Assessment of Health Status and Effects of Exposure to Chemicals at Agbogbloshie e-Waste Recycling and Dump Site - Accra, Ghana

April 2011

Green Advocacy Ghana
Green Ad
BLACKSMITH INSTITUTE
GHANA HEALTH SERVICE

ISBN: 978 – 9988 – 51 – 533 – 1

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1. INTRODUCTION

The effective use of information and knowledge is crucial for rapid economic growth and socio-economic wellbeing of every nation, and the computer is at the heart of all this. Hence the demand for increasing use of computers and other gadgets in most offices, schools and other institutions, and even homes in line with current trends in the global computer and information age.

In 2003 Ghana formulated its policy on information and communications technology (ICT) for accelerated development, which represents Ghana's vision in the information age. The premise of the policy is that Ghana's development process can be accelerated through the development and deployment of ICTs. In other words, Ghana's accelerated development within the emerging information and digital age will not be possible without an ICT-driven development agenda (i.e. information rich, knowledge-based and information driven economy and society). Among the specific objectives of Ghana's ICT policy is the application of ICTs to support the modernization of the civic, public, educational, social and health services.

Ghana, at present does not manufacture nor assemble the electronic equipment (computers) to support realization of its ICT policy. They are therefore imported into the country. The level of demand has led to an alarming influx of large quantities of the equipment into the country most of which are second-hand equipment. A considerable portion of these imports are old, obsolete or of little or no utility function, and sooner than later are consigned as waste for disposal. Unfortunately for the country, no facility exists for managing the disposal of such waste, in spite of the existing large stocks and the ever-increasing high rate of generation of the waste. This has given rise to the current interest in the issue of electronic waste which has come to be known in short as 'e-waste'. Wastes from the following electronic items may also be referred to as e-waste: television sets, cell phones, photocopiers, fax machines, stereos, batteries and electric lamps.

It is estimated that 20 to 50 million tonnes of e-waste is generated across the globe each year and 70 per cent of it is shipped from countries all over Europe and North America landing in third world nations. About 75% of electronic items are known to be stored, mostly in houses, institutions/offices, warehouses, etc, due to uncertainty of how to manage it. They may commonly be mixed with household wastes, and get finally disposed of at refuse dumps/landfills. Some initial surveys at the main dump sites in Ghana at Agbogbloshie and Galoway (in Accra) revealed that some institutions bring for disposal truck-loads full of e-waste either for free or for a token fee. The 'e-waste scavengers' also go around town soliciting for old e-waste to pick away. Operations at the dump sites include mainly dismantling of equipment and burning to recover copper wire. Cleaning of old vehicle batteries for export to China also constitutes an on-going activity that has the potential to pose risks to human health and the environment. The rate of 'dumping' in Ghana is thus assuming a rather alarming proportion.

The present situation of ‘e-dumping’ and its menace can be attributed to the lack of an appropriate framework to regulate their importation into the country, and the proper management of their disposal. The Ghana ICT policy for instance, makes no reference to the concerns regarding the importation and use of second-hand computers and related gadgets and their disposal on health and environment. It is also silent on the opportunity to collect computer wastes and required national capacity for recycling or proper disposal.

The menace of e-waste and its adverse implications on health and the environment could be unimaginable. Handling of e-waste results in contact of the human body with toxic substances notably heavy metals. The group of chemicals generally referred to as heavy metals include lead, mercury, iron, copper, manganese, cadmium, arsenic, nickel, aluminium, silver, and beryllium. Some of these metals such as iron and manganese which are needed in the body in minute concentrations are termed trace elements. The ones notably found in e-waste are lead, cadmium, copper and beryllium. Though contact occurs through the skin or ingestion, the burning during the process of recovering copper in particular releases toxic fumes of these substances into the atmosphere. These may get inhaled with potential dire health consequences. Other substances of exposure are the brominated flame retardants used as insulation materials

Examples from China and India indicate that activities at e-waste sites, including dismantling and burning, produce hazardous emissions that may have damaging health effects.[1] Workers at these sites are exposed to dust via inhalation, ingestion and dermal contact, which may contain harmful levels of heavy metals. For example, in Guiyu, China, a thriving area of illegal e-waste recycling , it is reported that 80% of children exposed to unsafe e-waste recycling practices suffer from respiratory diseases and are often overexposed to harmful heavy metals such as lead.[1] Computer wastes that are land-filled are known to produce contaminated leachates which eventually pollute ground water. Guiyu, is facing acute water shortages due to the contamination of water resources. Other studies have shown that e-waste recycling sites pose major threats to waterways such as contamination to nearby streams and rivers. Heavy metals and inorganic acids can leach into the waterways through wastewater or ambient air emissions and have the risk of contaminating natural resources such as soil, crops, drinking water, fish and livestock.[1]

1.1 Organization of the Study

The study was carried out by Green Advocacy Ghana (GreenAd) a health and environment not for profit organization working with the Ghana Health Service and the Ghana Environmental Protection Agency (EPA). It was sponsored by a not for profit organization called Black Smith Institute based in New York City. Alongside this phase of the study, a team from Hunter College in the USA led in the conduct of a site assessment. This included the determination of exposure levels of chemicals by collecting and analysing air and soil samples at Agbogbloshie.

1.2 Objectives

The overall objective of the study was to assess and describe the health status and extent of exposure of handlers of e-waste to the chemicals associated with electronic waste. Specifically, the study aimed:

1. To determine knowledge, perceptions and practices in relation to health risks associated with exposure to e-waste recycling among e-waste handlers at Agbogbloshie;
2. To describe the general state of health of the population of workers at Agbogbloshie who are involved in e-waste recycling; and
3. To determine body burden of chemicals comprising heavy metals and trace elements among people involved in e-waste recycling at Agbogbloshie.

Figure 1: Location of Ghana[2]

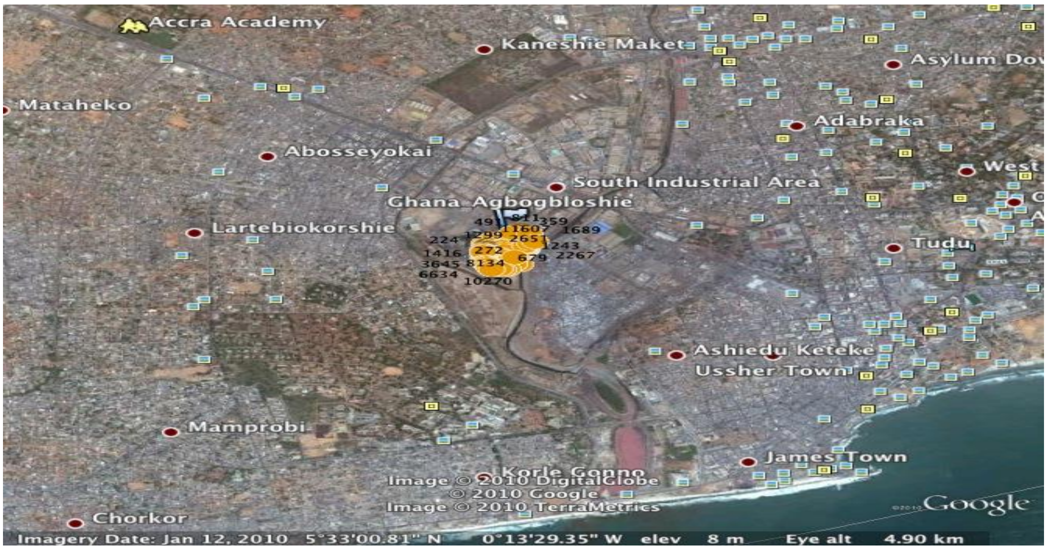


Figure 2: Location of Agbogbloshie in Accra, [3]
Ghana Courtesy: Caravanos et al 2010

2.0 METHODS

2.1 Study Type/Site

This was an exploratory cross-sectional study that was carried out at two sites in Accra; namely Agbogbloshie where e-waste dumping and recycling activities occur and the Makola market which is generally free of e-waste dumping and recycling activities.

The geographical location of Ghana and the e-waste dumping /recycling site at Agbogbloshie are shown in Figures 1 and 2 respectively. E-waste is dumped in the scrap metal portion of the Agbogbloshie market which is also separated into two main areas. The first area is located at the front of the market where numerous electronic and electrical items, car parts such as batteries and engines are hauled in, dismantled, sold and traded. In this area women and children also carry out their trade - cooking and selling food to shoppers to the scrap market or adjacent food market.

The second area is located on the edge of the market where materials considered by scrap dealers to be of no value are found scattered over a large field. Workers also use a portion of the field to build small fires, which are used to burn the plastic off electrical wires and coils in order to recover valuable metals such as copper. Southwards of the market is an informal settlement lying across the Odaw River.

2.2 Sampling

Using the method of contrast sampling, a non-random sample of 87 participants were selected from the Agbogbloshie area, while a comparison group of 87 participants were also non-randomly selected from the Makola market area, which is in another section of Accra that is free from e-waste dumping and recycling activities.

2.3 Data Collection

A 2-day orientation was held to provide training for 10 persons (5 from Ghana Health Service (GHS)), 2 from the Environmental Protection Agency (EPA), and 3 from Green Ad). The category of staff trained included 3 public health practitioners, one toxicologist and 3 environmental scientists, one social scientist, 2 laboratory technicians and a nurse. They were trained in questionnaire administration as well as collection of biological samples for chemical analysis through didactic and hands-on field instructional exercises. The various stages in data collection are given below.

i. Questionnaire administration: This was done to assess knowledge, perceptions and practices in relation to safe work practices and potential for poisoning from chemicals during e-waste handling. This was carried out over a 3-day period.

ii. Determination of general health status of participants (e-waste handlers): Participants were screened for general health indices as well as potential clinical symptoms and signs suggestive of effects of exposure from heavy metals. This was done by taking a medical history and conducting physical examination.

iii. Determination of body levels of 11 chemicals comprising heavy metals and trace elements that could be contained in e-waste: These were Zinc, Selenium, Mercury, Manganese, Lead, Copper, Cobalt, Chromium, Cadmium, Barium and Iron.

- Blood samples: 10 ml of blood was collected per subject. This was then spun to isolate cells to produce serum.
- Collection of urine samples: 10 ml of urine was collected per subject

Laboratory determinations were carried out to quantify chemical (heavy metals, including trace metals) levels in serum and urine samples collected. The samples were digested with nitric acid and determinations made using atomic absorption spectrophotometry (AAS). Due to limited volumes of some of the specimens collected, levels could not be assessed for levels of some heavy metals notably Cd, Co, Cr, Hg, Pb and Se.

In collecting blood and urine samples, specific precautions had to be taken to avoid contamination. In addition to investigators using aseptic techniques, the participants washed their hands thoroughly with soap and water before collecting urine. The samples were packed in a cool box containing some ice packs to maintain the integrity of the samples. The samples were then transported to the Ghana Standards Board Forensic laboratory for analysis.

2.4 Data Analysis

Data was entered into SPSS version 16 which was then used for descriptive analysis. This involved analysis of data pertaining to demographic characteristics, knowledge, perceptions and practices in relation to e-waste handling, health status and prevalence of elevated body levels of heavy metals among participants. Microsoft Excel workbook was also used to produce tables and charts.

Results of analysis were then reviewed in the light of results from analysis of soil and air samples that had been collected in a related study by the team from New York University. Air samples had been obtained by placing small air monitors on workers and collecting breathing zone samples for a 3-hour period per subject.

Data from the group from Makola market who had not been exposed to e-waste was compared to that obtained from the exposed group so as to indicate similarities or differences.

2.5. Ethical Considerations

Before contact with potential subjects, the survey was approved in writing by the Ethical Review Committee of the Ghana Health Service. The study was carried out in compliance with Ethical Review Committee conditions which seek to protect the interest and rights of study subjects as far as practicable. This included ensuring that no procedure causes harm or distress to the potential subjects, integrating the process of consenting subjects prior to enrolment with study procedures and ensuring that the confidentiality of all subjects who agreed to take part in this study would be protected to the fullest extent possible.

2.6. Study Limitations

The sample size of the study population was rather small. The sample sizes of specimens subjected to laboratory test for heavy metals also varied due to inadequate volumes of biological specimens for some subjects which could therefore not be run. The inadequate sample sizes made it difficult to investigate for significant associations between exposure and outcome variables. Furthermore, challenges in locating reference standards for some tests (using urine) meant that objective comparisons could not be made between test results obtained for these and those that may be obtained in other studies.

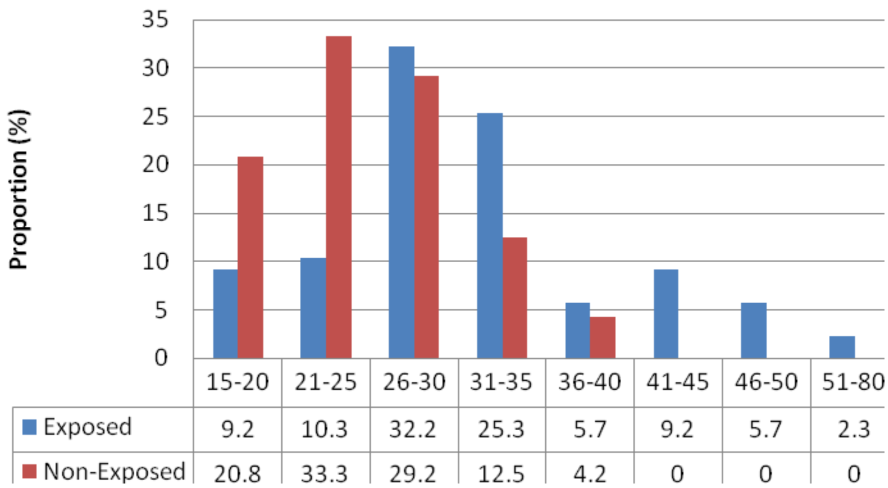
3.0 RESULTS

3.1 Demographic characteristics

The ages of the 87 e-waste exposed subjects from Agbogbloshie ranged from 15 to 73 years. The mean age was 32.4 years, median was 31 years and the modal age group was 26-30 years (Figure 3). The ages of the 87 non e-waste exposed subjects from Makola had a range of 15 to 37 years. The mean age was 25.5 years and the modal age group was aged 21 to 25 years.

In terms of gender representation of participants 83 (95.4%) and all 87 (100%) of participants from Agbogbloshie and Makola respectively were males.

Figure 3: Distribution of study participants by age groups



Thirty-four (34) participants representing about 39.1% had been educated up to the secondary school level, while 11 participants (12.6%) had received primary education, and 2 participants (2.3%) had had tertiary education. Forty of the participants (46%) had had no formal education – i.e. almost half of the participants had therefore had no formal education. This was however higher among non-e-waste workers, where 70.1% of the participants had had no formal education.

Table 1: Distribution of participants by highest level of education

Education Level	Frequency		%	
	E-waste workers	Non-Ewaste workers	E-waste workers	Non-Ewaste workers
Primary	11	22	12.6	25.3
Secondary	34	0	39.1	0
Tertiary	2	4	2.3	4.6

No formal education	40	61	46.0	70.1
Total	87	87	100	100

The distribution of participants by their home region and district is shown in Table 2 below. 71 participants (85.6%) came from the Northern Region, 5 participants (6.0%) from the Greater Accra Region, 3 participants (3.6%) from the Upper East Region, 2 participants (2.4%) from the Volta Region and 1 participant (1.2%) each from the Eastern and Central Regions. Most of them therefore hail from the Northern Region of Ghana, notably from the Tamale Municipality, Tolon/Kumbungu District and Savelugu/Nanton District. On the other hand, 91.3% of the workers at Makola hail from 2 districts in the adjoining Upper East Region.

Table 2: The distribution of participants by their home regions and districts

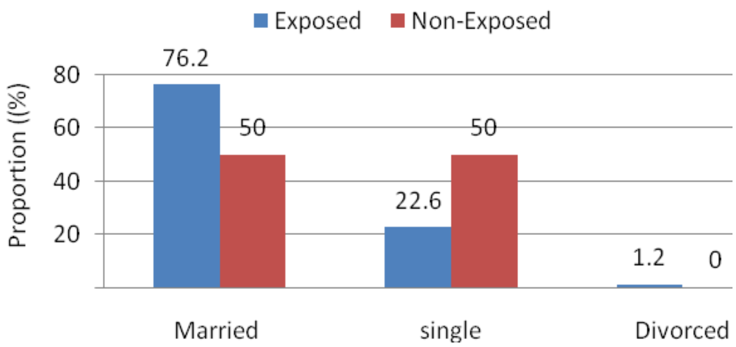
Regions	**Freq.**		**%**		**Districts**	**Freq.**		**%**	
	Exp	**Non-Exp**	**Exp**	**Non-Exp**		**Exp**	**Non-Exp**	**Exp**	**Non-Exp**
Northern	71	50	81.6	57.5	Tolon Kumbungu	11	4	12.6	4.6
					Tamale Municipal	45	-	51.7	-
					Savelugu Nanton	10	46	11.5	52.9
					Yendi Municipal	4		4.6	-
					Kpandai	1	-	1.2	-
Upper East	3	30	3.4	34.5	Bolga Municipal	3	5	3.4	6.3
					Builsa	-	21	-	24.1
					Sandema	-	4	-	4.6
Greater Accra	5	-	5.7	0.0	Dangme East	2	-	2.6	-
					Lower Manya Krobo	1	-	1.2	-
					Accra Metropolitan	2	-	2.6	-
Volta	2	-	2.3	-	Peki	1	-	1.2	-
					Hohoe Municipal	1	-	1.2	-
Central	1	-	1.2	-	Cape Coast Metropolitan	1	-	1.2	-
Eastern	1	-	1.2	-	Kwahu west	1	-	1.2	-
Other	**4**	**7**	**4.6**	**8.0**	**-**	**4**	**7**	**4.6**	**8.0**
Total	**87**	**87**	**100**	**100**		**87**	**87**	**100**	**100**

E-waste workers = Exposed (Exp.) ; Non E-waste workers =Non-Exposed (Non-Exp)

Marital Status

64 of the participants (76.2%) were married, 19 (22.6%) were single and 1 (1.2%) was divorced.

Figure 4: Distribution of participants by marital status



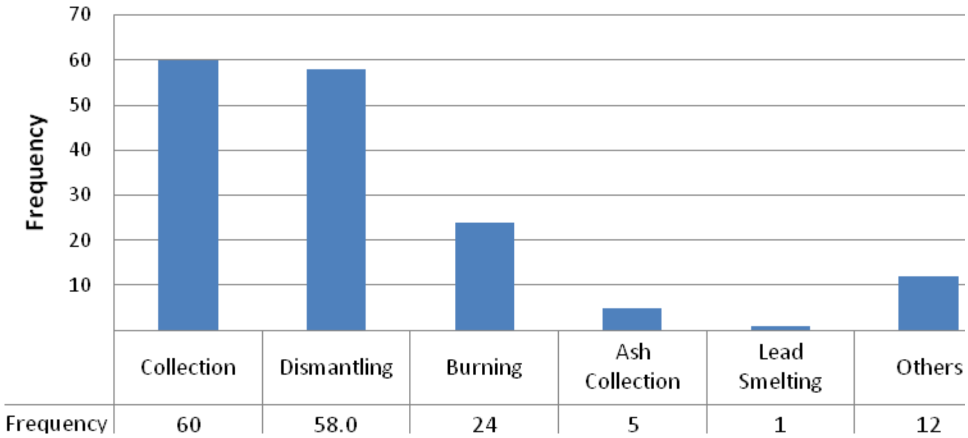
All participants from Agbogbloshie had been involved in e-waste handling for at least one year and were still involved in it at the time of the study. The mean period of time the participants had been involved in e-waste recycling was 7.8 years with a range of 1 to 33 years. The daily routine of 60 participants involved collection, 58 were involved in dismantling of electronic wastes, 24 involved in burning, 5 in collection of copper from ashes after burning, 1 in lead smelting and 12 in other activities in the same location as shown in figure 5.

Distribution of E-Waste Operatives by Process involved in

Of respondents who had been involved in burning, 11 had been involved with the process for a period of 3-5years, 7 for a period of 6-10 years, 4 for 11-15 years, 2 for 2 years or less and 1 respondent had been involved in the process for more than 20 years.

Of respondents who have been involved with ash/wire collection after burning 2 have been involved with the process for a period of 3-5years, 2 have been doing it for a period of 6-10 years and 1 respondent has been involved with the process for more than 11-15 years.

Figure 5: Distribution of people involved in ewaste recycling at Agbogbloshie by handling processes



3.2 Knowledge of hazards associated with exposure to e-waste recycling

62 (71.3%) of all respondents had no knowledge of possible hazards they could come in contact with at work. The remaining had knowledge of hazards as follows: 6(6.9%) respectively mentioned Acid, Dirty Oil and Powder each, 5(5.7%) mentioned knowledge of smoke or fumes, 3(3.4%) mentioned knowledge of fibre while 3(3.4) mentioned other gases.

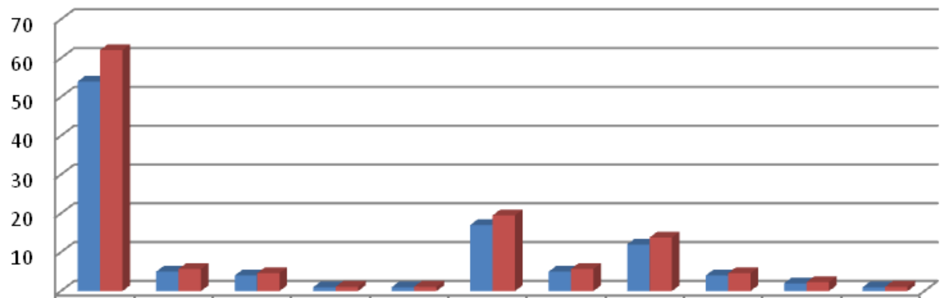
Table 3: Distribution of participants by knowledge of hazards in e-waste handling

knowledge about some e-waste hazards	Freq.	%
None	62	71.3
Fibre	3	3.4
Acid	6	6.9
Dirty Oil	6	6.9
'Powder'	6	6.9
Smoke or fumes	5	5.7
Gas	3	3.4

3.3 Knowledge about health risks associated with exposure to e-waste recycling

54 (62.2%) of all participants did not have knowledge of illnesses that could arise from their work. 17 (19.5%) participants mentioned knowledge of bodily pains while 12 (13.8%) mentioned headache. Other commonly mentioned illnesses included eye injury by 5 (5.7%), chest problems alluded to by 5 (5.7%), itching/rashes by 4 (4.6%), Cough by 4 (4.6%) joint pains, nausea and painful urination respectively each mentioned by 1 (1.1%) subject.

Figure 6: Distribution of respondents by knowledgeof illnessassociated with e-waste exposure

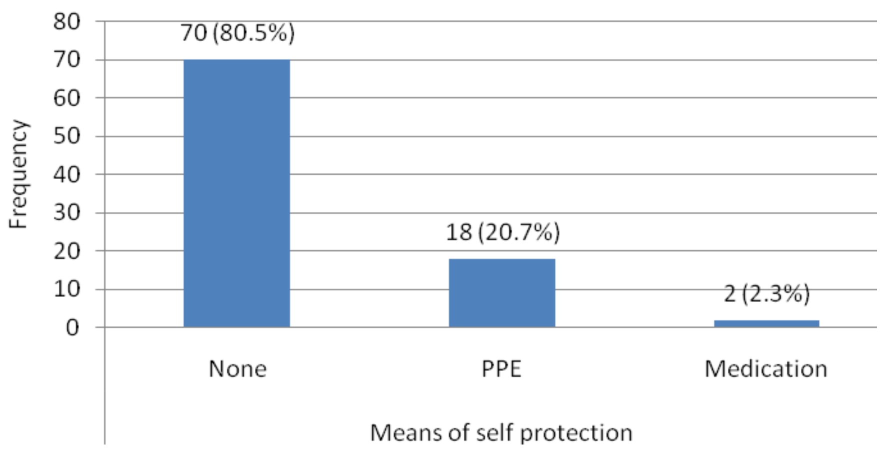


	None	Eye injury	Itching/Rashes	Joint pains	Nausea	Body pains	Chest problems	Headache	Cough	Lung disease	Painful urination
Frequency	54.0	5	4	1	1	17	5	12	4	2	1
Percentage	62.1	5.7	4.6	1.1	1.1	19.5	5.7	13.8	4.6	2.3	1.1

3.4. Perception about means of protection from e-waste hazards

Among the participants, 44 (50.6%) were sure that there are ways of protecting themselves during work to avoid being adversely affected by e-waste hazards. 39 (44.8%) did not think they could prevent effects of any E-waste hazards connected with their work, and 4 (4.6%) were not sure of whether it is possible to prevent such effects or not.

Figure 7: Distribution of exposed grop members by methods used for self protection fron ewaste



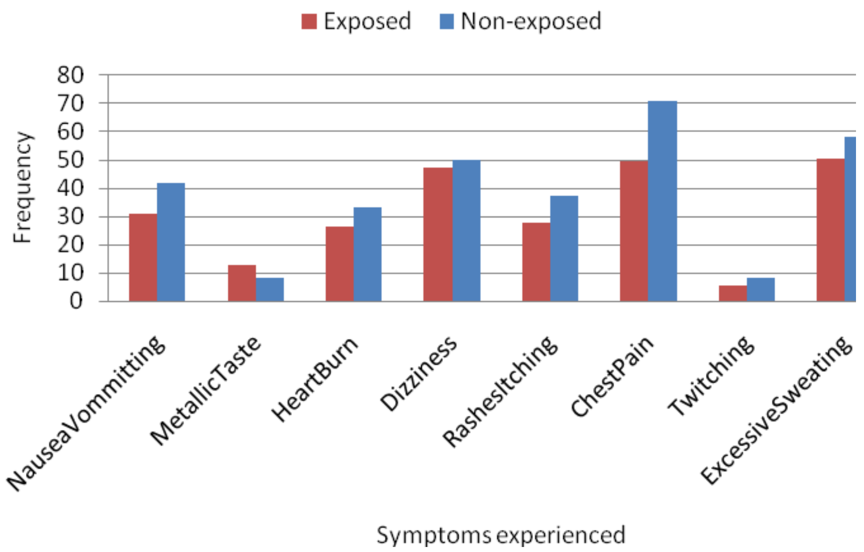
For those who believed in the possibility of prevention of symptoms caused by hazards related to e-waste work, 20 (23.0%) mentioned hospital care, 5(5.7%) mentioned protective clothing, 4(4.6%) mentioned education, 3(3.4%) mentioned gas mask and prevention of contact respectively while 1 (1.1%) mentioned good nutrition.

Of all participants, 70 (80.5%) took no precautions with regard to work, 18 (20.7%) used protective clothing, including 2 who wore gloves and 1 who used goggles when working. 2 (2.3%) took medication comprising orthodox drugs.

3.5 Medical History

Forty-one (47.1%) participants reported having experienced dizziness, 43 (49.4%) reported chest pains, and 44 (50.6%) reported excessive sweating over the 14 days preceding the interview. The distribution of their experience of specific symptoms that may be associated with exposure to heavy metal contamination is shown in figure 8.

Figure 8: Distribution of participants by experience of symptoms usually associated with heavy metal exposure



3.6. Findings on Clinical Examination

General: Table 4 shows a summary of findings on physical examination conducted on members of both groups, namely those exposed to e-waste and the non-exposed. 59 (67.8%) of the e-waste exposed group fell within normal weight range with BMI ranging from 18.5 to 24.9. Twenty-two (25.3%) were overweight with BMI of 25-29.9, 2(2.3%) were obese with BMI greater than 29.9 and 1 was underweight with a BMI of less than 18.5. For the non-exposed group, 72 (82.8%) had normal weight and 15 (17.2%) were overweight. None were underweight or obese.

The mean BMI for the exposed and non-exposed group was 24.2 and 23.3 respectively. A two sample test was done to test for any significant difference among these groups in terms of BMI. Without assuming equal variances among these two groups the calculated p value was 0.099

given α=0.05 ($t_{0.025,109}$ = -1.68). This means there was no significant difference between the two groups in terms of BMI at 0.05 significance level.

Table4: Summary of findings on physical examination

	Exposed		Unexposed	
	n=87	**%**	**n=87**	**%**
Under weight BMI <18.5	1	1.1	0	0
Normal weight BMI 18.5-24.9	59	67.8	72	82.8
Overweight BMI 25-29.9	22	25.3	15	17.2
Obesity BMI >29.9	2	2.3	0	0
Pale	1	1.1	0	0
Jaundiced	1	1.1	0	0
Abnormal Gait			0	0
Head/Neck abnormalities	2	2.3	0	0
Mouth/Throat abnormalities	4	4.6	4	4.6
Skin abnormalities				
Fungal rashes	22	25.3	7	8.0
Hypopigmentation	5	5.7	4	4.6
Hyperpigmentation	8	9.2	0	0
Scars on torso & limbs	4	4.6	0	0
other	8	9.2	4	4.6
Chest abnormalities	4	4.6	4	4.6
Elevated BP	10	11.5	15	16.7

Out of the 87 participants exposed to e-waste, one (1.1%) looked pale (a sign of possible anaemia) and another looked slightly jaundiced. Two (2.3%) had small scars in the neck region resulting from wounds which they explained had been due to a laceration and septic spots respectively. Three of them (3.4%) had lost one or two teeth, while one (1.1%) had prominent dental cavities. All participants had a normal gait.

Skin: Forty-six (52.8%) had no signs of abnormality of the skin while the remaining 41 (47.2%) had various abnormalities. The latter comprised of 22 (25.3%) with fungal rashes, while 2 (2.3%) had other kinds of rashes, 8 (9.2%) had patches of darkened skin and 5 had hypo-pigmented or lightened skin patches 2 of which were a result of bleaching. 4 (4.6%) had at least one scar on the chest, torso or limbs.

Chest examinations: 83 (95.4%) participants had no obvious abnormalities of the chest both on physical appearance and on auscultation. Of the remaining 4, 2 had a few rhonchi (signs of wheezing suggestive of mild bronchitis, asthma or other obstructive airway pathology.) There was a slight reduction in air entry for the other two.

Cardiovascular System: Blood pressure was normal for 77 (88.5%) and was slightly elevated above the threshold diastolic value of 140mmHg in 10 (11.5%). The liver was just palpable in 2 (2.3%) of participants while there was no organ enlargement in the remaining 85 (97.7%) of them. Heart sounds were normal in all participants.

Musculoskeletal: Limb movements were normal. No tenderness or sensory deficits were noted in the upper and lower limbs.

3.7. Results of Assessment of body burden of heavy metals and trace elements

Tables 5 and 6 show the distribution of elevated body levels of heavy metals and trace elements among those exposed to e-waste handling and those who are non-exposed. Reference standards[4,5] could not be quoted for urine levels of Fe, Mn and Se because no international reference standards could be located.

The exposed group had a higher proportion of members with elevated urine levels of Ba, Cd and Zn. All participants in both exposed and non-exposed groups also had elevated urine levels of Cr, Cu and Hg.

Table 5: Distribution of elevated URINE levels of heavy/ trace metals by exposure or non-exposure to e-waste handling

Urine heavy/ trace metals	Reference standard [2] (ppm)	Sample sizes		Mean urine levels (ppm)		Proportion with elevated level of heavy/ trace metals in urine (%)	
		N exposed	N non-exposed	Exposed	Non-exposed	Exposed	Non-exposed
Ba	< 0.6	86	86	0.72	0.75	24.4	20.8
Cd	< 0.001	33	33	0.01	0.02	100.0	75.0
Co	< 0.01	47	47	0.04	0.03	97.9	100.0
Cr	< 0.01	64	64	0.15	0.06	100.0	100.0
Cu	< 0.06	86	86	1.50	1.13	100.0	100.0
Fe	N/A	86	86	3.52	3.18	N/A	N/A
Hg	< 0.004	24	24	0.13	0.16	100.0	100.0
Mn	N/A	86	86	0.08	0.12	N/A	N/A
Pb	< 22.8	32	32	0.44	0.19	0.0	0.0
Se	N/A	36	36	0.39	0.20	N/A	N/A
Zn	< 1.4	85	85	3.66	2.72	91.8	79.2

However Table 5 shows that the mean urine levels of Co, Cr, Cu, Fe, Pb, Se and Zn was higher in the e-waste exposed group as compared to the non-exposed. On the other hand, mean urine levels of Ba, Cd, Hg and Mn were also higher in the non-exposed group.

Table 6: Distribution of elevated SERUM levels of heavy/ trace metals among those exposed or non-exposed to e-waste handling

Serum heavy / trace metals	Reference standard [2] (ppm)	Sample sizes		Mean serum levels (ppm)		Proportion with elevated level of heavy/ trace metals in serum (%)	
		$N_{exposed}$	$N_{nonexposed}$	Exposed	Non-exposed	Exposed	Non-exposed
Ba	< 0.001	86	86	0.72	0.75	100	100.0
Cd	0.0065 - 0.015	33	33	0.01	0.02	12.1	25.0
Co	0.001 - 0.02	47	47	0.04	0.03	91.5	66.7
Cr	< 0.00035	64	64	0.15	0.06	100	100.0
Cu	1.50 - 2.00	86	86	1.50	1.13	18.6	0.0
Fe	0.50 - 2.90	86	86	3.52	3.18	72.1	66.7
Hg	0.0005 - 0.015	24	24	0.13	0.16	100	100.0
Mn	0.004 - 0.012	86	86	0.08	0.12	100	100.0
Pb	0.45 - 0.60	32	32	0.44	0.19	18.8	0.0
Se	0.045 - 0.13	36	36	0.39	0.20	97.2	80.0
Zn	1.60 - 2.00	85	85	3.70	2.72	71.8	45.8

Table 6 shows that the mean serum levels of Co, Fe, Hg, Pb, Se and Zn was higher in the e-waste exposed group as compared to the non-exposed. However mean serum levels of Ba, Cd, Cr, Cu and Mn were rather higher in the non-exposed group.

As with the findings in urine, the exposed group had a higher proportion of members with elevated serum levels of Co, Cu, Fe, Pb, Se and Zn. All participants in both exposed and non-exposed groups also had elevated serum levels of Ba, Cr, Hg and Mn (Table 6).

Assuming unequal variances among the exposed and unexposed sample populations, urine mean levels of Co, Cr, Cu, Fe and Pb were significantly higher in the exposed group while the mean urine level of Mn was also significantly higher in the non-exposed group, using 0.05 significance level (Table 7).

Using the same assumptions in table 7 for testing the significance of differences between the means of the heavy metals, the mean serum levels of Co, Cr, Cu, Fe, Pb and Se were significantly higher among the exposed group while the mean serum level of Mn was also significantly higher in the non-exposed group using 0.05 level of significance (Table 8).

Table 7: Comparison of mean values of heavy or trace metal concentration in URINE samples taken from the exposed and non-exposed populations using the two sample t-test

Urine Heavy/ Trace metals	Sample sizes		Mean urine levels (PPM)		Mean Difference (PPM)	*t*	df	p-value
	$N_{exposed}$	$N_{nonexposed}$	Exposed	Non-exposed				
Ba	86	86	0.72	0.75	-0.026	-0.109	165.0	0.913
Cd	33	33	0.01	0.02	-0.008	-1.534	33.1	0.134
Co	***47***	***47***	***0.04***	***0.03***	***0.008***	***2.864***	***91.4***	***0.005***
Cr	***64***	***64***	***0.15***	***0.06***	***-0.978***	***-25.269***	***120.5***	***0.000***
Cu	***86***	***86***	***1.50***	***1.13***	***-0.370***	***4.928***	***129.3***	***0.000***
Fe	***86***	***86***	***3.52***	***3.18***	***3.360***	***23.792***	***98.3***	***0.000***
Hg	24	24	0.13	0.16	-0.038	-0.816	36.26	0.420
Mn	***86***	***86***	***0.08***	***0.12***	***0.019***	***1.068***	***24.3***	***0.009***
Pb	***32***	***32***	***0.44***	***0.19***	***0.247***	***-2.054***	***32.0***	***0.048***
Se	36	36	0.38	0.20	-	-	-	-
Zn	85	85	3.66	2.72	0.980	-1.194	49.1	0.077

Table 8: Comparison of mean values of heavy or trace metal concentration in SERUM samples taken from the exposed and non-exposed populations using the two sample *t*-test

Serum Heavy/ Trace metals	Sample sizes		Mean serum levels (PPM)		Mean Difference (PPM)	*t*	df	p-value
	$N_{exposed}$	$N_{nonexposed}$	Exposed	Non-exposed				
Ba	86	86	0.72	0.75	-0.03	-0.135	167.2	0.893
Cd	33	33	0.01	0.02	-0.01	-2.022	32.8	0.051
Co	***47***	***47***	***0.04***	***0.03***	***0.01***	***2.673***	***91.8***	***0.009***
Cr	***64***	***64***	***0.15***	***0.06***	***0.09***	***-40.723***	***93.0***	***0.000***
Cu	***86***	***86***	***1.50***	***1.13***	***0.37***	***-16.91***	***166.0***	***0.000***
Fe	***86***	***86***	***3.52***	***3.18***	***0.34***	***23.865***	***97.5***	***0.000***
Hg	24	24	0.13	0.16	-0.03	0.195	56.2	0.846
Mn	***86***	***86***	***0.08***	***0.12***	***-0.04***	***-30.728***	***91.5***	***0.000***
Pb	***32***	***32***	***0.44***	***0.19***	***0.25***	***2.05***	***32.1***	***0.049***
Se	***36***	***36***	***0.385***	***0.20***	***0.18***	***6.563***	***60.8***	***0.000***
Zn	85	85	3.695	2.72	0.98	1.775	150.1	0.078

4. DISCUSSION

This study was able to define and describe e-waste handlers at Agbogbloshie market in terms of their demographic characteristics as well as their knowledge, perceptions and practices in relation to health risks associated with exposure to e-waste recycling.

This cohort of workers involved in e-waste handling comprised mostly young men from the Northern Region of Ghana (81.6%) notably from the Tamale Municipality, Tolon/ Kumbungu and Savelugu/Nanton Districts). Many had had no formal education and have been involved in the business of e-waste collection and dismantling for several years. Many of them lacked knowledge about health risks posed by their occupation and what they could do to protect themselves. A group of manual workers from Makola market who were used for comparison hailed mostly from the Northern (52.9%) and Upper East (24.1%) Regions.

Most of the participants who underwent the examinations had a healthy demeanour. They all had a normal affect, understood questions asked and co-operated well with the research assistants and examiners. None of them admitted suffering from any chronic disease.

The majority (67.8%) had a normal body weight; however over 25% were overweight and two of them (2.3%) were obese. Blood pressure was normal in the majority (88.5%). The commonest health problem identified was skin abnormalities (47.2%), the commonest of which comprised fungal rashes (25.3%)

The results of serum and urine assay for heavy and trace metals showed significantly elevated levels of Co, Cr, Cu, Fe and Pb in the exposed compared to the non-exposed in both serum and urine. Similarly, Se in serum is more elevated. This may be attributable to exposure to the products of e-waste. However, it is also noteworthy that several of the metals which are elevated among e-waste handlers are also elevated among non e-waste handlers eg Cr, Hg, Ba and Mn in serum and Cr, Cu, and Hg in urine. Furthermore, levels of Mn are significantly higher among non-e-waste than among the e-waste handlers both in serum and urine. This suggests that non-handlers may be exposed to or may have been previously exposed to heavy metals from other sources other than e-waste. Possibilities of such sources could be in their current working or living environment, or possibly from the physical environment in their geographical area of origin.

These observations however require careful interpretation considering the fact the estimations are bound to be very sensitive to reference standards used for the analysis. The results will only be comparable with those from determinations that employed similar reference standards and laboratory testing methods. Besides, the unavailability of clear cut limits for normal or acceptable physiologic concentrations for some of these heavy and trace metals in some body fluids, puts a limitation on the interpretation of extent of toxicity likely to be engendered by various levels of elevation.

In the related environmental study carried out the same month, air samples were taken to assess chemical contamination to worker’s breathing zones and in ambient air in the environment. Soil samples collected around the perimeter of the area used by the scrap and e-waste dealers were also analyzed for heavy metals. Due to sampling limitations, worker breathing zone samples yielded insufficient data; however, ambient environmental air samples revealed that levels of aluminium, copper, iron, lead and zinc were above the US OSHA PEL standards.

The US EPA's standard for lead in bare soil in children's play areas is 400 ppm for 'play areas' and 1200 ppm for non-play areas[6] Mean lead levels determined for 100 samples in 5 areas within the perimeter of e-waste handling grounds showed that 56% were above USEPA standards. Of that 56%, the highest lead in soil content sample taken was 18,125 ppm, which is 15 times higher than the non-play areas standard. Results of the soil samples thus show that there is contamination at the site probably due to dismantling and burning and related activities. However, since the soil was only tested for lead, the extent of contamination from other heavy metals is unknown[7]. It however provides an indication of the source of lead that was demonstrably higher in e-waste handlers.

5. CONCLUSIONS

This was an exploratory study to ascertain the impact of e-waste handling on operatives. The study was able to define and describe e-waste handlers at Agbogbloshie market in terms of their demographic characteristics as well as their knowledge, perceptions and practices in relation to health risks associated with exposure to e-waste recycling.

The group of workers involved in e-waste handling comprised mostly young men from the Northern Region of Ghana notably from the Tamale Municipality, Tolon/Kumbungu and Savelugu/Nanton Districts. The high prevalence of fungal skin rashes and overweight persons is suggestive of underlying challenges of lifestyle health problems including personal hygiene and nutrition.

The results also revealed that all participants had elevated levels of some heavy and trace metals: Cr, Cu and Hg in urine and elevated levels of Ba, Cr, Hg and Mn in serum irrespective of whether they were exposed to e-waste handling or not. However the e-waste exposed group had a higher proportion of members with elevated urine levels of Co, Fe, Mn and Pb, and serum levels of Co, Fe, Pb and Se.

Higher mean urine levels of Co, Cr, Cu, Fe and Pb in the e-waste exposed group and higher mean serum levels of Co, Fe, Hg, Pb, Se and Zn in the same group were also statistically significant.

Paradoxically however the mean urine and serum level of Mn were rather significantly higher among the non-exposed group and this was difficult to explain. This fact and the fact that all of these persons also have elevations of some of the heavy metals indicates that there may be other environmental sources outside of ewaste that they are exposed to which needs to be investigated.

The fact that levels of the heavy metals in ambient air and soil are also elevated is highly suggestive of the fact that the increased body burden is likely to be due to exposures arising out of the activities of the operatives at the e-waste recycling and disposal sites.

6. RECOMMENDATIONS

On the basis of the above, it is recommended that:

1. A larger study, with adequate sample size will be required in future to more reliably identify and assess risk factors for heavy and trace metal poisoning among workers exposed to e-waste recycling.
2. However information and education should be provided to study participants, other e-waste operatives and the association of scrap dealers on the increased risks to health and safety likely being posed by their methods of operation and practices which are likely to promote exposure to heavy metals contained in e-waste.
3. Education to waste handlers should also extend to healthy lifestyle issues to forestall occurrences of higher incidence of fungal and other skin diseases as well as limit problems of obesity and the chronic diseases like diabetes and hypertension which obesity may predispose to.
4. Efforts should be initiated by government, the Environmental Protection Agency, the district assembly and organizations with a mandate for ensuring safe and healthy environments and working conditions to explore possibilities for improving the conditions under which e-waste is handled and instituting safer and sustainable means of managing the waste. It would be advisable to relocate the site particularly in view of the fact that there is a food market adjacent to the e-waste site posing a high risk of food contamination in order to protect the public. This will also enhance protection for persons living nearby particularly children and women from high levels of exposure to chemicals such as lead.
5. The changes should be planned and implemented with the participation of the e-waste handlers, in order for them to assume part ownership of the process as they are then more likely to comply with the changes.
6. The relocation of the recycling site should be accompanied by cleaning up of the area in which operations are currently carried out in order to minimize health risks not only to operatives but also to persons working and shopping in the nearby food market.
7. Furthermore, action on policies and legislation to minimize the influx of e-waste into the country should be expedited.

7. REFERENCES

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Burning of cables to extra copper from them.	Dr Edith Clarke sharing points during the workshop
	
An officer from the GHS extracting blood sample from a volunteer	Volunteers queuing to have their samples taken
	
GreenAd and GHS officers compiling records on the tests	Dr Edith examining a volunteer

	
Examining of volunteers; both male and female	A scrap dealer been examined by a doctor
	
Dark smoke emanating from the burning of cables to extract copper	Volunteers waiting to be examined by the medical officers
	
A member of the GreenAd field team explaining the importance of the blood and urine tests to a female volunteer	***Recycling and reuse practices at the scrap yard***