Perceived public health effects of occupational and residential exposure to electronic wastes in Lagos, Nigeria

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Abstract

High levels of environmental contamination can occur from e-waste processing, putting workers and residents in surrounding areas at risk as they are likely to be exposed to complex mixtures of unknown toxicity. This study was aimed at assessing the perceived public health effects of occupational and residential exposures to e-wastes in Alaba International and Computer Village markets, the two largest electronic markets in Lagos, Nigeria. A cross sectional, comparative study was carried out using questionnaire survey of randomly selected 150 workers and residents each, from the two markets. The data were compared with control (people working and living in areas with no e-wastes disposal or burning). Health data were correlated with demographic and exposure data. Majority of workers in both markets had only secondary education. Open burning was the main disposal method, with majority of workers not using any protective gear. Residents have multiple informal dumpsites within 100 m of their homes. All workers and residents reported that their drinking water had colour, odour and/or taste. Aches, migraine, nausea, spontaneous abortion and cancer were the major health problems reported by workers and residents of the two markets, and these were significantly ($p<0.05$) different from the control groups. Positive correlations were observed between health, demographic and exposure data. Working in, and living near electronic markets and e-waste dumpsites have resulted in significant increase in perceived detrimental health effects.

Keywords: e-wastes, public health effects, electronic markets, Nigeria.

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Introduction

Over the last three decades there has been increasing global concern about public health impacts attributed to environmental pollution. More and more people are concerned about environmental hazards and the resultant adverse health effects on humans and the environment at local, regional and global levels (Jones and Dunlap, 1992; Adeola, 2000; Kunzli *et al*, 2000). Pollution from industries may negatively impacts the health of employees and neighbouring communities and the potential for adverse health outcomes is heightened when the industries are located in residential areas where majority of the population is vulnerable.

Poor waste management poses a great challenge to the well-being of residents, particularly those living adjacent the dumpsites due to the potentials of the waste to pollute water, food sources, land, air and vegetation. The poor disposal and handling of waste thus leads to environmental degradation, destruction of the ecosystem and poses great risks to public health. The deficient environmental health awareness coupled with lack of sustainable environmental health programmes have therefore become major challenge in most developing countries (WHO, 2007).

Biomonitoring of industrial chemicals in human tissues has shown that all people, especially those working in or living near major pollution sources, carry a "body burden" of synthetic chemicals in their blood, fat, mother's milk, semen, urine and breath (Thornton *et al*, 2002). Some of these chemicals resist metabolism and excretion and therefore accumulate in body tissues. Several classes of chemicals, including the organochlorides and heavy metals are the object of considerable public health and regulatory concern because of their tendency to persist in the environment, bioaccumulate and bioconcentrate in food webs, and disrupt biological processes at low doses (Klaassen, 1996; Lippman, 2000).

Electronic products are a complex mixture of several hundred tiny components, many of which contain deadly chemicals and metals such as lead, cadmium, mercury, polyvinyl chloride (PVC), brominated flame retardants (BFRs), polychlorinated biphenyls, polyaromatic hydrocarbons, chromium, beryllium, etc. Electronic wastes (e-wastes) have raised concerns because many components in these wastes are toxic and are not biodegradable. Based on these concerns, many European countries banned e-waste from landfills long before in

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the 1990s. Alarming levels of dioxin compounds, linked to cancer, developmental defects, and other health problems in the samples of breast milk, placenta, and hair, have been linked to improper disposal of electronic products (Macauley *et al*, 2003; Hilty, 2005; Monika, 2010). These e-wastes have long lasting effects on the environment when improperly disposed (incinerated/land filled instead of recycling) with domestic waste. It could have serious repercussions for those in proximity to places where e-waste is recycled, processed or burnt. Only recently have studies produced causal evidence that there is a strong relationship between environmental pollution and e-wastes. Research on air pollution has shown that activities at e-wastes sites, including dismantling and burning, produce hazardous emissions that may have damaging health effects (Sepulveda *et al*, 2010). Workers at these sites are also exposed to dust via inhalation, ingestion and dermal contact, which may contain harmful levels of heavy metals (Leung *et al*, 2008).

Other studies have shown that e-wastes 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 waste-water or ambient air emissions and have the risk of contaminating natural resources such as soil, crops, drinking water, fish and livestock (Sepulveda *et al*, 2010). Pollutants in e-wastes are released as a mixture, and the effects of exposure to a specific compound or element cannot be considered in isolation. Exposure to e-wastes is a complex process in which many routes and sources of exposure, different lengths of exposure time, and possible inhibitory, synergistic, or additive effects of many chemical exposures are all important variables.

Previous studies have shown environmental contamination of soil, groundwater and edible plants in the major electronic markets in Lagos, Nigeria (Alabi *et al*, 2012). Soil leachate and well-water samples from the study-area have been shown to be mutagenic and genotoxic in both plant and animal models (Alabi and Bakare, 2011; 2014; Bakare *et al*, 2012; Alabi *et al*, 2012). However, despite the high level of environmental contamination with e-wastes in these areas, there had been no report on the public health implications of exposure to e-wastes contaminants, especially in humans occupationally and residentially exposed. Evidence of human health effects of e-wastes exposure would be key to the development of effective protective policies. Therefore, this study aimed at investigating the possible association between exposure to e-wastes and related health effects in workers and residents of two major electronic markets in Lagos, Nigeria.

Materials and methods

Study location and motivation

The study-sites were Alaba International and Computer Village electronic markets in Lagos State, south-west, Nigeria. Information about the types of electronic materials, duration of operation, types of workers and residents, sources of the electronic materials in these markets have been previously reported (Alabi and Bakare, 2011; Alabi *et al*, 2012; 2013).

Three factors motivated the selection of the two electronic markets: (i) both were the largest electronic markets in Lagos, Nigeria, with an average of 500,000 tons of obsolete Waste Electrical and Electronic Equipment (WEEE) dumped into these markets every month despite the fact that there was no official recycling technology in Nigeria (Alabi and Bakare, 2011); (ii) the electronic markets were the largest employers in the area and therefore a backbone of the region's economy; (iii) children, pregnant women, elderly, people with disabilities, etc. were workers and residents of these markets, hence, the study would show effects on different age-groups.

Study design and administration of questionnaires

A cross sectional, comparative study was used to assess possible health effects due to exposures that have occurred over time. A questionnaire survey of 150 participants each, of randomly selected residents in the neighbourhood and workers in each of the two electronic markets was carried out through personal interview. The workers in the markets were surveyed irrespective of their age range. Information regarding age, gender, income, type of work and electronic gadget worked with, usage of protective gear during work, duration of work, and the experienced health problems were collected. The residents in the neighbourhood of the electronic markets who are also workers in the market were also included. Information regarding age, gender, income, duration of stay, presence of e-wastes dumpsite in the home vicinity, exposure to burning e-wastes and odor and the experienced health problems were also collected from the residents. The control group at Ajah Town consists of randomly selected people who do not work with any electronics and are not living in the area with any electronic workshop or dumpsite. All respondents signed provided informed consent before the questionnaires were administered.

Statistical analysis

All quantitative analyses were done using Statistical Package for the Social Sciences ® version 15. *Chi*-square (x^2) test was used to test for the relationship, as all variables were categorical. Correlation analysis of the parameters was also carried out. Statistical levels of significance were set at 0.01 and 0.05.

Results

The characteristics of the volunteers are summarized in Tables 1 to 3.

Most of the workers in both markets (78.7% in Alaba International and 76.7% in Computer Village markets) had not more than a secondary school education, which is significantly higher than in the control group (39.2%). There was a significant ($p<0.01$) difference between alcohol and tobacco consumption of the workers in both markets and the control group. Methods of e-wastes disposal included open disposal and burning in informal dumpsites; these accounted for 74.7% and 84.7% in Alaba International and Computer Village markets, respectively. A total of 122 (81.3%) and 115 (76.7%) of the 150 workers each, in Alaba International and Computer Village markets, respectively, used no protective gear during working hours irrespective of their type of work. All the workers (100%) in both markets believed their drinking water had taste, odour and/or colour which was significantly (p<0.01) different from the control-group where 78.0% of the people believed their water had no taste, odour and/or colour.

Aches, migraine and nausea were the major health problems reported in the questionnaire by the workers in both markets, and these accounted for a combined total of 86.6% and 78.0% of the total health problems in Alaba International and Computer Village markets, respectively. This was significantly (p<0.01) different from the control-group (7.9%). Reports of spontaneous abortion and cancer accounted for a total of 8.7% and 5.3% of the total health problems in Alaba International and Computer Village markets, respectively, and was significantly (p<0.01) different from the control-group (0%). Workers who had spent longer time/duration (6 years and above) doing this work at the markets experienced more of the reported health problems than those who were more recent (less than 6 years) on the job. However, no significant differences (p>0.05) in other variables such as: age, sex, income, consumption of egg products, and water source between the control and the exposed groups.

The correlation analyses between the demographic, health and other parameters, of workers in both markets showed that there was a significant (p<0.01) negative correlation (r = -0.723) between the level of education and cigarette and alcohol consumption; and positive correlation (r = 0.869) with the usage of protective gear during work in Computer Village markets. A significant (p<0.01) positive correlation (r) of 0.832, 0.857, 0.737, 0.991 and 0.908 were also observed between the duration of work, cigarette consumption, types of electronic materials worked with, water characteristics and health problems respectively. In Alaba International Market on the other hand, there was significant (p<0.01) positive correlation (r) of 0.992, 0.763, 0.823 and 0.865 between duration of work, types of electronic material worked with, exposure to e-wastes odour, water characteristics and the reported health problems respectively. A similar trend with Computer Village was recorded in the relationship between the level of education and cigarette and alcohol consumption; and the usage of protective gear during work.

Majority of the residents in the exposed groups were self-employed accounting for 74.0% and 85.0% of the volunteers in Alaba International and Computer Village markets, respectively. E-wastes dumpsites of less than 100 m distance (57.3% and 59.0% in Alaba International and Computer village markets, respectively) to residential apartments were present in most of the surroundings of the residents of the two markets. The residents were constantly exposed to odour from the weekly burning of e-wastes from the dumpsites. The result further showed that there was a significant (p<0.01) difference between alcohol and tobacco consumption of the residents in both markets and the control-group. All the residents (100%) in both markets believed their drinking water had taste, odour and/or colour which was significantly (p<0.01) different from the control-group where 92.8% of the people believed their water had no taste, odour and/or colour. Similar to the workers, aches, migraine and nausea were the major health problems reported in the questionnaire by the residents in both markets; and this accounted for 78.7% and 76.0% of the total health problems in Alaba International and Computer Village markets, respectively. The values were significantly (p<0.01) different from the control-group (3.9%).

Reports of spontaneous abortion and cancer account for 5.3% and 6.0% of the total health problems in Alaba International and Computer Village markets, respectively; and this was significantly (p<0.01) different from the control-group (0%). Residents who have spent longer time (6 years and above) living near these electronic markets experienced more of the reported health problems than those who were more recent (less than 6 years) in the vicinity. A total of 24.7% and 16.7% of the residents in Alaba International and Computer Village markets, respectively used e-wastes materials picked from electronic workshop/dumpsites at home, which was significantly (p<0.01) different from the control group (0%). However, no differences in other variables such as age, sex, education, income, consumption of egg products, and water source were observed between the control and the exposed groups.

The correlation analyses of the demographic, health and other parameters of the residents in Alaba International and Computer Village markets, respectively, showed significant (p<0.01) positive correlation (r) 0.794, 0.935, 0.540 and 0.870 between health problems and stay duration, presence of e-waste dumpsites and water source respectively, in Computer Village markets. In Alaba International Market, there was significant (p<0.01) positive correlation (r) 0.692, 0.815, 0.923, 0.871 and 0.589 between the health problems and age, duration of exposure, cigarette smoking, alcohol consumption and proximity to dumpsites, respectively.

Table 1. Selected demographic characteristic of the residents and workers of Alaba International Market, Computer Village Market, Lagos State, Nigeria.

	Residents					Workers				
Characteristics	Alaba Market (n=150) Frequency (%)	*p* value	Control (*n*=150) frequency (%)	Computer Village (*n*=150) Frequency (%)	*p* value	Alaba Market (*n*=150) frequency (%)	*p* value	Control (*n*=150) frequency (%)	Computer Village (*n*=150) frequency (%)	*p* value
Age (yrs)										
18-25	32 (21.3)		28 (18.4)	26 (17.3)		22 (14.7)		21 (13.7)	30 (20.0)	
26-30	43 (28.7)		52 (34.2)	35 (23.3)		51 (34.0)		50 (32.7)	42 (28.0)	
31-40	33 (22.0)		39 (25.7)	40 (26.7)		56 (37.3)		55 (35.9)	44 (29.3)	
41-50	31 (20.7)		25 (16.4)	40 (26.7)		16 (10.7)		19 (12.4)	20 (13.3)	
>51	11 (7.3)	0.543	6 (3.9)	9 (6.0)	0.605	5 (3.3)	0.645	5 (3.3)	14 (9.3)	0.661
Sex										
Male	82 (54.7)		77 (50.7)	83 (55.3)		108 (72.0)		97 (63.4)	93 (62.0)	
Female	68 (45.3)	0.801	73 (48.0)	67 (44.7)	0.574	42 (28.0)	0.813	53 (34.6)	57 (38.0)	0.599
Stay Duration (yrs)										
1-5	28 (18.7)		42 (27.6)	34 (22.7)		28 (20.0)		30 (19.6)	34 (22.7)	
6-10	57 (38.0)		51 (33.6)	48 (32.0)	0.841**	53 (34.0)		51 (33.3)	48 (32.0)	
>11	65 (43.3)	0.711**	57 (37.5)	68 (45.3)		69 (46.0)	1.000	69 (45.1)	68 (45.3)	0.963
Marital status										
Single	48 (32.0)		48 (31.6)	48 (31.6)		48 (30.7)		46 (30.1)	48 (32.0)	
Married	92 (61.3)		100 (65.8)	100 (65.8)		96 (65.3)		98 (64.1)	100 (66.7)	
Widowed	10 (6.7)	0.464	2 (1.3)	2 (1.3)	1.000	6 (4.0)	1.000	6 (3.9)	2 (1.3)	0.772
Education										
Primary	28 (18.7)		28 (18.4)	28 (18.4)		28 (18.7)		28 (18.3)	25 (16.7)	
Secondary	83 (55.3)		90 (59.2)	90 (59.2)		92 (60.0)		32 (20.9)	90 (60.0)	
University/ HND	39 (26.0)	0.583	32 (21.1)	32 (21.1)	1.000	30 (21.3)	1.000**	90 (58.8)	35 (23.3)	0.885**
Income										
<10,000	19 (12.7)		16 (10.5)	19 (12.7)		18 (12.7)		19 (12.4)	16 (10.7)	
10,001-20,000	53 (35.3)		34 (22.4)	44 (29.3)		45 (29.3)		44 (28.8)	45 (30.0)	
>20,001	78 (52.0)	0.406	100 (65.8)	87 (58.0)	0.860	87 (58.0)	1.000	87 (98.0)	89 (59.3)	0.926
Occupation										
Self-employed	111 (74.0)		43 (28.3)	127 (84.7)						
Civil servant	39 (26.0)	0.275**	107 (70.4)	23 (15.3)	0.270**					

* Significant at (*p*<0.01).

Table 2. Selected e-waste exposure, eating habit and health characteristic of the residents of Alaba International Market and Computer Village Market, Lagos State, Nigeria.

Characteristics	Alaba Market (*n*=150) Frequency (%)	*p* value	Control (*n*=150) Frequency (%)	Computer Village (*n*=150) Frequency (%)	*p* value
Cigarette consumption					
No	66 (44.0)		115 (75.7)	73 (48.7)	
Yes	84 (56.0)	0.489**	35 (23.0)	77 (51.3)	0.537**
Alcohol consumption					
No	60 (40.0)		55 (36.2)	61 (40.7)	
Yes	90 (60.0)	0.932**	95 (62.5)	89 (59.3)	0.919**
Consumption of egg products					
Twice weekly	68 (45.3)		97 (63.8)	85 (56.7)	
Weekly	65 (43.3)		40 (26.3)	51 (34.0)	
Monthly	9 (6.0)		10 (6.6)	10 (6.7)	
Quarterly	8 (5.4)	0.654**	3 (2.0)	4 (2.7)	0.881**
No. of electronic workshop in the area					
0	38 (25.3)		150 (100)	28 (18.7)	
1-5	79 (52.7)		–	84 (56.0)	
6-10	33 (22.0)	0.001	–	38 (25.3)	0.001
E-waste dumpsite in the area					
Absent	19 (12.7)		150 (100)	12 (8.0)	
Present	131 (87.3)	0.017	–	138 (92.0)	0.021
Proximity to e-waste dumpsite					
<100m	86 (57.3)		–	89 (59.3)	
101m-1km	49 (32.7)	0.066	–	46 (30.7)	
1.1km-5km	15 (10.0)		–	15 (10.0)	0.006

Table 2 (cont'd)

Characteristics	Alaba Market (*n*=150) Frequency (%)	*p* value	Control (*n*=150) Frequency (%)	Computer Village (*n*=150) Frequency (%)	*p* value
No. of e-waste dumpsite in the area					
0					
1	–				
2-5	113 (75.3)		150(100)	–	
Exposure to e-waste odor	37 (24.7)	0.047	–	121(80.7)	
Weekly			–	29(19.3)	0.012
Monthly	105 (70.0)				
Quarterly	37 (24.7)		–	108(72.0)	
None	8 (5.3)		–	34(22.7)	
Child playing time around the e-waste	0	0.046	–	8(5.3)	
dumpsite (hr)			150 (100)	0	0.005
0					
<1	41 (27.3)		15 0(100)	51(34.0)	
>1	89 (59.3)		–	95 (63.3)	
e-waste material seen with child	20 (13.3)	0.177	–	4 (2.7)	0.002
Daily					
Weekly	91 (60.7)		–	74 (49.3)	
Monthly	13 (8.7)		–	13 (8.7)	
None	46 (30.7)		–	63 (42.0)	0.055
Home usage of e-waste material	–	0.071	150 (100)	–	
No					
Yes	113 (75.3)		150 (100)	125 (83.3)	
Water source	37 (24.7)	0.278**	–	25 (16.7)	0.278**
Well					
Tap	84 (56.0)		27 (18.0)	71 (47.3)	
Borehole	27 (18.0)		39 (26.0)	21 (14.0)	
Water characteristics	39 (26.0)	1.000	84 (56.0)	58 (38.7)	0.787
Taste, color, odor					
Odour, colour	12(8.0)		3(2.0)	12 (8.0)	
Taste, odor	28(18.7)		2(1.3)	52 (34.7)	
Taste, color	58(38.7)		3(2.0)	28 (18.7)	
None	52(34.7)		1(0.7)	58 (38.7)	
Health problems	0	0.084	141(92.8)	0	0.084
Skin problem					
Nausea	24(16.0)		6(3.9)	27 (18.0)	
Aches/Migraine	52(34.7)		–	55 (36.7)	
Spontaneous abortion/cancer	66 (44.0)		–	59 (39.3)	
None	8 (5.3)		–	9 (6.0)	
	0	0.060*	144(94.7)	0	0.082*

*significant at $p<0.05$.
**significant at $p<0.01$.

Table 3. Selected e-waste exposure, eating habit and health characteristic of the workers of Alaba International Market and Computer Village Market, Lagos State, Nigeria.

Characteristics	Alaba Market (*n*=150) Frequency (%)	*p* value	Control (*n*=150) Frequency (%)	Computer Village (*n*=150) Frequency (%)	*p* value
Cigarette consumption					
No	73 (48.7)		113 (73.9)	83 (55.3)	
Yes	77 (51.3)	0.557**	37 (24.2)	67 (44.7)	0.606**
Alcohol consumption					
No	61 (40.7)		5 (34.6)	56 (37.3)	
Yes	89 (59.3)	0.751**	97 (63.4)	94 (62.7)	0.785**
Consumption of egg products					
Twice weekly	80 (56.7)		85 (55.6)	92 (61.3)	
Weekly	56 (34.0)		51 (33.3)	44 (29.3)	
Monthly	12 (6.7)		10 (6.5)	9 (6.7)	
Quarterly	2 (2.7)	1.000**	4 (2.6)	5 (2.7)	0.959**
Occupation					
Repair	66 (44.0)		–	57 (38.0)	
Sell	38 (25.3)		–	41 (27.3)	
Disposal	21 (14.0)		–	27 (18.0)	
Repair and sell	25 (16.7)		–	25 (16.7)	
None	0	0.035	150 (100)	0	0.024

Table 3 (cont'd)

Characteristics	Alaba Market (*n*=150) Frequency (%)	*p* value	Control (*n*=150) Frequency (%)	Computer Village (*n*=150) Frequency (%)	*p* value
Types of electronics work with					
Refrigerators	18 (12.0)		–	18 (12.0)	
Computers	46 (30.7)		–	46 (30.7)	
Cell phones	32 (21.3)		–	31 (20.7)	
Television	10 (6.7)		–	10 (6.7)	
Radio	7 (4.7)		–	11 (7.3)	
Cables	6 (4.0)		–	7 (4.7)	
Computers & cell phones	18 (12.0)		–	14 (9.3)	
Television & radio	13 (8.7)		–	13 (8.7)	
None	0	0.006	150 (100)	0	0.041
Method of e-waste disposal					
Incineration	5 (3.3)		–	4(2.7)	
Dumpsite	112 (74.7)		–	127(84.7)	
Burying	9 (6.0)		–	9(6.0)	
Open air burning	24 (16.0)		–	10(6.7)	
None	0	0.132	150 (100)	0	0.106
Duration before disposal					
1-5months	104 (69.3)		–	125 (83.3)	
6-11months	39 (26.0)		–	20 (13.3)	
1-2yrs	7 (4.7)		–	5 (3.3)	
None	0	0.011	150 (100)	0	0.092
Exposure to e-waste odor					
Daily	28 (18.7)		–	27 (18.0)	
Weekly	80 (53.3)		–	98 (65.3)	
Monthly	30 (20.0)		–	18 (12.0)	
Quarterly	12 (8.0)		–	7 (4.7)	
None	0	0.021	150 (100)	0	0.005
Usage of protective gear					
None	122 (81.3)		150 (100)	115 (76.7)	
Hand gloves	23 (15.3)		–	27 (18.0)	
Nose masks	5 (3.3)	0.091	–	8 (5.3)	0.038
Water source					
Well	84 (56.0)		27 (18.0)	71 (47.3)	
Tap	27 (18.0)		39 (26.0)	21 (14.0)	
Borehole	39 (26.0)	1.000**	84 (56.0)	58 (38.7)	0.787**
Water characteristics					
Taste, color, odor	12 (8.0)		13 (8.5)	10 (6.7)	
Odour, colour	52 (34.7)		10 (6.5)	43 (28.7)	
Taste, odour	28 (18.7)		4 (2.6)	49 (32.7)	
Taste, colour	58 (38.7)		3 (2.0)	48 (32.0)	
None	0	0.285**	120 (78.4)	0	0.207*
Health problems					
Skin problem	7 (4.7)		5 (3.3)	25 (16.7)	
Nausea	59 (39.3)		7 (4.6)	51 (34.0)	
Aches/Migraine	71 (47.3)		–	66 (44.0)	
Spontaneous abortion/cancer	13 (8.7)		–	8 (5.3)	
None	0	0.166*	138 (90.2)	0	0.066*

*significant at $p<0.05$.
**significant at $p<0.01$.

Discussion

Human population exposed to potentially hazardous substances through inappropriate and unsafe management practices related to disposal and unofficial recycling of e-wastes, is increasing. We assessed the evidence for possible association between exposures and adverse health outcomes via questionnaires filled by residents and workers of Alaba International and Computer Village electronic markets.

Data collected showed that workers in these markets had only basic education, with majority only having primary and secondary educations. This had significant effects on their usage of protective gear while working with e-wastes. The lower the educational status, the less frequent was the usage of protective gear during work. The level of education might be responsible for lack of information about potential dangers involved in their work and the benefits of constant usage of protective gear. Also, since low education amounted to low salary income in the markets, lack of fund might also have discouraged these workers from obtaining necessary protective gear for their work, thus, less frequent utilization of protective gear during work might be responsible for more exposure to the toxic constituents of e-wastes through inhalation and direct skin absorption.

Exposures of workers and residents to e-wastes constituents were probably enhanced as a result of the method of disposal commonly employed in the two markets. Open burning in informal dumpsites was the main disposal method for e-wastes in the markets. Open burning of e-wastes would not only contaminate the soil but also pollute the air, leading to emission of toxic chemicals which could have been contaminating the immediate environment and also be transported far away from the dumpsites into nearby residence by wind. Burning of e-wastes at high temperature can convert toxic constituents to more toxic chemicals thereby causing greater harms to both workers and residents of these markets. Indeed, atmospheric contamination by e-wastes recycling and disposal activities had been shown to cause bioaccumulation of toxic chemicals in exposed humans, especially children, in a similar site in China. Eighty per cent of children in Guiyu, an e-wastes recovery and processing site, suffered from respiratory diseases, they were particularly vulnerable to Pb poisoning (Wasserman *et al*, 1998; Needleman *et al*, 2002; Qiu *et al*, 2004; Jain and Hu, 2006).

The reported health effects, ranging from skin problems, nausea, aches, migraine, spontaneous abortion and cancer, were probably as a result of exposure to e-wastes because of the positive correlation between exposure rate and these health effects, and the significant difference from the control group. The major routes of exposure to the toxicants in e-wastes by the workers and residents were through e-wastes contaminated drinking water, which were generally characterized with odour, colour and taste; and inhalation of smoke from the open e-wastes burning from several informal dumpsites surrounding the markets. The well-waters, which were the main sources of drinking and cooking water in these areas, have been previously reported to contain heavy metals and organics (Bakare *et al*, 2013; Alabi and Bakare, 2014) which are present in e-wastes. These well-waters have also been shown to induce genetic damage in somatic and germ cells and oxidative stress of exposed animals (Bakare *et al*, 2103; Alabi and Bakare, 2014). Exposure routes could vary depending on the substance and processing. Generally, exposure to the hazardous components of e-wastes is most likely to arise through inhalation, ingestion, and dermal contact. In addition to direct occupational (formal or informal) exposure, people can come into contact with e-wastes materials, and associated pollutants, through contact with contaminated soil, dust, air, water, and through food sources, including meat (Robinson, 2009; ATSDR, 2012). Workers and residents of the markets with longer work duration and prolong stay periods experienced more of the reported health problems. This could be as a result of chronic exposure and bioaccumulation of e-wastes toxicants in these exposed groups. Constant exposure through contaminated water and inhalation over time by both long-time workers and residents compared to new workers and residents might be responsible for the observed health problems.

The positive correlation (r = 0.540 and 0.589 in Computer Village and Alaba International markets, respectively) between close proximity of the residential apartments to e-wastes dumpsites (<100 m) and reported health problems underlines the detrimental effects that co-habitation of electronic markets with residential areas had on public health, hence, the need for immediate separation and evacuation of residents from these electronic markets. Because of the high levels of environmental, food, and water contamination, residents living within a specific distance of e-wastes processing areas are also at risk of environmental exposure, although at lower levels than through occupational exposure (Yu *et al*, 2006; Wong *et al*, 2007; Fu *et al*, 2008).

The positive correlation between age, home usage of electronic materials, exposure rate and the associated health problems herein is of public health importance. Children are a particularly sensitive group because of additional routes of exposure (e.g., breast-feeding and placental exposures), high-risk behaviours (e.g., hand-to-mouth activities in early years and high risk-taking behaviours in adolescence), and their changing physiology (e.g., high intakes of air, water, and food, and low rates of toxin elimination) (Pronczuk de Garbino, 2004; Grant *et al*, 2013). The children of e-wastes workers also faced take-home contamination from their parents' clothes and skin and direct high-level exposure if informal recycling or repair was taking place in their homes.

Spontaneous abortion and cancer which were reported as part of the perceived health effects experienced by workers and residents in the two electronic markets might be due to exposure to e-wastes constituents. About 50% of all spontaneous abortions involve incidences of chromosomal abnormalities (Jia *et al*, 2011). Our previous studies have shown that e-wastes constituents in soil, leachates and ground water from these areas induced DNA damage *in vitro* and *in vivo* (Alabi and Bakare, 2011; Alabi *et al*, 2011; 2013; Bakare *et al*, 2012; 2013). Studies (Jia *et al*, 2011; Wang *et al*, 2012) have also shown the potential of e-wastes contaminants inhalation to cause lung cancer. An association between exposure to e-wastes and various outcomes in human beings is very likely.

Mechanisms of action, from animal and *in vitro* models, have been developed for individual and mixtures of chemical compounds implicated in e-wastes. Additionally, important associations have been recorded between the chemical compounds found in e-wastes and mental, physical, and learning outcomes due to e-wastes sources of exposure. Many of the individual chemical pollutants found in e-wastes have substantial effects on human health. The International Agency for Research on Cancer has identified TCDD (2,3,7,8-tetrachlorodibenzo-pdioxin), cadmium, hexavalent chromium, and beryllium as carcinogenic (WHO-IARC, 1993;1997); some polychlorinated biphenyls and some polycyclic aromatic hydrocarbons as probably carcinogenic (WHO-IARC, 2010; 2012); and polybrominated diphenyl ethers, metallic nickel, and some polycyclic aromatic hydrocarbons as possibly carcinogenic (WHO-IARC, 2010; 2011). Polybrominated diphenyl ethers, polycyclic aromatic hydrocarbons, chromium, nickel, and aluminum are confirmed genotoxins (Barber *et al*, 2006; Hirano *et al*, 2011), while copper, iron, and aluminum are known cytotoxins (Seth *et al*, 2004; Lankoff *et al*, 2006).

Exposure to dioxins, dioxin-like polychlorinated biphenyls, perfluroalkyls, lead, and possibly cadmium has been associated with increased incidence of chronic diseases later in life, including obesity, type 2 diabetes, hypertension, and cardiovascular diseases (Everett *et al*, 2011; Halldorsson *et al*, 2012; Zhang *et al*, 2012). Lung cancer, lung damage, and decreased lung function are also associated with compounds common in e-wastes, including polycyclic aromatic hydrocarbons, hexavalent chromium, cadmium, nickel, arsenic, and lithium (Pearson *et al*, 2005; Martin *et al*, 2011; Abakay *et al*, 2012).

The effects of simultaneous exposure to many chemicals, for example, involvement in e-wastes processing, burning and recycling, are not well explored or understood. This knowledge gap becomes a larger problem in areas where other hazardous wastes are present in the environment. Although e-wastes contain a unique combination of persistent hazardous compounds, other sources of exposure are difficult to rule out. Other variables, such as smoking and alcohol consumption were found to be confounding factors in the reported health problems by the studied subjects. The mechanisms of action of the mixture of chemicals that make up e-wastes are not completely known, nor are the full range of effects that arise from the combined exposure to many chemical elements and compounds from other compounding variables.

Therefore, the widespread production and use of electronic and electrical equipment, the increasing contamination of the environment, and the persistence and bioaccumulation of these chemical components warrant special consideration of e-wastes as an emerging health risk for many populations, especially in many developing countries including Nigeria. A precautionary approach towards exposure, especially in children, seems warranted.

The control-groups showed insignificant level of the health challenges reported by the exposed-groups in the markets. They had no record of spontaneous abortion and cancer which were reported in the workers and residents of the electronic markets. This was an indication that working and living near e-wastes were indeed associated with the reported health effects.

The health effects of exposure to e-wastes must become a priority of the international community. Informal and low management practices of e-wastes had long been accepted as sources of dangerous environmental pollution, but the health risks it posed to exposed populations were only beginning to be recognized. An international research agenda should be set by experts to increase the body of evidence of the health effects of e-wastes exposure, especially in children and vulnerable populations. Simultaneously, the international health community, academia, policy experts, and non-governmental organizations, in conjunction with national governments, should create policy solutions, educational programmes, and interventions (such as environmental remediation, medical treatment of the affected, provision of protective gears at affordable prices for workers, design of a safer method of e-wastes disposal, etc.) to reduce e-wastes exposure and its health effects.

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