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Determination of heavy metals and other elements in surface dust from e-waste and human health risk assessment at Agbogbloshie

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ABSTRACT

This study was aimed at assessing the concentrations of heavy metals and other elements in surface dust at Agbogbloshie, where crude methods are used for e-waste processing. Dust samples were collected from fourteen locations within Agbogbloshie including the dismantling site and burning site of the scrap market. The X-ray fluorescence spectroscopy (XRF) was used to evaluate the concentrations of the heavy metals and other elements in the samples. Heavy metals such as Zn, Cu and Pb gave concentrations in the range of (422.54 – 181752.94mg/kg), (101.83 – 9144.50mg/kg) and (117.03 – 14448.46mg/kg). All these concentrations and that of most elements exceeded the New Dutch List Action Values (for which intervention is required) over thousand times. The road surface, dismantling site, burning site and the Domod office recorded very high concentrations of heavy metals. The Ayalolo cluster of schools also gave alarming concentrations of heavy metals. Assessment of human heath risk of these heavy metals indicated that, exposure to dust through dermal contact posed the highest health risk to children under 6 years. Hg was the only element which indicated a higher risk through the inhalation of vapour. The hazard indices (HI) computed indicated that the values from all the sites were above the safe level of one. The dismantling site gave the highest HI value of 882.57 for Pb from all the sites. Further research work on health risk assessment should be conducted for those directly involved in the recycling activities.

Introduction

Electronic waste (e-waste) refers to an end of life electronic products including computers, printers, photocopy machines, television sets, mobile phones toys which are made of sophisticated blends of plastics, metals, among other materials (UNEP, 2005). E-waste is increasing as the global market of electronics is growing exponentially. Recent statistics indicate that the total annual global volume of waste electrical and electronic equipment (WEEE) is soon expected to reach 40 million metric tonnes (UNU, 2007). The disposal and recycling of electronic and electric waste (e-waste) pose a threat to the environment and to human health, especially in developing counties but is also a new economic opportunity. E-waste contains valuable metals (Cu, Pt, Au) as well as potential environmental contaminants especially Lead, Mercury, Cadmium, Nickel, Antimony, Polybrominated diphenyl ethers (PBDEs) and polybrominated biphenyl ethers (PCBs). Burning e-waste may generate dioxins, furans, polycyclic aromatic hydrocarbons (PAHs) polyhalogenated aromatic hydrocarbons (PHAHs) and hydrogen chloride (Brigden et al., 2007). WEEE is thus important not only in terms of its quantity but also in terms of its toxicity (Hicks et al., 2005; Widmer et al., 2005). There is uncontrolled e-waste recycling and disposal leading to possible contamination from heavy metals and toxic elements from these products. Such reprocessing initially results in extreme localized contamination followed by migration of the contaminants into receiving waters and food chain. E-waste workers suffer negative health effects through skin contact and inhalation while the wider community is exposed to the contaminants through smoke, dust drinking water and food (Huo et al., 2007, Bi et al., 2007, HRA2008, Leung et al., 2008). Ghana has not been spared this menace and has e-waste recycling activities scattered all over the country especially in Accra, the capital city. Unspecified quantities of e-waste are brought into the country under the guise of bridging the digital divide. Recent data indicates that Ghana imports 215 thousand tons of EEE out of which 70% is second hand. About 20% of this figure is complete junk. Most of these are not functioning and therefore have to be disposed off. Functioning parts are removed and used to refurbish or repair other equipment. What is left ends up in the hands of recyclers who use primitive methods to recover useful metals for economic gains. A study by Brigden et al., 2008 by which Agbogbloshie, a suburb of Accra (and a major commercial centre) was labelled an e-waste hot spot determined the workplace exposure to chemical contaminants from the recycling process. However, the study did not determine the human health risk of these contaminants. At Agbogbloshie, computers and TV sets are the main e-wastes processed at the scrap yard. These are manually dismantled at numerous small workshops within the market. Some parts are burned to remove valuable metals from plastics. Materials of no value are dumped along with other waste. Much of the work is being carried out by children, with no protective equipment, using basic tools or bare hands. During this process, metals and non-metals released are deposited and transported in dust. Dust is a significant environmental medium that can provide information about the level, distribution and fate of contaminants present in the surface environment. As the

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composition of settled dust is similar to atmospheric suspended particles, it can be an indicator of pollutants such as heavy metal contamination in the atmosphere. In an investigation by Leung et al. (2008) into the presence of seven heavy metals in dust of printed circuit boards of recycling workshops in Guiyu, the levels of Pb, Cu and Zn were found to be very high. Further more, the elemental composition and concentration in dust reflected the characteristics of short and long term activities in the area. Humans can become exposed to heavy metals through several routes which include ingestion, inhalation and dermal absorption. In dusty environments, it has been estimated that adults could ingest up to 100 mg dust/day. Children are usually exposed to greater amounts of dust than adults as a result of pica and play behaviour. The daily dose intake of heavy metals for children are determined through three routes of exposure (ingestion, inhalation and dermal contact).

Dose intake through inhalation of dust [D (inh)] particles is given by the relation

$$Dinh\,(mg/kg/day) = C(mg/kg)\,\frac{InhR * EF * ED}{PEF * BW * AT} \qquad InhR * EF * ED$$

Where C is the concentration of elements in the sample,
PEF is the particulate Emission Factor (m3/kg), InhR is the inhalation rate (m3/day),
EF is the exposure frequency (d/y),
ED is the exposure duration (years),
BW is the body weight (kg)
AT is the averaging time (days),
C is the concentration of elements in the sample
Dose intake by dermal contact [D (derm)] is given by

$$Dderm\,(mg/kg/day) = C(mg/kg)\,\frac{SA * SL * ABS * EF * ED}{BW * AT} * 10^{-6}$$

SA is the exposed surface area (cm^2/day),
SL is the skin adherence factor,
ABS is the skin absorption factor,
EF is the exposure frequency (days/year),
ED is the exposure duration (years),
BW is the body weight (kg),
AT is the averaging time (days),
C is the concentration of elements in the sample.
Dose intake by ingestion [D(ing)] of dust particles is given by
C is the concentration of elements in the sample,
IngR is ingestion rate (mg/day),
EF is the exposure frequency (days/year),
ED is the exposure duration (years),
BW is the body weight (kg),
AT is the averaging time (days)
To determine the non-cancer risk of exposure, the following relation was used
HQ = DI/RFD
Where
HQ is the hazard quotient for a particular route of exposure,
DI is the dose intake by a given route of exposure,
RfD is the reference dose for a particular element through a particular exposure.

The hazard index was calculated to determine the overall risk of exposure through ingestion, inhalation and dermal by the relation;

$$HI = HQ(inh) + HQ(ing) + HQ(derm)$$

Where
HI is the hazard index and
HQ (inh, ing and derm) represents the hazard quotients for inhalation, ingestion and dermal routes of exposure respectively.

Materials and methods

Site selection and sample collection

The study area, Agbogbloshie is located in Accra, the capital city of Ghana. It covers approximately four acres and is situated on the banks of the Korle Lagoon, northwest of Accra's central business district. The principal consideration for the selection of the site was the scrap market which is widely recognized as an electronic waste dump site after the publication of the report by Greenpeace international (Brigden et al., 2008). Agbogbloshie is popularly known to be a commercial area having a lot of human activities for most of the day. In this respect, there is a likelihood of both children and adults being exposed to suspended dust particles from the scrap market.

Sample collection

Samples were collected from fourteen sites including the dismantling site, burning site and a road using a soft touch brush and plastic dust pan kept in pre-cleaned self-sealed polythene bags. Each sample was collected with a new brush and dust pan to avoid cross contamination. About 500g of sample was collected at each site and stored in Ziploc bags for transport to the laboratory. The specific geographic location of the sampling sites was obtained from GPS reading.

Sample preparation and analysis

Daily dust samples collected from each site were air dried and homogenously mixed to form a composite sample. the samples were sieved using a mesh (metric test sieve BS410 VS Tyler) with geometric diameter 100µm. The analysis was restricted to the size fraction below 100µm because particles of such nature are known to be suspended by air. The sieving was done on a mechanical shaker (Retsch AS 200) for 30 minutes at amplitude of 10mm/g. 10g of the samples were made into thick sample pellets of diameter 2.5cm using the hydraulic press (hydraulic Specac press) with an applied load of 10 metric tons.

Results and Discussion

Action: Minimum concentration for which intervention is required; Optimum: Minimum concentration at which no remediation is required.BSS1: Burning site; BSS2: Road dust; BSS3: Rooms of nearby houses; BSS4: Ayalolo cluster of schools; BSS5: Market; BSS6: Ayalolo community clinic; BSS7: Dismantling site;BSS8: Lorry station; BSS9: Mosque; BSS10: Saloon; BSS11: Stores within the Market; BSS12:1ST class financial investment ltd; BSS13: MTN office; BSS14: In front of Domod office.

Table 1a and 1b represents the mean concentration of elements in dust. The results show that the concentrations of most the metals exceeded the New Dutch List Optimum value (VROM, 2010) and action values in some cases. The concentration of Pb in surface dust ranging between 117.03mg/kg and 14448.46mg/kg with the highest value recorded at the dismantling site where the electronic equipments are dismantled to recover metals of interest. This concentration is about two thousand times more than the action value of 530 for which intervention required. The second highest recorded value for Pb was at the burning site. Pb is known to cross the blood-brain barrier and exerts its toxic effect on children such as lowering of IQ and can cause cancer later in life (Atiemo et al., 2012).

Table 1a: Mean Element concentrations of Dust

Elements(mg/kg)

Sample Location	**K**	**Ca**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**
BSS1	15270.00	89956.67	28590.44	bdl	361.12	2116.19	218276.67	6714.26	613.22
BSS2	28800.00	101273.33	10525.65	698.44	bdl	1145.29	70923.33	bdl	258.94
BSS3	13770.00	38570.00	4474.83	bdl	89.21	662.69	50250.00	bdl	88.25
BSS4	13493.62	59840.00	4601.10	bdl	434.45	660.10	54130.00	bdl	150.47
BSS5	9273.33	80036.67	5275.12	bdl	255.03	677.23	53113.33	bdl	129.87
BSS6	14890.00	51626.67	4410.64	bdl	176.76	507.43	36873.33	bdl	73.08
BSS7	19169.91	155576.67	25643.33	bdl	2754.96	2946.51	279600.00	3436.00	821.88
BSS8	21306.67	94903.33	6579.90	346.51	95.09	933.44	49393.33	bdl	127.27
BSS9	11808.67	43400.00	7345.75	428.47	127.87	447.96	94983.33	bdl	98.98
BSS10	11346.90	48280.00	8103.26	389.07	117.20	441.45	96583.33	bdl	102.97
BSS11	14952.86	46270.00	5523.55	334.24	151.63	448.73	57603.33	bdl	94.44
BSS12	16993.33	37010.00	2965.80	bdl	147.28	344.69	25443.33	bdl	71.56
BSS13	19880.00	35963.33	5836.13	220.87	128.42	634.03	69633.33	bdl	109.06
BSS14	12110.00	38930.00	10204.80	bdl	298.25	1469.30	164655.00	bdl	203.17
OPTIMUM					100			20	35
ACTION					380			240	210

bdl=below detection limit

Table 1b: Mean Element concentrations of dust continued

				Elements				
Sample Location	**Zn**	**As**	**Br**	**Rb**	**Sr**	**Zr**	**Hg**	**Pb**
BSS1	181752.94	bdl	741.38	62.33	394.26	1470.93	bdl	7263.17
BSS2	3546.13	bdl	80.56	143.52	815.74	2597.65	bdl	973.84
BSS3	985.24	bdl	19.49	29.14	182.82	837.53	bdl	458.74
BSS4	1200.47	bdl	15.67	35.31	219.69	815.74	bdl	407.59
BSS5	1194.37	bdl	43.12	37.38	248.71	916.62	bdl	386.12
BSS6	461.03	bdl	12.15	39.58	214.57	852.93	bdl	179.13
BSS7	34408.26	bdl	5088.54	109.51	686.81	1430.08	22.58	14448.46
BSS8	2159.61	bdl	30.72	59.68	415.79	1042.67	bdl	538.41
BSS9	836.59	bdl	23.12	33.54	245.22	872.02	bdl	326.77
BSS10	934.41	bdl	62.00	39.25	263.18	935.58	bdl	329.00
BSS11	972.89	16.84	24.22	35.79	199.08	786.22	bdl	251.10
BSS12	422.54	bdl	23.65	33.06	146.55	522.69	4.75	385.57
BSS13	1603.36	bdl	33.37	49.21	201.51	1410.05	bdl	117.03
BSS14	4276.45	67.27	29.30	41.76	206.14	1000.38	bdl	2106.47
OPTIMUM	140	29					0.3	85
ACTION	720	55					10	520

Table 2.1: Hazard Quotient for Dermal Absorption

Sample Location	Element												HI
	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Hg	Pb	
BSS1	0.00	21.50	4.12	0.78	1.50	0.41	1.68	10.84	0.00	0.01	3.85	50.78	95.47
BSS2	35.71	0.00	2.23	0.25	0.00	0.17	0.18	0.21	0.00	0.02	0.00	6.65	45.43
BSS3	0.00	5.32	1.29	0.18	0.00	0.06	0.12	0.06	0.00	0.00	0.00	1.25	8.27
BSS4	0.00	26.00	1.28	0.19	0.00	0.10	0.08	0.07	0.00	0.01	0.00	2.78	30.51
BSS5	0.00	15.22	1.32	0.19	0.00	0.09	0.08	0.07	0.00	0.01	0.00	2.63	19.60
BSS6	0.00	10.60	0.99	0.13	0.00	0.05	0.03	0.03	0.00	0.01	0.00	1.22	13.06
BSS7	0.00	164.33	5.73	1.00	0.77	0.54	2.73	2.05	0.00	0.02	0.00	98.52	275.70
BSS8	17.71	5.67	1.82	0.18	0.00	0.08	0.12	0.13	0.00	0.01	0.00	3.68	29.39
BSS9	21.86	7.63	0.87	0.34	0.00	0.07	0.25	0.01	0.00	0.01	0.00	2.23	33.26
BSS10	19.86	6.99	0.86	0.35	0.00	0.07	0.05	0.06	0.00	0.01	0.00	3.39	31.63
BSS11	17.14	9.05	0.88	0.21	0.00	0.06	0.05	0.06	0.49	0.01	0.00	1.71	29.65
BSS12	0.00	8.78	0.67	0.09	0.00	0.05	0.03	0.03	0.00	0.00	0.81	2.63	13.09
BSS13	11.30	7.67	1.23	0.25	0.00	0.07	0.11	0.10	0.00	0.01	0.00	0.80	21.53
BSS14	0.00	17.83	2.86	0.59	0.00	0.13	0.16	0.26	1.96	0.01	0.00	14.36	38.16

Table 2.2: Hazard Quotient for Ingestion

Sample location	Element												HI
	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Hg	Pb	
BSS1	0.00	0.15	0.06	0.28	0.43	0.04	0.18	0.77	0.00	0.00	0.10	2.65	4.67
BSS2	0.13	0.00	0.03	0.09	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.36	0.66
BSS3	0.00	0.04	0.02	0.06	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.17	0.31
BSS4	0.00	0.19	0.02	0.07	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.15	0.46
BSS5	0.00	0.11	0.02	0.07	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.14	0.36
BSS6	0.00	0.08	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.21
BSS7	0.00	1.17	0.08	0.36	0.22	0.05	0.29	0.15	0.00	0.00	0.00	5.28	7.60
BSS8	0.06	0.04	0.03	0.06	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.20	0.42
BSS9	0.08	0.05	0.01	0.12	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.12	0.40
BSS10	0.07	0.05	0.01	0.12	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.12	0.40
BSS11	0.06	0.06	0.01	0.07	0.00	0.01	0.01	0.00	0.07	0.00	0.00	0.09	0.39
BSS12	0.00	0.06	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.14	0.28
BSS13	0.04	0.05	0.00	0.09	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.04	0.25
BSS14	0.00	0.13	0.04	0.21	0.00	0.01	0.02	0.02	0.29	0.00	0.00	0.77	1.48

Table 2.4: Hazard Quotient for inhalation

Sample Location	Element												HI
	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Hg	Pb	
BSS1	0.00	0.61	0.07	11765.11	361.90	33.05	302.89	9796.48	0.00	21.25	1.22	391.48	27079.90
BSS2	37.65	0.00	0.04	3822.77	0.00	13.96	31.82	191.14	0.00	43.97	0.00	52.49	4562.92
BSS3	0.00	0.00	0.06	2708.48	0.00	4.76	21.14	53.10	0.00	9.85	0.00	24.73	3955.73
BSS4	0.00	0.01	0.02	2917.61	0.00	8.09	14.03	64.71	0.00	11.84	0.00	21.97	7731.81
BSS5	0.00	0.00	0.02	2862.81	0.00	7.00	14.62	64.38	0.00	13.41	0.00	20.81	5831.63
BSS6	0.00	0.00	0.02	1987.47	0.00	3.94	6.26	24.85	0.00	11.57	0.00	9.66	4030.34
BSS7	0.00	0.05	0.1	15070.44	185.20	44.30	492.9	1854.61	0.00	37.02	0.00	778.77	47826.99
BSS8	18.68	0.00	0.03	2662.30	0.00	6.86	21.01	116.40	0.00	22.41	0.00	29.20	101019.32
BSS9	23.09	0.00	0.00	5119.60	0.00	5.34	11.16	45.09	0.00	13.22	0.00	17.61	6698.31
BSS10	20.97	0.00	0.01	5205.84	0.00	5.55	9.17	50.36	0.00	14.19	0.00	17.73	6674.86
BSS11	18.02	0.00	0.02	3104.82	0.00	5.09	9.39	52.44	0.91	10.73	0.00	13.53	4923.42
BSS12	0.00	0.00	0.01	1371.40	0.00	3.85	5.49	22.77	0.00	7.90	0.26	20.78	3062.53
BSS13	11.90	0.00	0.02	3753.24	0.00	5.88	19.4	86.42	0.00	10.86	0.00	6.31	5422.85
BSS14	0.00	0.01	0.05	8874.90	0.00	10.95	29.35	230.50	3.63	11.11	0.00	113.54	12493.62

Table 4: Hazard Index for the three exposure pathways

Sample location	Name of Elements											
	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Hg	Pb
BSS1	0.00	22.27	4.25	76984.27	2.50	33.50	304.75	9808.10	0.00	21.26	5.16	444.92
BSS2	73.49	0.00	2.30	3823.11	0.00	14.15	32.01	191.36	0.00	43.99	0.00	59.49
BSS3	0.00	10.16	1.31	2708.72	0.06	4.82	21.26	53.17	0.00	9.85	0.00	26.14
BSS4	0.00	26.19	1.32	27.52	0.00	8.21	14.11	64.78	0.00	11.85	0.00	24.90
BSS5	0.00	15.33	1.36	2863.07	0.00	7.09	14.71	64.45	0.00	13.41	0.00	23.58
BSS6	0.00	10.68	1.02	1987.65	0.00	3.99	6.30	24.88	0.00	11.57	0.00	10.94
BSS7	0.00	165.55	5.91	15071.80	1.28	44.90	495.88	1856.80	0.00	37.04	0.00	882.57
BSS8	36.45	5.71	1.87	2662.54	0.00	6.95	21.14	116.54	0.00	22.42	0.00	33.08
BSS9	45.03	7.69	0.88	5120.06	0.00	5.41	11.42	45.11	0.00	13.23	0.00	19.96
BSS10	40.90	7.04	0.89	5206.31	0.00	5.62	9.23	50.43	0.00	14.19	0.00	21.24
BSS11	35.22	9.12	0.90	3105.10	0.00	5.16	9.45	52.50	1.47	10.74	0.00	15.34
BSS12	0.00	8.85	0.69	1371.52	0.00	3.90	5.52	22.80	0.00	7.91	1.09	23.55
BSS13	23.25	7.72	1.26	3753.57	0.00	5.96	19.52	86.52	0.00	10.87	0.00	7.15
BSS14	0.00	17.97	2.95	8875.70	0.00	11.10	29.53	230.77	5.87	11.12	0.00	128.67

Zn was recorded at high concentrations in all sampling locations ranging between 461.03 mg/kg and 181752.94mg/kg. The highest concentration recorded at the burning site is thousamd times 25,000% more than the action value. The second highest value was recorded in road dust which is thousand times more 4,700% than the action value. The Domod office recorded the highest concentration of 67.27mg/kg for As which is9.34% more than the action value for which an intervention is required. Arsenic (As) is one of the top four most toxic elements and known to be carcinogenic in humans and causes lung cancer by inhalation of contaminated dust. Mercury (Hg), a highly toxic metal was recorded at the burning site and the 1st Class Financial Investment Ltd, with the highest value of 22.58mg/kg recorded at the burning site with 2251% exceeding the action value. Hg is a profoundly toxic substance. Exposure to Hg is particularly dangerous for growing children and developing foetus. The most alarming issue is that, children are also engaged in this burning process of the sites and there is the risk of inhalation of the liquid vapour by both the workers and the children. Hg is known to diffuse from the lungs into the blood stream, and then crosses the blood-brain barrier to the brain, the result is a serious damage to the central nervous system (CNS) and tactile senses (Marques et al, 2009). Chromium (Cr) was also recorded with concentrations between 89.21mg/kg and 2754.96mg/kg with the highest value being recorded at the dismantling site. This concentration is also found to be over 700% above the action value. The Ayalolo cluster of schools also recorded a high concentration of 434.45mg/kg which is 114% above the action value and requires intervention.

Human Health Risk Assessment

Exposure assessment involves quantifying the estimated intake of the contaminant by humans for each exposure pathway identified. The value obtained is then used to determine the risk of non-cancerous or cancerous effect resulting from exposure to the chemical. In this study, non-cancerous effect was estimated for children between the ages of 0-6 years using the three exposure pathways; ingestion, dermal and inhalation.

For risk assessment, HQ<1 suggests unlikely adverse health effects, HQ>1 suggests the probability of adverse health effects, and HQ>10 is considered a high chronic risk.

The results of hazard quotient for dermal exposure (Table 2.1) reveals that, with the exception of road dust, there is high probability of adverse health effect resulting from bodily contact with Cr contaminated dust from all the sites with the dismantling sites indicating the highest chronic risk. The road recorded a value as high as 164.33 and the Ayalolo Cluster of schools also recorded a very high value of 26.00 which is of much concern. This is because children spend most of their time during the day in school engaging themselves in vigorous activities with parts of their bodies being exposed to the highly contaminated dust. Cr is known to cause skin rashes, respiratory problems and weakened immune system. Co on the other hand showed unlikely adverse health effect at all the sites except for the burning site where there is the probability of adverse health effect like vomiting and nausea, vision and heart problems. The highest HQ value of 2.72 for Cu was recorded at the dismantling site and a value of 1.68 at the burning site. A long time exposure to Cu can result in irritation of the nose, mouth and eyes and also cause headache, stomach ache, dizziness, vomiting and diarrhoea. Apart from these two sites, dermal contact with Cu contaminated dust from any of the sites will have little adverse health effect on children. Children being exposed to Zn contaminated dust from the dismantling site and the burning sites are likely to develop stomach cramps, skin irritation, vomiting nausea and anaemia. Arsenic showed adverse health effect only at the Domod office with a value of 11.96. Arsenic (As) is likely to cause skin disturbances as well as resistance to infection in exposed children. Hg only recorded a value of 3.85 at the burning site and 0.8 at the 1st class financial investment offices. Though the latter value is less than 1, if contacted by children in large enough doses can lead to skin effects such as dermatitis (ASTSDR, 1999; IOMC, 2008). Pb on the other hand recorded HQ values greater than 1 at all the sites except for the MTN office. The dismantling site poses the highest risk for Pb with a value as high as 98.52. The Ayalolo cluster of schools which is of much concern recorded HQ value of 2.78.Children in these schools are thus at risk of neurological and developmental disorders and action ought to be taken to save these children.

In the case ingestion of dust (Table 2.2), it is only the dismantling site which showed adverse health effect of Pb and Cr with values of 5.28 and1.17 respectively. The burning site also recorded an HQ value of 2.65 for Pb. The combined effect of all elements at the various sites indicates that the dismantling site gives serious health effect by ingestion with a hazard quotient value of 7.60 which is far greater than one. The next polluted site is the burning site with a hazard quotient of 4.67. Hg is the only element for which inhalation (of vapours) seems to pose a high risk due to the significant vapour pressure of Hg at ambient temperature. The HQ values for Hg were 1.22 at the burning site and 0.26 at the 1st Class Financial Investment Ltd office. Apart from Mn and Cr which had HQ values less than 1, all other elements had HQ values greater than one.

A hazard index more than 1 indicates potential health risk. From the results obtained for HI (Table 2.4), there is an indication that, with the exception of Mn recorded at the mosque, saloon, store in the market and 1st class Financial Investment Ltd, all elements recorded at various sites exceeded the “safe” level of 1. This indicates that about 99% of the heavy metals and other elements released from e-waste processing activities into the environment have potential human health risk. The HQ value for Pb was as high as 882.57 at the dismantling site and 444.92 at the burning site which are 882.45% and 444.92% above the safe level. This is alarming and therefore requires intervention.

Conclusion

The objective of this work was to assess the concentration of heavy metals and other elements and their human health implications. Surface dust samples were collected from fourteen locations within Agbogbloshie. The Atomic Absorption Spectrometer was used to evaluate the concentration of heavy metals in the sample. The results of the investigation reveal that the site is highly contaminated with heavy metals and other elements which may be due to inappropriate methods used in the recovery process. . Heavy metals such as Zn, Cu and Pb gave concentrations in the range of (422.54 – 181752.94mg/kg), (101.83 – 9144.50mg/kg) and (117.03 – 14448.46mg/kg). All these concentrations and that of most elements exceeded the New Dutch List Action Values (for which intervention is required) over thousand times. In Agbogbloshie, it appears the exposure of dust through dermal contact by children of 6years and below posed the highest health risk. Hg is the only element that appeared to pose a high risk through inhalation of vapour due to the significant vapour pressure Hg at ambient temperature. The ingestion of dust by children of 6years and below posed no health risk. Health screening should be conducted for children at Agbogbloshie at least once a year to reduce the health effects from heavy metals.

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