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Full Length Research Paper

Qualitative analysis of the presence of PBDE in ashes, soils and vegetables from Agbogbloshie e-waste recycling site

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This paper assesses qualitatively, the presence of PBDEs in ashes, soils and vegetables found at the Agbogbloshie e-waste recycling site in Accra, Ghana. The motivation for the study was not only because the area serves as a major food center of the city where vegetables are cultivated extensively but additionally, a place where informal e-waste recyclers incinerate wires to harvest copper for survival. The dilemma is how to ascertain the safety of foods coming from the area since vegetables for example, are known to be very susceptible to contamination by ubiquitous lipophilic organic compounds including PBDEs which can be health threatening. Moving beyond speculative considerations that have characterized prior reports, this paper employs the EI Gas chromatography mass spectrophotometric method to analyse the presence of PBDEs in the ashes, soils and vegetables found at the site. The intent is to contribute to the debate and literature on how livelihood strategies impact food security. The results confirm the presence of five different PBDEs (BDE- 1, BDE- 7, BDE- 28, BDE- 47, BDE- 99 or BDE- 100) in all the samples, indicating a propensity of the e-waste recycling activities to disrupt food coming from the area and possibly affect human health. The paper calls for a more comprehensive study that will help create a set of converging policies and strategies that can reconcile the need for access to livelihood strategies – such as e-waste recycling, despite its health and environmental risks – and the right to healthy working conditions, a clean environment and safe food in Accra.

Keywords: E-waste, Polybrominated diphenylethers, Environmental Hazards, Occupational Hazards, Food Security.

INTRODUCTION

Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstance beyond his control. Universal Declaration of Human Rights (1948), Article 25 (1).

Studies by food scientists have revealed that vegetables can potentially prevent certain chronic diseases (Lampe, 1999; Messina, 1999; Duranti, 2006). In addition, they (vegetables) as well as fruits are lower in calories and fat (Vicenti et al., 2009) and are so imperative for the human metabolism that World Health Organization (WHO) has set, at least, minimum human intake levels (WHO, 2004). Yet, accessing these

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necessities in healthy but affordable quantities in cities, especially in developing economies, pose a challenge not only financially, but also regarding how such foods are sourced, prepared, handled and stored (Drechsel et al., 2002).

Various factors account for this development including the fact that most urbanising cities' economy struggle to sustain primary agriculture due to increasing sprawling which has made land physically unavailable and astronomically prohibitive in terms of value (Flynn-Dapaah, 2001; Oteng-Ababio, 2011). Under the circumstances, farming is typically done along available (accessible), often times, "over-polluted" water bodies, drains and in backyards where irrigation is feasible (Obosu-Mensah, 1999; Zakaria et al., 1998). In Accra, most such farming activities are along the Odaw River at Agbogbloshie, an area that has achieved notoriety in the global media and among non-governmental organizations (NGOS), as being the e-waste recycling hub of Ghana. Accordingly, researchers at Blacksmith Institute estimate 40,000 - 250,000 people are at risk from various e-waste handling, processing, recovery and dumping centered at the Agbogbloshie recycling and scrapyard facility (Blacksmith Institute 2013). It is an area where the e-waste market has grown hand-in-hand with burgeoning informal economic activities and rapid urbanization. The market serves general food sellers as well as specialized niche vendors of tomatoes, yams, and onions, and draws buyers and sellers from a wide hinterland. At the same time, the main e-waste recycling operations performed at the site are dismantling and open incineration. Hence, possible local health and environmental consequences of e-waste toxicants wafting into the immediate atmosphere and leaching into soils, the lagoon, and the nearby sea are highlighted by Environmental Non-Governmental Organisations (ENGOs) and other authorities (see Brigden et al., 2008; Puckett, 2011).

This has reflected in frantic policy developments, such as the revision of the national environmental sanitation policy of 1999 in 2010 (MLGRD, 2010), the enactment of efficient refrigerator rebate scheme in 2012 (Energy Commission, 2012) and the 'draft e-waste management policy bill receiving cabinet consideration (Oteng-Ababio, 2012). The swell of interest is also related to the recognition that human being has the capacity of creating, modifying and destroying his ecosystem; for example, how the current governance structure is festering poverty and informality and how people's livelihood strategies have led to the prevalence and accumulation of hazards in the city (Oteng-Ababio, 2010). The interest has also been spurred by greater understanding of several interrelated factors and pathways that can exacerbate chronic human vulnerabilities including the sources, content and quality of food supplies, especially within the urban milieu. Despite this hyped interests, most commentaries on the safety of food from Agbogbloshie have all too often been very speculative, ad-hoc, ill-judged, poorly coordinated and based on empirical vacuum (see Brigden et al., 2008; Puckett, 2011).

While recent ENGOs literature explores issues pertaining to health possibilities and awareness creation (Puckett, 2011), there has been far less discussion on the level of contamination and the possible pathways that generate the complex emergencies. Indeed, the links between incineration of wires to harvest copper and the accumulation of heavy metals in the soils, and their potential impact on the security of foods grown in the area has been poorly researched. Consequently, our analysis on this pilot study aims to address some of the gaps in knowledge by exploring how the current e-waste recycling activities provide routes by which toxic substances can be emitted into the atmosphere, the soil, and indeed the human body. Specifically, it analyses the presence of polybrominated diphenylethers (PBDE) in soils, ashes and vegetables grown in the area. The intent is to establish possible link between the e-waste recycling activity and the security of food coming from the site. This will allow for some reflections on the implications for the current environmental policies.

Livelihood Strategies And Risks Accumulation At Agbogbloshie

The growing inequalities in cities, especially in developing countries, are expressed vividly in the enormous discrepancies in access to livelihood, food and basic services between different urban residents (Satterwaithe, 1998; UN-Habitat, 2010). Although living standards have increased dramatically over the last two decades (Owusu, 2008), the recent increasing urbanization has meant that the number of urban poor, who have traditionally taken the brunt of the blame for causing society's many problems, has remained steady (Oteng-Ababio, 2012).

McGranahan (2001) indicates that there is a close correlation between poverty, livelihood and risk accumulation both at the macro and micro levels. There is empirical evidence indicating that as the poor (over) exploit environmental resources for survival, disaster risk increases (Grant, 2009). The World Bank had earlier in the 1992 World Development Report explicitly indicated that, "poor families who have to meet short term needs mine the natural capital by excessive cutting of trees for firewood and fail to replace soil nutrients" (World Bank, 1992). Furthermore, urbanization of poverty and the lack of choices for alternative livelihood tend to compel the poor to exploit its environment to dangerous levels (Hardoy et al., 1992).

Figure 1: A section of e-waste workers incinerating wire to harvest copper
Source: Authors' fieldwork, 2012

Thus, unplanned urbanization, couple with disproportionate growth in poverty, continues to increase the risk of marginalized residents (urban poor) who often live on unsafe land. UN-Habitat (2011) puts it frankly that one out of 4 urban dwellers lives in 'absolute poverty' and that disaster risks often signify unsolved development problems where poverty is a factor, affecting both the choices for a safer livelihood and environment. Admittedly, there has been a rising trend in the economic literature, which disputes this conventional theory on poverty-risk accumulation nexus. Leach and Mearns, (1995) for example, argue that a simple generalization of such a multi-dimensional problem is erroneous and that a more complex set of demographic, cultural, and institutional factors are at play. Though these studies are few and isolated, they point to an intricate web of factors and the existence of feedback loops. Yet, a critical analysis of these factors trace their antecedent to the upsurge in city living, given weight for an in-depth empirical research to examine urbanization of poverty and environment hazards causality links as the following subsections discuss.

E-waste recycling and PBDE risks accumulation

Prior studies have shown that Agbogbloshie recycling site received approximately 171,000 tonnes of e-waste in 2009, which are exclusively processed through informal practices (Amoyaw-Osei et al., 2011). Their modus operandi includes collection, manual dismantling, open-burning to recover metals and open-dumping of residual fractions. Figure 1 depicts a section of recyclers burning wires to harvest copper. According to earlier scholarship (see Caravanos et al., 2011) the practice has simultaneously made the area become a potential source of local health and environmental risk even though it serves as the major food distribution centre for the city. These challenges come together in a unique pattern at the study area (Agyei-Mensah and Oteng-Ababio, 2012).

This observation emanates from earlier laboratory studies (see Pinto, 2008), which revealed that open, uncontrolled, burning of e-waste, can result in atmospheric releases of hazardous metals, polychlorinated dioxins, furans and brominated analogues. Other studies (BAN, 2005) further highlight how the urban population tends to face acute vulnerability as a result of such uncontrolled informal practices. Given the complex drivers of urban risks and the emotions exhibited by some commentators, the actual ills of e-waste recycling on the urban economy tends to be masked.

The PBDEs are persistent and increasingly common in the environment partly because such chemicals are typically used as flame-retardants. There are 209 possible PBDE congeners but the commonest include, BDEs 47, 99, 100, and 153. These happen to be the most frequently found in human tissues due to their

Figure 2: Vegetable farms at the study area (figure A and B)
Source: Authors' fieldwork, 2012

ubiquitous nature (Schreiber, 2010) and their lipohilic tendency (solubility in fat), which makes them bio-accumulate in fatty tissues (Lampe, 1999; Yu et al., 2011). They can often find their way into food supplies, dust, soil and sediment. The main pathway to human exposure is through ingestion of contaminated foods - vegetables or inhaling contaminated dust (WHO, 2004; Schreiber, 2010). By their nature (bio-accumulate in fatty tissues), exposure in unborn babies and infants occur through breast-feeding or through the placenta (Lampe, 1999; Zhao et al., 2007).

Asante et al. (2012) identify high concentration of PBDEs in breast milk samples in three main regions in Ghana and opine that the toxicological endpoints of concern for environmental levels of PBDEs are likely to be thyroid hormone disruption, neuro-developmental deficits and cancer. Though PBDEs have been nominated for possible inclusion on the Stockholm Convention on Persistent Organic Pollutant (POP), high production of electronic and electrical equipment (EEEs) means high generation of e-waste. Meanwhile, there is no formal framework for the proper disposal of e-waste and therefore, the final destination of the inherent PBDEs is not certain. The current knowledge of the presence and levels of PBDEs at the site is explicitly meager and limited, giving another justification for the current qualitative analysis.

PBDE accumulation and threats to food security

As cities grow both spatially and demographically under conditions of poor planning, economic stagnation and institutional collapse, they tend to take on more of the qualities of their rural communities: increasing importance of urban agriculture by disobeying restrictive land-use controls - paving the way for more diverse use of urban space; the spontaneous growth of illegal settlements and of petty commodity production (Cheru, 1989). The situation is not different in Accra where urban agriculture is practiced extensively with the result that the economic differences between city and its peri-urban zones have become blurred (Farvacque-Vitkovic and Godin, 1998). Figure 2 depicts some of the vegetable farms in the study area captured during the fieldwork.

The increasing urbanization of Accra has made land for urban agriculture economically prohibitive, creating socio-economic pressures for those who engaged in the practice for livelihood. Accordingly, many prospective urban farmers are compelled to live and work in available (accessible) but dangerous locations, without the necessary resources to protect themselves and/or guarantee the safety of what they produce. Indeed, their desire to find their daily food tends to override the more remote threat of risks embedded in their livelihood strategies either to themselves or to the larger society. Thus, farmers in Accra have dammed highly contaminated (polluted) drains (see Oteng-Ababio, 2013) to harvest water to irrigate their farms' (Zakaria et al., 1998; Obuobie, 2003) while the lands on which they farm have seen lots of e-waste recycling activities (Amoyaw-Osei et al., 2011; Grant and Oteng-Ababio, 2012), all of which can potentiate health challenges (Pinto, 2008).

We argue that without understanding why people tamper

Table 1: Parameters for Gas Chromatography/Mass spectrophotometer Analysis

Apparatus:	**GC/MS**
Instrument	Description
Gas Chromatography	Varian CP-3800 GC-Saturn 2200 MS with a CP-8400 Auto sampler
Analytical column	30m +10m EZ Guard x 0.25mm internal diameter fused silica capillary coated with VF-5ms (0.25µm film) from Varian
Temperatures:	
Item	Conditions
Injector	Split less mode, temperature 270℃
Oven	$50^{\circ}C$ / 1min $\xrightarrow{25^{\circ}C/min}$ $180^{\circ}C$ $\xrightarrow{5^{\circ}C/min}$ $300^{\circ}C$/6min
Gases:	
Gas	Flow rate
Helium (carrier)	1.0 ml/min constant flow
Mass Spectrometry	
Segment start time	3.0 min
Segment end time	36.0 min
Segment low time	45 m/z
Segment high time	650 m/z
Ionization mode	EI
Injection volume	2 µL

with, live and farm on dangerous locations, it will not be easy to enact appropriate policies that will ensure long-lasting solutions. In the Accra situation, it is not only the poor who are at risk of the impact of poor e-waste recycling practices but also the entire urban population who consume the vegetables produced in the area. Without doubt, the poorest have fewer assets and therefore tend to reach their 'threshold of collapse' faster than the affluent. It is equally true that small-scale risks such as the accumulation of heavy metals in the soils which eventually end up in the vegetables or the direct inhalation of such metals are often left to the affected people to deal with (Pinto, 2008). This is a major setback yet governments are generally inclined to enthusiastically shoulder the burden of addressing large-scale disasters (Hardoy et al., 1990).

There is a persistent tendency for policy makers to equate urban life with a small group of elites who govern the city. This tends to mask, downplay or dichotomise more complex and varied dynamics associated with e-waste recycling, such as the mobility and linkages between survivalist strategies and risks accumulation more generally. The result has been an apparent neglect of the main problem facing majority of urban poor who live and work under health threatening conditions (Lee-Smith and Stren, 1991). This is against the backdrop that substantial numbers of household are ill-equipped to handle small-scale and localized risks. Such groups often fall outside all safety nets and are pushed into destitution without being voiced. Yet, the circular nature and consequence of survivalist approach and risks accumulation on individuals and indeed, the society at large, does not preclude effective action.

MATERIALS AND METHODS

The study area

The research locality – Agbogbloshie, is an e-waste dumping area, scrap processing zone, and food market in the heart of Accra. The area exemplifies the challenges most policy makers face with respect to e-waste recycling and its impacts on health, food security, and the environment. The site is geographically hemmed within the main of Abosey Okai Road, the Odaw River, and the Agbogbloshie drain (see Figure 3). The area is about 31.3 hectares and less than a kilometer from the Central Business District (CBD) with a current available population of 79,684 ("Housing the Masses," 2010:2). In particular, the burning of sheathed cables by local informal workers engaged in the recovery of copper from discarded electronic devices has been highly controversial (Brigden et al., 2008; Puckett, 2011). Preliminary public health assessments show high lead levels of 18,125 ppm in the soil (by contrast USEPA standard for lead in soil is 400 ppm) and blood and urine samples taken from e-waste workers show elevated levels of barium, cobalt, copper, iron and zinc (Caravanos et al., 2011). Other prior studies from countries with longer established informal e-waste nodes (for example, China and India) demonstrate that hazardous e-waste emissions have damaging health effects.

General methods

In general, all the n-hexane (99%), acetone (99%) and silica gel used for extraction and cleaning - up of the samples for the entire study were obtained from Wagtech International Ltd, London (United Kingdom). Thereafter, a Varian CP-3800 GC-Saturn 2200 coupled with a CP-8400 Auto sampler mass spectrometer were used in analyzing the presence or otherwise of PBDEs in the samples. Table 1 lists the instrumental conditions for the Gas Chromatography/Mass spectrophotometer (GC/MS) used.

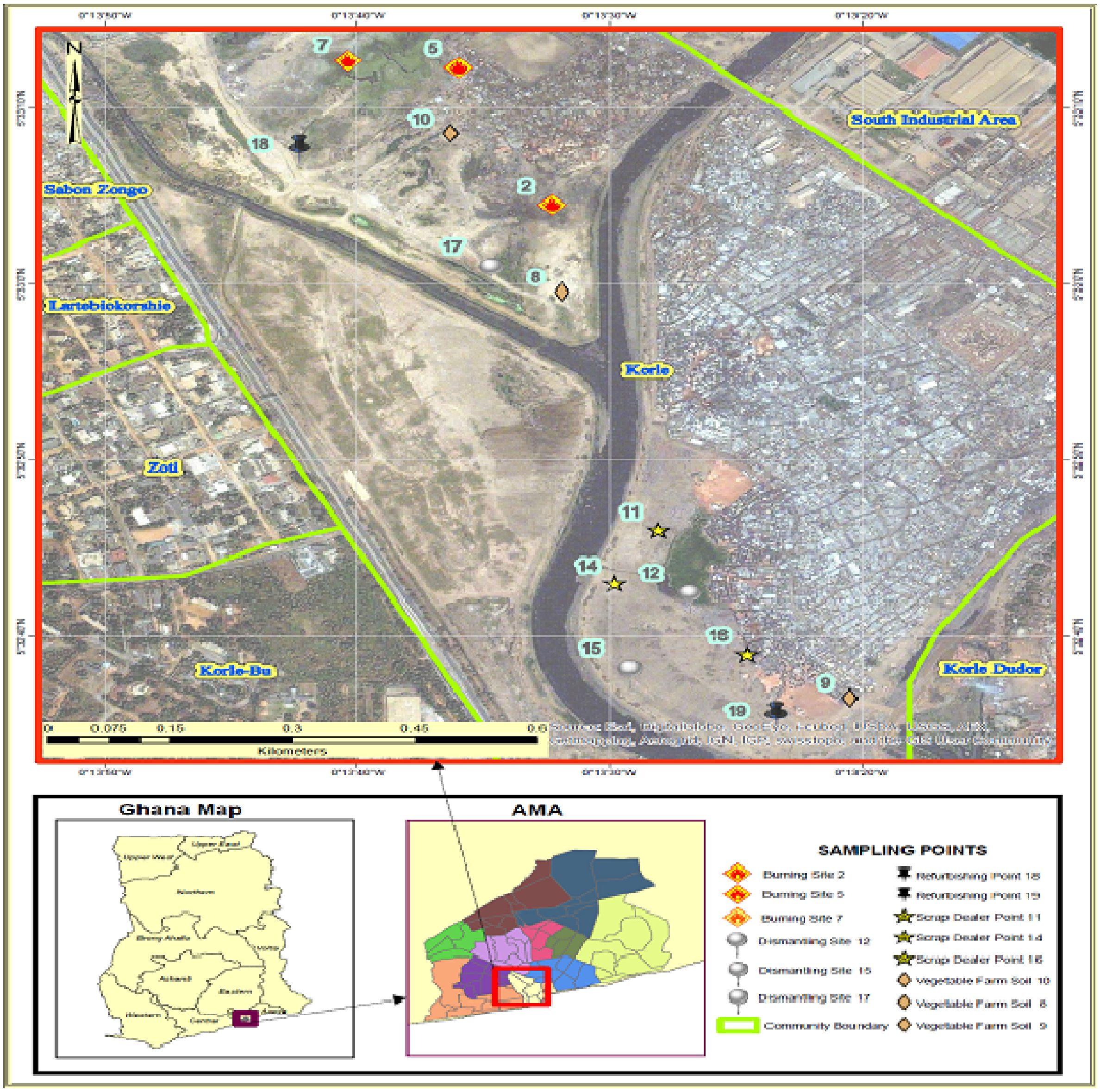

Figure 3: Map of the study area showing the sampling points
Source: Authors' Construct, 2013

Sampling of ash, soils, substrate and vegetables

To achieve the set objectives, the study adopted explorative case study approach (Yin, 2003). A total of 17 samples (10 top soils, 3 ashes and 4 vegetables) were collected from the Agbogbloshie e-waste recycling site. The soil and ash samples were collected from different points where dismantling and incineration of e-waste activities take place as well as where the scrap dealers and refurbishers operate. Three ash samples were collected from the burning site, while three (3) top-soils each were collected from the dismantling and scrap dealers sites, and two (2) from the refurbishers points. In addition, two (2) more samples each of soil, lettuce and *Amaranthus sp* were also collected from two different vegetable farms at the e-waste recycling site at Agbogbloshie.

The sampling process was aided by a global positioning system (GPS). To assist in comparing the relative levels of contaminations, four additional samples

Table 2: Possible PBDEs identified at different sampling locations

	Sample location (X)	Possible types of congener
	Burning site (3)	BDE- 1, BDE- 7, BDE- 28, BDE- 47, BDE- 99 of BDE- 100
	Scrap dealer point (3)	BDE- 1, BDE- 7, BDE- 47
	Dismantling site (3)	BDE- 7, BDE- 28, BDE- 47
	Refurbishing point (2)	BDE- 1, BDE- 7, BDE- 47
	Vegetable Farm soil (2)	BDE- 1, BDE- 7, BDE- 28, BDE- 47, BDE-99 or BDE-100
	Amaranthus sp (2)	BDE- 1, BDE- 7, BDE- 28
	Lettuce (2)	BDE- 1, BDE- 7, BDE- 28, BDE- 47
Control		
	U/G Agric (substrate)	BDE- 1, BDE- 7
	U/G Agric (*Amaranthus sp*)	BDE- 1, BDE- 7, BDE- 28
	U/G Agric (lettuce)	BDE- 1, BDE- 7, BDE- 28
	U/G Chemistry (soil)	BDE- 1, BDE- 7, BDE- 28

Source: Authors' fieldwork, 2013. NB: *U/G- University of Ghana; (X)- Number of samples*

from a non e-waste recycling site at the University of Ghana were collected (one soil from the chemistry department and one each of substrate, lettuce and *Amaranthus sp* from the Agricultural department Gardens). These served as control units in testing for the presence of the PBDEs. About 50.0 g each of all ash, soil and substrate samples was scooped (1-10 cm depth zone) with a hand trowel into chemically clean air-tight plastic bags. All vegetables were also collected into chemically clean air-tight plastic bags for laboratory analysis.

Drying and extraction

To facilitate data analysis, ash, soil, substrate and vegetable samples were air dried for one week to prevent any photo-chemical degradation if exposed to sunlight. It was also to ensure that the samples are rid of all water since that could affect the GC/MS analysis. Approximately 10.0 g each of the air dried ash, soil or substrate samples were extracted with 100 ml 1:1 mixture of acetone (99%) and hexane (99%) using a soxhlet extractor for 6 hrs. After extraction the mixture was allowed to cool and concentrated to about 2 ml into 5 ml vials using the rotary evaporator. Air dried vegetables were also pulverized with mortar and pestle and about 5 - 10.0 g of each extracted with 100 ml 1:1 mixture of acetone (99%) and hexane (99%) using a soxhlet extractor for 6 hrs. After extraction the mixture was allowed to cool and concentrated to about 2 ml into 5 ml vials using the rotary evaporator.

Cleaning-up the sample

A clean-up of all the extracts obtained from the extraction was done using silica solid phase extractor (SPE) and hexane as the eluting solvent to remove interfering compounds. The silica solid phase extractor was conditioned with 10 ml of the eluting solvent followed by the introduction of the concentrated sample extract. Elution was continued with about 20 ml of the hexane and the eluate also concentrated to dryness followed by addition of 1 ml of fresh hexane with a micropipette. The resultant solution was then transferred into vials for analysis.

RESULTS AND DISCUSSION

The study set out to analyze the presence of PBDEs in the collected samples. We reckon that the mere presence of PBDE does not indicate health hazards unless the quantity level is empirically ascertained, something that is beyond the scope of the current study. It is however hoped that the results will stimulate more comprehensive studies. The findings show that the concentrations of five classes of pollutants (different PBDEs) were identified in all the samples (see Table 2). These are mono-BDE, di-BDE, tri-BDE, tetra-BDE and penta-BDE (BDE- 1, BDE-7, BDE- 28, BDE- 47, BDE-99 or BDE-100 respectively) which are lower brominated PBDEs and the commonest in the environment.

From the table, the findings identified mono and di-BDEs in almost all the sampling sites (10 out of 11). Additionally, Tri-BDE was identified in 8 sampling areas (73% of total sample) with fairly equal representations in both the e-waste and non e-waste sites. However, both tetra- and penta-BDEs were not present in the control group with any known occupational (e-waste) exposure. The Tetra-BDE and penta-BDE were identified in 6 (55%) and 2 (18%) locations respectively of the e-waste recycling sites sampled.

Among the e-waste sampling sites, the burning sites and vegetable farm areas recorded significantly higher presence of all the five BDEs, while the other sites showed the presence of 4 (i.e. excluding BDE-99 or 100). This is not unexpected as the areas, which recorded the 5 PBDEs presence also coincide with areas of intense incineration of wires to retrieve copper. Since mobility of these lower brominated PBDEs is nil or little, leaching is unexpected but rather, might have been absorbed unto the soils or transported in their vapour state into the vegetable farm soils to be absorbed by plants.

The sample from the control group showed only 3 BDEs (BDE- 1, 7 and 28). The results further showed that all sampled vegetables sampled vegetables recorded the presence of BDE-1, 7 and 28. The presence of lower PBDEs in all the samples confirms the assertion that these flame-retardants are ubiquitously present in the environment - air, soil and food. Particularly, *in vitro* studies have shown that PBDE-47 and PBDE-99 are neurotoxins at very low concentrations (Lampe, 1999; Yu et al., 2011).

It is important to state that the Gas Chromatography/ Mass spectrophotometer (GC/MS) used for the study could analyze masses up to 650 m/z, so PBDEs with masses greater than 600 m/z (e.g. from octaBDE to decaBDE) would not be analyzed. Thus, the absence of BDE-209 m/z for example does not necessarily mean it was not present in the samples. It is also important to see the presence of some amount of PBDEs in the control samples from the same perspective.

The GC/MS instrument is very sensitive and requires as small as 10^{-12} g of the analyte. Because of their ubiquitous nature, their total absence in the control samples was not anticipated.

The findings make the situation in Accra a potential candidate for immediate comprehensive research interest if the safety of the vegetables grown at the site and its environs is to be ascertained. Currently, an estimated 60% of the urban households, mostly the urban poor, are engaged in some form of backyard gardening for livelihood, with about 50-70 hactares distributed over 80, 000 backyards (Obuobie et al., 2004). The dominant activities, being undertaking by the many vegetable farmers are irrigated, market-oriented, vegetable production that contributes up to 80% of the total supply of fresh exotic vegetables consumed in the city (RUAF Exploratory Survey, 2006).By implication, the residents at the area in particular and Accra in general can be at a higher risk of exposure through intake of foods such as the lettuces and *Amaranthus sp* as well as through inhalation. It can also be inferred that since these lower BDEs can potentially bio-accumulate in fatty tissues with lower rate of metabolism and elimination from the body, they have the high propensity to disrupt thyroid hormones, cause neurobehavioral deficits and possibly cause cancer as indicated by earlier studies (Pinto, 2008; Asante et al., 2012).

CONCLUSION

It is counter-productive to contain urbanisation, even for environmental concerns, and therefore, the country must exploit its own unique urbanisation features. The country can achieve quality growth (lower inequality, less poverty and better environment) through a well-managed urbanisation. Thus, while there is good reason to be optimistic about the future of urbanising cities, there are still important challenges. The most pressing issue is how to tackle the widespread urbanisation of poverty and human deprivation (Satterwaithe, 1998). Africa in general has the world's highest proportion of poor people (46%), and is home to more than 30% of the world's poor (UN-Habitat, 2010). The challenge is huge not only because vulnerability to hunger remains pervasive, but also the fact that poverty is multi-dimensional and requires actions and resources on all fronts.

The finding highlights the growing evidence for negative environmental impacts and health concerns arising from uncontrolled informal e-waste recycling and disposal. This conclusion was based on the results of our research location, an area subjected to several studies. The study identified the area as having a great potential for urban farming. Apart from that large tract of land (i.e. 33.1 ha^2) being waterlogged and a "no man's land", the area used to be a refuse dumpsite in the late 1960s and the early 1970s. From all indications therefore, the site is potentially rich in organic manure and has provided livelihood option for many jobless youth who have thronged into the city with hope of availing themselves for higher income opportunities.

The land, which is sandwiched between the Korle Lagoon and the Odaw River, provides ample opportunity to the urban poor to make a living through farming. During the fieldwork, at least 15 urban farmers were counted operating on the land, producing exotic vegetables like lettuce, cabbage, spring onions, cucumber, green pepper and cauliflower, or the more traditional vegetables such as tomatoes, okro, eggplant and hot pepper. It is from this perspective that the authors strongly support the need for a continuous monitoring of persistent organic pollutant (POPs) in foodstuffs emanating from the site. The presence of 5 lower brominated PBDEs in all the sample matrices has confirmed its ubiquitous nature and this resonates with earlier studies (see McDonald, 2002; Yu et al., 2011).

The results also give enough justification for expressed concerns about the health of the e-waste workers and the urban residents in general. It also evokes the urgent need for further comprehensive studies in order to establish the actual level of contamination and provide further insights into the potential for the current practices impacting negatively on the local population. In other words, this explorative study has confirmed that the concerns raised by ENGOs and other interested parties are real and must be addressed sufficiently through the promulgation and strict implementation of appropriate public policies and regulations. It is however necessary to guard against simplistic assumptions or narrow prescriptions that deepen economic impoverishment and social marginalization or undermine environmental sustainability.

We share in the concerns raised but argue that these public interests cannot be adequately addressed based on empirical vacuum, hence the need for a more detailed quantitative analysis. Such studies may also include a risk-benefit analysis which will consider the following: the range of food sources produced in the area; the level of PBDEs in each product; and knowledge of different pathways (exposure) to POPs, particularly with respect to those who patronize the area for other occupational transactions other than e-waste related ones. Such a study should necessarily aim at solving a conundrum: the challenge of creating a set of converging policies and strategies that can reconcile the need for access to livelihood strategies – such as e-waste recycling, despite its health and environmental risks – and the right to healthy working conditions, a clean environment and safe food.

In conclusion, we wish to emphasise that expanding opportunities for gainful employment remains a critical challenge in Ghana where more than 80% of the population is outside the formal sector (African Union, 2008). The high unemployment rate, particularly among the youth, who are often poorly educated, is not only a major challenge for economic policy makers but has long-term consequences for aggravating inter-generational transmission of downward poverty spirals. Lack of accessibility and mobility for the majority widens the development gap between the 'haves' and the 'have-nots' and leads to declining opportunity in the social, economic and political spheres. Growing social polarization leads to a loss of faith in the system, and consequently many resort to other socio-economic activities, which tend to create citywide negative health-threatening consequences.

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