7.91	15320	29.25
AMD	7.77	9410	1.25
AD	7.37	12090	11.13
WD	7.93	12710	4.25

Table 3: Physiochemical results for indoor dust

Mean of heavy metals concentration in e-waste soils, road side soil and indoor dust.

The results of heavy metal concentration in e-waste soil in all the site locations are shown in Table 4. The results showed that the concentration of arsenic ranged from ND-258.75 µg/g; cadmium 22.66-662.47µg/g; lead 54.73-791.03µg/g and copper 4.87-4147.71µg/g. The lowest concentration (27.76µg/g) of As was from Westminister e-waste soil (WES) while the highest concentration (258µg/g) of As was from Agbara Morogbo e-waste soil (AMES). This is due to the fact cleaning and burning activities in WES are well monitored and controlled than AMES. The highest concentration of Cu (4147.71µg/g) was found in Lawanson E-waste soil. This can be attributed to the fact that the LES site is more contaminated with Cu which is released from the discarded electronic materials and during dismantling and burning of electronic gadgets thereby causing damaging effects to the people's health and environment. The concentration of Cu-metal in the LES location is above the safe level (80-200mg/kg) set by USEPA. Westminister e-waste soil (WES) because of the cleanliness of the site had the least Cu concentration of 32.61µg/g. Agbara morogbo (AMES) was most contaminated site with Pb-metal with concentration level of 791µg/g. This is might be caused by the incineration and burning of electronic equipment releasing Lead compounds in the surrounding. Reports have also shown that Pb levels in soil appear to be readily affected by anthropogenic factors (11, 20). Short-term exposure to Pb could result in diarrhea, vomiting, convulsion or coma, while long term exposure could result in kidney and nervous damage, cause brain and blood disorder and could leads death. Alaba E-waste soil (AES) is the least contaminated with Pb concentration of 54.73µg/g. The highest concentration (662.47µg/g) of

Cd was from Agbara Morogbo e-waste soil (AMES) while the lowest concentration (22.46µg/g) of Cd was from Alaba e-waste soil (AES). Cadmium is highly toxic to plants, animals and humans, having no known biochemical or nutritional function (5,31).

Exposure can result in bioaccumulation of cadmium in humans. Table 5 showed the mean concentration of heavy metals in road soil samples. The ranges of heavy metal analyzed are Cu- 4.87-2263.84µg/g; Pb-12.58-312.67µg/g; Cd-11.76-254.89µg/g and As-ND-74.31µg/g. Lawanson road side soil (LRS) had the highest concentration and greatest pollution level of all the trace metals analyzed when compared to other road side soil locations. Apart from the e- waste recycling and dismantling going on in LRS, other activities such traffic emission and congestion, vehicular movement etc. can also contribute to the high values of heavy metals concentration. Table 6 revealed the concentration of metals in indoor dust samples. The highest concentration (58.76µg/g) of As was from Alaba indoor dust (AD).This may be due to many broken and dismantled circuit boards, semiconductors, LCD displays and computer chips found in the indoor shop which release arsenic compounds. The indoor dust from Agbara morogbo (AMD) had the highest concentration (910.98µg/g) of Cu and the least concentration of Cu (87µg/g) was from Alaba indoor dust. Westminister indoor dust (WD) had the highest concentration (126.71µg/g) of Cd than other indoor dust locations. This value was remarkably higher than that reported for surface dust in e-waste components by Adaramodu et al., 2012 (1). The Pb concentration levels (135.94µg/g) in Lawanson indoor dust (LD) were higher compare to other indoor dust locations. The higher concentration of Pb in the indoor could be assumed to be as a result of contribution of e-waste to the overall Pb concentration in indoor dust. This is to say that there is interaction between e-waste and dust deposited on them over time. Pb exerts toxic effects on various systems in the body such as the central and peripheral nervous systems, the hemopoietic system (anemia), the genitourinary system (capable of causing damage to all parts of the nephron) and the reproductive systems (male and female). However, the Pb concentration (135.94µg/g) value from LD still falls within the safe limit (300mg/kg) set by USEPA.

Sample	Arsenic	Cadmium	Copper	Lead
LES	153.46±0.94	517.71±0.14	4147.71±0.48	465.39±0.42
AMES	258.75±0.15	662.47±0.15	441.79±0.05	791.03±0.34
AES	58.02±0.30	22.46±0.02	1820.30±0.34	54.73±0.07
WES	27.76±0.30	28.87±0.01	32.61±0.01	61.87±0.06
Control	ND	87.75±0.02	4.87±0.01	80.04±0.09

Table 4: Mean concentration of metals in e-waste soil

Sample	Arsenic	Cadmium	Copper	Lead
LRS	74.31±1.15	254.89±0.11	2263.84±0.30	312.67±0.15
AMRS	26.83±0.12	22.62±0.04	9.52±0.02	28.64±0.05
ARS	62.27±0.22	11.76±0.06	11.99±0.01	34.08±0.05
WRS	ND	20.07±0.02	6.21±0.01	12.58±0.06

Table 5: Mean concentration of metals in road side soil

Sample	Arsenic	Cadmium	Copper	Lead
LD	ND	96.52±0.08	113.30±0.02	135.94±0.05
AMD	0.87	52.71±0.01	910.98±0.09	27.48±0.03
AD	58.76±0.50	67.10±0.02	87.00±0.02	54.56±0.03
WD	ND	126.71±0.06	104.02±0.01	95.82±0.07

Table 6: Mean concentration of metals in indoor dust

Correlation Analysis of CEC and heavy metals in the soils and indoor dust

In Table 7 (e-waste), all the metals displayed positive correlation with CEC. Cu showed strong positive correlation compared other metals. The positive correlation of the metals with CEC implies the reduction of CEC in the e-waste soil increase with increase in the concentration of the metals. Pb showed strong positive correlation with As and Cd; Cd showed strong positive correlation with As. The positive correlation among the metals suggests they were likely to originate from the same sources. Observation similar to this was reported by Ofudje et al., 2015 (24).

In Table 8 (road side soil), all the metals displayed weak positive correlation with CEC except As. The negative correlation of As with CEC implies there was no significant association between them. Pb showed strong positive correlation with As, Cd and Cu; Cu showed strong positive correlation with As and Cd.

In Table 9 (Indoor dust), As and Cu displayed negative correlation with CEC; Pb showed strong positive correlation with CEC. All the metals displayed negative correlation with each other except Pb and Cd. The negative correlation among the metals indicates that they have no common source of contamination.

	CEC	*As*	*Cd*	*Cu*	*Pb*
CEC	1				
As	0.304	1			
Cd	0.490	0.961	1		
Cu	0.967	0.0952	0.270	1	
Pb	0.312	0.991	0.979	0.0860	1

Table 7: Correlation between CEC and metals in E-waste soil

	CEC	*As*	*Cd*	*Cu*	*Pb*
CEC	1				
As	-0.036	1			
Cd	0.404	0.635	1		
Cu	0.376	0.660	0.999	1	
Pb	0.368	0.702	0.996	0.998	1

Table 8: Correlation between CEC and metals in road side soil

	CEC	*As*	*Cd*	*Cu*	*Pb*
CEC	1				
As	-0.026	1			
Cd	0.194	-0.391	1		
Cu	-0.530	-0.344	-0.658	1	
Pb	0.797	-0.347	0.739	-0.696	1

Table 9: Correlation between CEC and metals in indoor dust

Speciation results of Lawanson e-waste soils, road side soil and indoor dust

In Table 10, Cu metal is more predominant in each of the fractions compare to other metals. Its average percentage (50.39%) being very high in the Fe/Mn oxide fraction. This fraction could be considered relatively stable (slowly mobile and poorly available) but could change with variations in redox conditions and less under oxidizing ones (13). Since the mobility of a metal is related to its toxicity, an increase in reducing condition in the soil could increase toxicity. Cu was also found high in Organic matter (27.42%).

High Cu in organic fraction of soil extract has been reported by others (12, 27). Cu percentages in other fractions are Organic matter-27.42%, Residual-20.56%, Carbonates-1.36% and exchangeable-0.26%. Pb had the least percentage in the exchangeable fraction makes it less available for uptake by living organisms and plant in the environment. The percentage of exchangeable fraction in Pb reported by Okuo et al., 2011 (25) in electronic waste was higher than this study. In Table 11, Cu was more bound to the Fe/Mn oxide fraction (49.64%) compare to other fractions which is a similar occurrence to the e-waste soil but less in percentage. Its average percentage in the organic matter is 38.68%. High percentage abundance of metals in the Fe-Mn oxide phase has been reported to be influenced by the high concentration of Fe-Mn minerals in the soil (9) and may limit the mobility and bioavailability of heavy metals attached to these mineral. Cd also found more pronounced in Fe/Mn oxide (48.52%) and residual (48.18%) fractions but less associated with the exchangeable (0.15%) and organic matter (2.38%). As had highest percentage concentration (63.43%) in Fe/Mn oxide fraction but the least concentration (0%) was from the organic fraction making more mobile and available in the soil thereby posing threat to the ecosystem. Table 12 showed that Pb is appreciably high in most of fractions compared to other metals except in the organic matter fraction. It is bulkier (54.09%) in the residual fraction and has the least amount (5.30) in the exchangeable. Cu was more attached to the organic matter fraction than Pb. The highest percentage (74.52%) of Cu in the organic matter fraction can make it relatively immobile in the sediments and less bioavailable in organic soil.

Metals	**Exchangeable**	**Carbonates**	**Fe/Mn Oxide**	**Organic Matter**	**Residual**
As	1.9	4.35	34.14	ND	119.51
Cd	0.62	2.92	119.58	ND	279.2
Cu	11.09	58.92	2175.054	1183.752	887.94
Pb	10.43	10.87	101.71	13.44	305.08

Table 10: Concentration (µg/g) of heavy metals in different fractions (E-waste)

Metals	**Exchangeable**	**Carbonates**	**Fe/ Mn Oxide**	**Organic Matter**	**Residual**
As	4.27	5.36	32.85	ND	9.31
Cd	0.37	1.83	118.4	5.83	117.56
Cu	2.48	22.69	645.14	502.68	126.76
Pb	10.51	10.67	128.12	13.46	125.53

Table 11: Concentration (µg/g) of heavy metals in different fractions (Road side soil)

Metals	**Exchangeable**	**Carbonates**	**Fe/Mn Oxide**	**Organic Matter**	**Residual**
As	ND	0.78	7.71	ND	25.78
Cd	1.39	2.08	32.43	5.01	78.04
Cu	2.15	0.87	26.94	130.65	14.71
Pb	9.96	10.46	45.82	20.12	101.73

Table 12: Concentration (µg/g) of heavy metals in different fractions (Indoor dust)

Health Risk Assessment

The average daily intake of heavy metal via several exposure pathways by adults and children is shown in Table 13, 14, 15. The hazard quotient (HQ) as shown in the Table 16 was calculated from the average daily intake and reference dose to evaluate cancer and non-cancer risks in adult and children. It has been established that if HQ ≥ 1 is an indication of risk of cancer hazard.

In Table 13, the average daily dose (ADD) intake for all the heavy metals for adults via ingestion is lower than the reference doses for ingestion. This occurrence is same for the heavy metals' intake for adult via dermal contact and inhalation. The calculated hazard quotients (HQ) based on the lower values of ADD via the various exposure routes in relation to the reference doses are lower than one which is an indication of lower risk of cancer and chronic diseases in adults. The reverse is the case for children. The ADD ingestion of trace metals for children is greater than the reference dose for ingestion. ADD dermal and inhalation routes for children are lower in values compared to their reference's doses. The calculated HQ in Table 16 for all the metals in children via ingestion are greater than one which indicate that children in the e-waste soil site have higher risk of chronic diseases than adults' Similar results were reported by Xiao et al., 2017 (32). In Table 14, the ADD intake of trace metals in adults via the various pathways is similar to what occurred in the e-waste soil. The ADD intake of heavy metals for children via ingestion was high compared to the reference dose but lower in the intake of Cu. In Table 16, the HQ values for children are lower in Cu (0.75) but high in As (3.3), Cd (3.4) and Pb (1.2). Children in the road side soil have more exposure to arsenic and cadmium than other metals which can increase their risk of cancer, lung damage, high blood pressure and kidney damage.

In Table 15, the ADD results revealed that no risk of arsenic exposure in all the routes both in children and adults. The ADD values of trace metals for adults in all the exposure pathways were lower than the reference doses which make calculated HQ lower than one thereby lowering the risk of diseases in adults. For children, ADD values intake was only high for Cd but lower in Cu and Pb and calculated HQ showed that Cd had value (1.3) greater than one compared to Cu (0.04) and Pb (0.51). Adaramodu et al., 2012 (1) reported high value of Cd in children in the risk assessment of heavy metal exposure of surface dust in e-waste components.

CONCLUSION

The analysis results revealed that the concentration of heavy metals was higher in e-waste soil and road soil samples compared to the dust samples indicating high toxicity level in the people around soil area. The speciation results revealed that the trace metals from the e-waste soils and road side soils were more bound and had higher concentration in the various fractions than the indoor dust. The health risk assessment shows that hazard quotient values of the metals were found greater than 1 in children than in adults. This suggested that children around the e-waste soil, road side soil and indoor dust run a greater risk of metal toxicity and can contact diseases in the polluted environment.

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Table 14: Average daily dose (ADD) of heavy metal in Road soil via various exposure pathways

Metal	RDIn	RDd	RDInh	ADULT In	CHILDREN In	ADULT dm	CHILDREN dm	ADULT Inh	CHILDREN Inh
As	$3x10^{-4}$	$1.23x10^{-4}$	$3.01x10^{-4}$	$1.2X10^{-4}$	$9.9X10^{-4}$	$8.2x10^{-7}$	$2.8x10^{-6}$	$1.8X10^{-8}$	$7.3X10^{-8}$
Cd	$1x10^{-3}$	$1x10^{-5}$	$2.4x10^{-6}$	$4.2X10^{-4}$	$3.4X10^{-3}$	$2.8x10^{-6}$	$9.5x10^{-6}$	$6.2X10^{-8}$	$2.5X10^{-7}$
Cu	$4x10^{-2}$	$1.2x10^{-2}$	$4.02x10^{-2}$	$3.8X10^{-3}$	$3.0X10^{-2}$	$2.5x10^{-5}$	$8.5x10^{-5}$	$5.5X10^{-7}$	$2.2X10^{-6}$
Pb	$3.5x10^{-3}$	$5.25x10^{-4}$	$3.52x10^{-4}$	$5.2X10^{-4}$	$4.2X10^{-3}$	$3.4x10^{-6}$	$1.2x10^{-6}$	$7.7X10^{-8}$	$3.1X10^{-7}$

Metal	RDIn	RDdm	RDInh	ADULT In	CHILDREN In	ADULT dm	CHILDREN dm	ADULT Inh	CHILDREN Inh
As	$3x10^{-4}$	$1.23x10^{-4}$	$3.01x10^{-4}$	$2.6x10^{-4}$	$2x10^{-3}$	$1.7x10^{-6}$	$5.7x10^{-6}$	$3.7X10^{-8}$	$1.5X10^{-6}$
Cd	$1x10^{-3}$	$1x10^{-5}$	$2.4x10^{-6}$	$8.6x10^{-4}$	$6.9x10^{-3}$	$5.7x10^{-6}$	$1.9x10^{-5}$	$1.7X10^{-7}$	$5.1X10^{-7}$
Cu	$4x10^{-2}$	$1.2x10^{-2}$	$4.02x10^{-2}$	$6.9x10^{-3}$	$5.5x10^{-2}$	$4.6x10^{-6}$	$1.5x10^{-4}$	$1.0X10^{-6}$	$4.7X10^{-6}$
Pb	$3.5x10^{-3}$	$5.25x10^{-4}$	$3.52x10^{-4}$	$7.8x10^{-4}$	$6.2x10^{-3}$	$5.1x10^{-5}$	$1.7x10^{-6}$	$1.1X10^{-7}$	$4.6X10^{-7}$

Table 15: Average daily dose (ADD) of heavy metal in

Metal	RDIn	RDd	RDInh	ADULT In	CHILDREN In	ADULT dm	CHILDREN dm	ADULT Inh	CHILDREN Inh
As	$3x10^{-4}$	$1.23x10^{-4}$	$3.01x10^{-4}$	ND	ND	ND	ND	ND	ND
Cd	$1x10^{-3}$	$1x10^{-5}$	$2.4x10^{-6}$	$1.6X10^{-4}$	$1.3X10^{-3}$	$1.1X10^{-6}$	$3.6X10^{-6}$	$2.4X10^{-8}$	$9.46X10^{-8}$
Cu	$4x10^{-2}$	$1.2x10^{-2}$	$4.02x10^{-2}$	$1.9X10^{-4}$	$1.5X10^{-3}$	$1.2X10^{-6}$	$4.2X10^{-6}$	$2.8X10^{-8}$	$1.1X10^{-7}$
Pb	$3.5x10^{-3}$	$5.25x10^{-4}$	$3.52x10^{-4}$	$2.3X10^{-4}$	$1.8X10^{-3}$	$1.5X10^{-6}$	$5.1X10^{-6}$	$4.5X10^{-8}$	$1.3X10^{-7}$

Dust samples via various exposure pathways