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Loss of secondary metals from informal recycling of e-waste at Agbogbloshie in Ghana

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ABSTRACT

This study was aimed at assessing the loss of secondary metals from informal recycling of e-waste at Agbogbloshie, where primitive methods are used for e-waste processing. Samples were collected from fourteen (14) 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 sample. Non-ferrous 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), respectively. All these concentrations those of ferrous and specialty metals exceeded the New Dutch List Action Values over thousand times. The highest index of geoaccumulation (Igeo) value of 9.589 was recorded at the dismantling site and 8.597 at the burning site for Pb. High Igeo values of 5.07, 5.34 and 4.36 were also recorded for Zinc in road dust, Domod office and store in the market respectively. As and Hg recorded Igeo values between 2.6409 - 4.6389 and 5.3068 - 7.559, respectively. This is an indication that ferrous, non-ferrous and specialty metals are being lost into the soil and further research should be carried out into the mode of operation of the scrap dealers in order to design a suitable method of extracting the desired metals from the waste.

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KEYWORDS

E-waste;
Metals;
X-ray;
Fluorescence;
Spectroscopy;
Agbogbloshie.

INTRODUCTION

The amount of electronic scrap is increasing all over the world. According to the European Commission, the waste stream of electronic and electrical equipment has been identified as one of the fastest growing waste streams in the EU, at present being less in quantity than Municipal Solid Waste (MSW) but increasing, annually by more than the growth of MSW. United Nations University's estimations indicate that current e-waste arising across the twenty seven members of the European Union amount to around 8.3 – 9.1 million tons per year; global arising are estimated to be around 40 million tons per year.

As the use of computers expands in all countries, their many benefits are joined by new challenges at their end-of-life. The Waste Electrical and Electronic Equipment Directive (WEEE Directive, 2002/96/EC), issued by the European Commission aims to minimise the impact of end-of- life electrical and electronic goods on the environment, by increasing re-use and recycling and then reducing the amount of WEEE used for landfill. A decision of the Commission stated that, within December 2006, 4 kg WEEE/inhabitant should have been collected yearly. Nevertheless, at present, 19 kg/inhabitant are collected in Sweden, 16 kg/inhabitant in Norway but less than 2 kg/inhabitant in Italy. According to the Italian Environmental Ministry, 938k tonnes of WEEE were disposed of in a controlled landfill in 2006[3].Computers contain many metals, plastics and other substances, some of which are hazardous (e.g., lead, beryllium, mercury, halogens), and some of which are valuable resources equipment (e.g., gold, silver, palladium, copper, aluminium, and plastics) that should not be wasted but can be recovered for use in new products. Recovery can also provide raw materials to the market with a lower environmental footprint than mining. Some substances like lead are both hazardous (if emitted) and valuable (if properly recovered) at the same time. "Mining" our old computers to recover the contained metals – if done in an environmentally sound or correct manner, needs only a fraction of energy compared to mining ores in nature. A wide range of components made of metals, plastics and other substances are contained in electrical and electronic equipment. The metal resources used yearly for electrical and electronic equipment are added to the existing metal resources in society of the devices in use. These metal resources become available again at final end-of-life of the devices[4].Effective recycling of the metals/materials is crucial to keep them available for the manufacture of new products, be it electronics, renewable energy applications or applications not invented yet. Modern electronics can contain up to 60 different elements. These elements or metals can be grouped into ferrous, non-ferrous, precious and specialty metals. The most complex mix of substances is usually present in the printed wiring boards (PWBs)[4]. In its entirety, electrical and electronic equipment is a major consumer of many precious and special metals and therefore an important contributor to the world's demand for metals. Despite all legislative efforts to establish a circular flow economy in the developed countries/EU, the majority of valuable resources today are lost. Several causes can be identified: firstly, insufficient collection efforts; secondly, partly inappropriate recycling technologies; thirdly, and above all large and often illegal exports streams of e-waste into regions with no or inappropriate recycling infrastructures in place [4].The most important parameter to measure the efficiency of an overall recycling system is the functional EOL recycling rate. An important thing to note is that a functional EOL recycling rate of (for example) 40% means that there are 60% losses of a valuable metal[5].At Agbogbloshie, computers and television (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[1].The aim of the present work is to determine the concentration and the probable loss of secondary metals from informal recycling of e-waste at Agbogbloshie in Ghana.

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[2]. Agbogbloshie is popularly known to be a commercial area having a lot of human activities for most of the day.

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 contami-

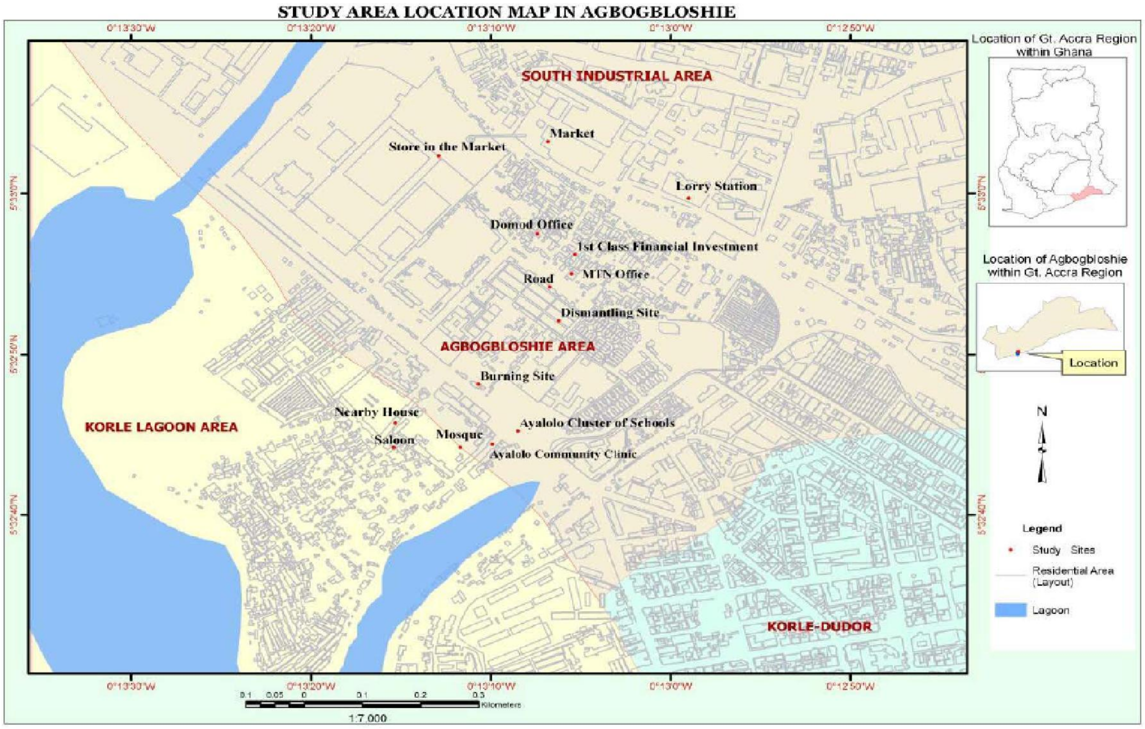

Figure 1: Map of study location

nation. 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. The irradiation was done using a Mo secondary target arrangement coupled to pettier cooled silicon drift detector (SDD) detector with a 12um beryllium window thickness. The SDD detector has a resolution of 136 eV for 5.9 KeV x-ray energy. Samples pellets were placed at an angle of 45^{o} to the primary beam irradiated and for 600 seconds. An energy dispersive X-ray spectrometer (EDXRF spectrometer) was used for the elemental analysis.

RESULTS AND DISCUSSION

The ferrous metals are predominantly iron based. Iron is the principal constituent of steel, and steel is by far the most widely-used metal. In 2009, more than 1.2 billion tonnes of steel were produced worldwide, and the demand for steel-especially in emerging economies-growing further[5].From the results obtained, the concentration of Iron in surface dust was very high at all the sampling sites. This indicates that all these amounts are lost due to improper recycling. The other ferrous metals (vanadium, chromium, Manganese and nickel,) are components in steel, stainless steels, and super alloys. These metals are of great importance in the metals manufacturing industries but due to unsuitable way of their recovery they are being lost to the soil. Chromium (Cr) was recorded with concentrations between 89.21mg/kg and 2754.96mg/kg with the highest value being recorded at the dismantling site and the igeo value is between -0.0264 and 4.199. 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 of the new Dutch list. The concentration of

TABLE 1A : Concentration of ferrous metals

Sample Location	Ferrous metals (mg/kg)				
	V	Cr	Mn	Fe	Ni
BSS1	bdl	361.12	2116.19	218276.7	613.22
BSS2	698.44	bdl	1145.29	70923.33	258.94
BSS3	bdl	89.21	662.69	50250	88.25
BSS4	bdl	434.45	660.1	54130	150.47
BSS5	bdl	255.03	677.23	53113.33	129.87
BSS6	bdl	176.76	507.43	36873.33	73.08
BSS7	bdl	2754.96	2946.51	279600	821.88
BSS8	346.51	95.09	933.44	49393.33	127.27
BSS9	428.47	127.87	447.96	94983.33	98.98
BSS10	389.07	117.2	441.45	96583.33	102.97
BSS11	334.24	151.63	448.73	57603.33	94.44
BSS12	bdl	147.28	344.69	25443.33	71.56
BSS13	220.87	128.42	634.03	69633.33	109.06
BSS14	bdl	298.25	1469.3	164655	203.17
OPTIMUM		100			35
ACTION		380			210

TABLE 1 B : Concentration of non-ferrous metals

Sample Location	Non -Ferrous metals (mg/kg)				
	Ti	Co	Cu	Zn	Pb
BSS1	28590.44	6714.26	5619.55	181752.9	7263.17
BSS2	10525.65	bdl	590.29	3546.13	973.84
BSS3	4474.83	bdl	392.12	985.24	458.74
BSS4	4601.1	bdl	260.28	1200.47	407.59
BSS5	5275.12	bdl	271.25	1194.37	386.12
BSS6	4410.64	bdl	116.14	461.03	179.13
BSS7	25643.33	3436	9144.5	34408.26	14448.46
BSS8	6579.9	bdl	389.88	2159.61	538.41
BSS9	7345.75	bdl	207.12	836.59	326.77
BSS10	8103.26	bdl	170.19	934.41	329
BSS11	5523.55	bdl	174.18	972.89	251.1
BSS12	2965.8	bdl	101.83	422.54	385.57
BSS13	5836.13	bdl	359.91	1603.36	117.03
BSS14	10204.8	bdl	544.47	4276.45	2106.47
OPTIMUM		20	36	140	85
ACTION		240	190	720	520

Nickle (Ni) at the burning and dismantling sites all exceeded the action value of the new Dutch list. Fe recorded an igeo value between –0.2519 and 4.738.

The non-ferrous metals contain no iron, and are used in quantities second only to the ferrous metals. Copper is third among metals (about 24 million tonnes in 2007) and sees wide use in conducting electricity and heat. Cobalt's major uses focus on super alloys, catalysts and batteries. Lead's use centres on batteries. Titanium's main applications are paint and transportation while zinc's major use is coating steel (galvanizing)[5]. From the results 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 equipment are dismantled to recover metals of interest. This concentration is about two thousand times more than the action value of 520. The second highest recorded value for Pb was at the burning site. The highest Igeo value of 9.589 was recorded at the dismantling site and 8.597 at the burning site for Pb. Zn was recorded at high concentrations in all sampling locations ranging between 461.03 mg/kg and 181752.94mg/kg. The highest concentration was recorded at the burning site which is 25,000% more than the action value. The second highest value was recorded in road dust which is 4,700% higher than the action value. With the exception of the Ayalolo community clinic, the saloon, stores within the market and the 1st class financial investment ltd, Copper recorded very high concentrations which were all above the Action value of the new Dutch list for all the sites. High Igeo values of 5.07, 5.34 and 4.36 were also recorded for Zinc in road dust, Domod office and store in the market, respectively. Zn is used as plastic casing of electronics and the mother board of computers. Titanium on the other hand was no exception. The highest Igeo value for Cu was observed at the dismantling site with Igeo value of 6.79. This high value was

TABLE 1 C : Concentration of specialty elements

	Specialty metals(mg/kg)			
Sample Location	**As**	**Zr**	**Hg**	**Sr**
BSS1	bdl	1470.93	bdl	394.26
BSS2	bdl	2597.65	bdl	815.74
BSS3	bdl	837.53	bdl	182.82
BSS4	bdl	815.74	bdl	219.69
BSS5	bdl	916.62	bdl	248.71
BSS6	bdl	852.93	bdl	214.57
BSS7	bdl	1430.08	22.58	686.81
BSS8	bdl	1042.67	bdl	415.79
BSS9	bdl	872.02	bdl	245.22
BSS10	bdl	935.58	bdl	263.18
BSS11	16.84	786.22	bdl	199.08
BSS12	bdl	522.69	4.75	146.55
BSS13	bdl	1410.05	bdl	201.51
BSS14	67.27	1000.38	bdl	206.14
OPTIMUM	29		0.3	
ACTION	55		10	

recorded because Cu is used in electrical cables and wires for contact.

Most of the specialty metals can be thought of as "new corners" regarding their technological applications. Many of them show therefore a rapidly increasing relevance in the last decades or even the last few years, driven by innovative technologies with high potentials for a sustainable future. It can be expected that the demand for many specialty metals will grow rapidly in the next few years due to the increasing market potentials of new and innovative technologies. The Domod office recorded the highest concentration of 67.27mg/kg for As which is 9.34% more than the action value and igeo value between 2.6409 and 4.6389. Mercury (Hg), 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 and igeo value between 5.3068 and 7.559.

Action

Minimum concentration for which intervention is required; Optimum: Minimum concentration at which no remediation is required; igeo: index of geoaccumulation. 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.

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