

## Decision Analysis

# Structured Identification of Response Options to Address Environmental Health Risks at the Agbogbloshie Electronic Waste Site

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### ABSTRACT

Electronic waste (e-waste) is a growing problem across low- and middle-income countries. Agbogbloshie (Accra, Ghana) is among the world's largest and most notorious e-waste sites, with an increasing number of studies documenting a range of environmental health risks. The present study aimed to provide national, regional, and international stakeholders with a summary of expert opinion on the most pressing problems arising from e-waste activities at Agbogbloshie, as well as suggested solutions to address these problems. Structured interviews were performed between April and September 2015 that used a Logical Framework Approach as a scoping exercise to gauge problems and benefits of e-waste recycling, and the Delphi methodology to identify response options. Stakeholders ( $n = 19$ ) from 15 institutions were interviewed with 2 rounds of a Delphi Poll: open-ended interviews followed by an electronic questionnaire in which experts ranked various proposed response options based on health, environmental, social, and economic benefit and feasibility. The goal was to prioritize potential interventions that would address identified problems at Agbogbloshie. Experts identified the most beneficial and feasible options in decreasing rank order as follows and prefaced by the statement "it is recommended that": 1) there be further research on the health effects; 2) e-waste workers be given appropriate personal protective equipment; 3) the Ministry of the Environment, Science, Technology and Innovation re-visit Ghana's Hazardous Waste Bill; 4) e-waste workers be involved in the planning process of interventions and are kept informed of any results; and 5) there be increased education and sensitization on hazards related to e-waste for both workers and the general public. These solutions are discussed in relation to ongoing dialogue at the international level concerning e-waste recycling interventions, with strengths and weaknesses examined for the Ghanaian context. *Integr Environ Assess Manag* 2017;13:980–991. ©2017 SETAC

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### INTRODUCTION

The use of electronic devices across the globe has brought about many benefits, especially in low- and middle-income countries. There has been evidence of mobile phone usage leading to increased long distance communication and access to jobs as well as agricultural, health, and educational services (Aker and Mbiti 2010). However, once electronic devices become obsolete they become waste, known as "electronic waste" (e-waste) (Caravanos et al. 2011). Globally, around 41.8 million tonnes (Mt) of e-waste was generated in 2014, and that number is expected to grow to 49.8 Mt in 2018 (Baldé et al. 2015). In certain high-income countries, such as countries in the European Union and Japan, e-waste has the potential to be recycled in country

(Lundgren 2012); however portions of what is not recycled in country are transported to low- and middle-income countries where the recycling practices are informal and generally unregulated (Brigden et al. 2008). A United States Environmental Protection Agency (USEPA) study found that it was 10 times less expensive to export e-waste to Asia from the United States than to process it in country, with the highest proportion of all e-waste being sent to China (Lundgren 2012). Recently, legislation on electrical and electronic equipment (EEE) imports into Asia has been tightening; therefore imports of EEE into West Africa are estimated to be on the rise (Lundgren 2012). Ghana and Nigeria have been identified as the major entry points for e-waste into the continent (Lundgren 2012).

Ghana is a country that receives imports of EEE such as mobile phones, television sets, computers, stereos, and radios (Amoyaw-Osei et al. 2011), most frequently coming from Europe and North America (Nukpezah et al. 2014).

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Importation of EEE into Ghana has increased by 2.7 times from 2003 to 2008 (Amoyaw-Osei et al. 2011), which was partly due to government implementation of certain policies that aimed to increase the technical capacity and efficiency in the country. In 2004, the government reduced the duty on the importation of secondhand computers to zero (Grant and Oteng-Ababio 2012). Although certain imported secondhand devices were usable, this was not always the case. In 2009, approximately 30% to 40% of all secondhand electronics imported into Ghana did not function (Schluep et al. 2011). Of these nonfunctional devices, approximately 50% were repaired and sold locally, whereas the other 50% was deemed unusable and became e-waste. Several sources report different amounts of e-waste being treated annually in Ghana, ranging from 10 000 metric tonnes (Prakash et al. 2010) to 69 000 tonnes in 2009 (Amoyaw-Osei et al. 2011). This large variation in numbers highlights a lack of foundational data and the need for more robust reporting.

Once in Ghana, most of the e-waste reaches informal sector recycling sites (Schluep et al. 2011), notably the site at Agbogbloshie. Agbogbloshie is located in Ghana's capital city of Accra, and is the largest e-waste recycling site in West Africa (Oteng-Ababio 2012; Basu et al. 2016). Originating as a scrap metal site, Agbogbloshie developed into a recycling area for e-waste as the levels of e-waste in the country began to grow (Amoyaw-Osei et al. 2011). E-waste recycling has been described as "urban mining," because upon the breakdown of electronic devices, valuable metals such as Cu, Al, and Au can be isolated and sold (Oteng-Ababio et al. 2014). The individuals who undertake these activities at Agbogbloshie make between a reported range of \$16 to \$52 per day, providing some of them with a livelihood they otherwise would not have (Akormedi et al. 2013). In 2010, it was reported that the total number of e-waste recyclers in Ghana was between 14 000 and 24 000 people; and in Accra alone, the number of people was between 4500 and 6500 (Prakash et al. 2010). In recent years, Agbogbloshie has come under tremendous media scrutiny due to the crude methods of recycling undertaken at the site and the negative health and safety conditions under which these activities are performed. Pure Earth (formerly the Blacksmith Institute) and Green Cross Switzerland rated Agbogbloshie e-waste site as one of the world's top 10 toxic threats in 2013 (Bernhardt and Gysi 2013).

Although the income provided by e-waste activities is beneficial to the workers, the methods with which the materials are recovered can have harmful effects on the environment and human health (Schluep et al. 2011). Workers manually disassemble parts in order to isolate the valuable metals from plastics, which usually involves using tools such as hammers, metal rods, stones, and chisels to break down larger equipment in order to remove metals such as Cu and steel (Brigden et al. 2008). Because workers at the site do not use personal protective equipment (PPE), these methods lead to injuries such as cuts on hands of workers (Akormedi et al. 2013). Furthermore, certain e-waste workers spend many hours per

day lifting heavy loads of e-waste onto handcarts to transport e-waste from 1 location to the other. This strenuous physical activity can lead to back pain and spinal injuries (Prakash et al. 2010). Burning of e-waste is another crude method of recycling and is done to isolate plastic components from valuable metals (Lundgren 2012). During this process, toxic substances are released into the air, soil, and water, contaminating the local environment (Amoyaw-Osei et al. 2011). Potentially toxic elements found in e-waste such as As, Sb, Sn, Fe, Ni, Br, Al, Cu, Zn, Ba, Mn, Hg, and Se have been found in the soil, ash, sediment, and dust around Agbogbloshie (Atiemo et al. 2012). High levels of Pb, PAHs, PCBs, and polybrominated diphenyl ethers (PBDEs) have also been found in soil, dust, and ash (Brigden et al. 2008; Caravanos et al. 2011; Oteng-Ababio et al. 2014), and Pb was found in ambient air at the site (Caravanos et al. 2011). Some of these chemicals, as well as dioxins and furans, have also been found in the blood and urine of e-waste workers (Caravanos et al. 2013; Feldt et al. 2014; Basu et al. 2016). Halogenated contaminants and PCBs, both having potential to lead to cancer or neurodevelopmental issues in children (USEPA 2016), have been found in the breast milk of women working and living near the site (Asante et al. 2011). Because Agbogbloshie e-waste workers are working closely with their environment, the contaminated water, air, and soil becomes a pathway of exposure for these chemicals. This exposure is likely through the inhalation of toxic fumes or ingestion of contaminated food or dust (Atiemo et al. 2012; Feldt et al. 2014).

A growing body of evidence suggests that practices at the Agbogbloshie e-waste site are harmful to workers and the broader community and environment. This e-waste site is in need of context-specific interventions due to the unique political, social, and cultural norms of Agbogbloshie and its surrounding community, though it also provides a case study of global relevance given its notoriety among stakeholders worldwide and the relatively large number of active research studies focused on the site. The purpose of the present study is to identify response options, or actions, to address environmental health (both human and ecosystem) and safety concerns specific to the e-waste activities at Agbogbloshie. The Logical Framework Approach (LFA 1979) was used as an initial scoping exercise to identify stakeholders and the problems and benefits associated with e-waste activities at Agbogbloshie. Following this, the Delphi method was used to collect and analyze response options from these same experts. Information was gathered in a 2-step manner: open-ended interviews and an electronic questionnaire. The goal of the present study was to provide policymakers (at the national, regional, and international levels) with a summary of expert opinion on the most pressing problems at Agbogbloshie and which solutions were most beneficial and feasible at this time.

## METHODOLOGY

### Overview

The LFA is an analytical process that assists in thinking through development problems and in collecting information

in a structured manner (Australian Government 2005; European Integration Office 2011). It includes a set of tools that ensure important questions are asked, providing decision makers with a broader understanding of the existing situation when planning interventions (European Integration Office 2011). The present study used 2 tools from the LFA (the stakeholder analysis and the problem tree analysis) in order to identify which individuals or institutions are affected by e-waste activities at Agbogbloshie and to identify the causes, problems, and consequences of these activities. A benefit analysis was added to this stage, in order to properly understand the opportunities brought about by e-waste recycling. These analyses were conducted through open-ended interviews.

Following the scoping exercise, the Delphi method, a structured process that helps obtain expert consensus on a complex issue (Hsu and Sandford 2007), was used to identify possible response options to the problems present at Agbogbloshie. This was done with multiple iterations of a Delphi poll, where the first round consisted of collecting expert suggestions of possible response options, which was built into the open-ended interviews. This was followed by the second round of Delphi polling, during which experts were invited to rank the options identified in Round 1 on the basis of certain criteria in order to prioritize goals for policy makers. The Delphi methodology has been shown to be more beneficial than focus groups, in which 1 person may dominate the conversation (Hsu and Sandford 2007). We had previously used Delphi polling among Ghanaian stakeholders to identify response options associated with artisanal and small-scale Au mining (Basu et al. 2015). The methodology is represented in Figure 1.

#### Participants

Participants recruited for an interview were chosen on the basis of their knowledge of e-waste as well as expertise in their domain. Twenty-eight participants with varying professional expertise were targeted for an interview. These experts were contacted up to 3 times through telephone or e-mail, and 19 experts agreed to participate, which was within an acceptable sample size for this type of study (Cricher and Gladstone 1998). The participants hailed from 16 different

institutions spanning academia, government, private sector, and civil society, and were all located in Accra, Ghana (Canadian High Commission Support Staff offices; Council for Scientific and Industrial Research [CSIR]-Water Research Institute; Ecological Restorations; Ghana Environmental Protection Agency; e-waste workers; Ghana Post Clinic; Greater Accra Scrap Dealer's Association [GASDA]; Green Advocacy; Ministry of Environment, Science, Technology and Innovation; Ministry of Local Government and Rural Development; Ministry of Trade and Industry; National Development Planning Commission; Pure Earth; University of Ghana; University of Bonn; Science and Technology Policy and Research Institute [STEPRI-CSIR]). Institutional Review Board (IRB) approval for human subjects interactions was obtained from the University of Ghana and McGill University, Montreal, Quebec, Canada. All interviews were conducted in English, and all participants provided consent prior to being interviewed.

#### Open-ended interviews

**Stakeholder analysis.** The goal of this stakeholder analysis phase was to identify all parties involved with the problem to ensure that their interests and concerns were understood in order to incorporate them into future intervention strategy selection (European Integration Office 2011). Experts were asked open-ended interview questions in order to identify different stakeholders affected by e-waste recycling activities.

**Problem tree analysis and benefit analysis.** The problem tree analysis was performed through a set of questions in the open-ended interviews. Participants were asked to identify the negative aspects of e-waste activities at Agbogbloshie and to determine their causes and consequences. The problems and their cause-and-effect relationship were developed into a problem tree using Microsoft Excel. Participants were also asked to identify the benefits of Agbogbloshie e-waste activities in order to gain an understanding of what opportunities arise from e-waste activities.

**Delphi Poll I.** The first Delphi poll was built into the open-ended interviews by asking experts to suggest 3 response

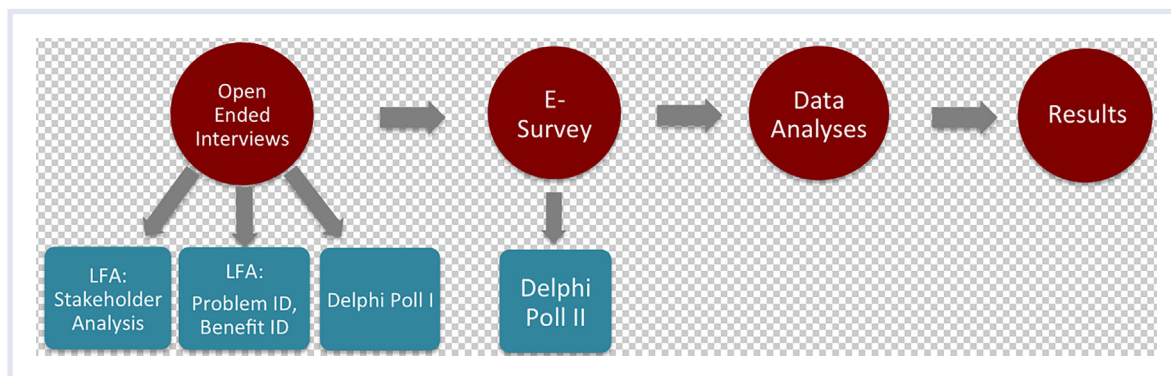


Figure 1. Study methodology using Logical Framework Approach (LFA) tools and the Delphi method. Electronic surveys were conducted using SurveyMonkey.

options to the problems that were identified, and to rank them based on impact and feasibility (with 1 indicating the most impact or feasibility and 3 indicating the least impact or feasibility). Next, all solutions identified by the experts were analyzed and compiled into 15 response options. Unweighted frequencies and weighted scores were reported for each option. Weighted scores were determined by assigning points to different ranks, with a rank of “1” worth 3 points, a rank of “2” worth 2 points, and a rank of “1” worth 1 point.

*Delphi Poll II: Electronic questionnaire.* Guided by the Delphi method, the 15 response options that were identified in Delphi Poll I were developed into an electronic questionnaire, using SurveyMonkey ([www.surveymonkey.com](http://www.surveymonkey.com)). The electronic questionnaire was based on Delphi methodology of past work in Ghana (Basu et al. 2015). Experts were asked to rank each response option on the basis of its economic, social, and environmental benefit and feasibility using a Likert-scale ranking system with 4 measures for both benefit and feasibility (1: will not have any impact/very unlikely to be feasible; 2: will have a low impact/not likely to be feasible; 3: will have a significant impact/likely to be feasible; and 4: will have a high impact/very likely to be feasible). The questionnaire was emailed to all original experts between 2 to 4 weeks following the first Delphi poll, and 15 people responded. Along with the electronic survey, the participants received a summary of the results from the open-ended survey. This was consistent with the Delphi method, because knowing the views of other members of the group, albeit anonymous, gave them the chance to revisit their answers from the first round and develop new insight based on other opinions (Hsu and Sandford 2007). This new insight would allow the group to come to a consensus as to what options should be pursued.

#### Data analysis

The data from the open-ended interviews, including Delphi Poll I, were transcribed and analyzed using thematic analysis, based on methodology by Guest et al. (2011). Each interview question was reviewed for common themes, with each theme coded by a number. Coded themes were then compiled into categories, and the frequencies of each theme were then manually counted and represented in tabular form. The results from Delphi Poll II (electronic questionnaire) were compiled into Excel and the mean rank was calculated for each scenario, based on their corresponding ratings from experts. Graphs were produced to represent the data. Participants were able to skip any question that they did not wish to answer. In Delphi Poll II, one participant did not rate political feasibility for response option A. The total was adjusted accordingly in order to calculate a representative mean.

## RESULTS

#### Stakeholder analysis

*Stakeholders who benefit from e-waste activities.* The top 3 groups identified by experts as benefiting the most from

e-waste activities were e-waste workers and their dependents, the metals industry, and the middlemen (Table 1). Eighty-nine percent of experts agreed that workers and their dependents benefited from e-waste recycling activities. According to 1 expert, these dependents mostly consisted of family members living in Agbogbloshie, but many of the workers also sent money to their families in Northern Ghana. Identified by 44% of experts as benefiting from e-waste activities were the metal companies that purchased raw materials from Agbogbloshie. According to an expert, instead of importing raw metals into the country to produce their products, they obtained them at a cheaper price: “Because of [e-waste] dealing, [the e-waste workers] are able to supply to local steel metal companies in [the city of] Tema and things like importing raw materials is out of the question.” Experts explained that steel companies did not purchase the metals directly from e-waste workers; they purchased from middlemen. Middlemen were identified by 28% of experts as benefiting from Agbogbloshie because they profited from selling recovered metals to the metals industry.

*Stakeholders who are negatively affected by e-waste activities.* Experts also identified which groups of people were the most negatively affected by activities at Agbogbloshie (Table 1). The top 3 groups were e-waste workers and

**Table 1.** Groups identified by 19 experts to be positively and negatively affected by activities at the Agbogbloshie (Accra, Ghana) e-waste site

Group affected	Beneficiaries: Expert agreement (%)	Negatively affected: Expert agreement (%)
Workers and dependents	89	100
Metals industry	44	—
Middlemen	28	—
Members of GASDA	11	—
Society	11	39
Individuals working near Agbogbloshie	11	67
Citizens discarding their e-waste	9	—
Producers of electronics	9	—
Unknown entrepreneurs	9	—
Vulnerable population (women, children, elderly)	—	22
Aquatic organisms	—	11
The government	—	11
Telecommunications networks	—	6

GASDA = Greater Accra Scrap Dealer’s Association.

their dependents (agreed on by all experts), the individuals who worked near Agbogbloshie, and society as a whole. According to 1 expert, workers who burned e-waste were the most at risk for health problems because “there is no protective gear and they are burning this plastic, so the dioxins, mercury, heavy metals are released.” Another expert identified workers who dismantled e-waste and those who loaded metals into the trucks as being most at risk of injuries. Experts explained that families of the workers were not only exposed to health risks but may have had to take on the high costs of a relative who fell sick from working directly at the site. Two-thirds of experts agreed that the health of individuals who resided or worked near the site was at an increased risk, primarily due to toxic fumes resulting from the burning of e-waste. This at-risk group included those who worked in surrounding businesses, at Agbogbloshie market, or those living in the Agbogbloshie community. One expert explained that while those living near the site would be at an increased risk, the problems did not only affect the local community: “Environmental problems don’t have borders, so the impact goes beyond Agbogbloshie.” This expert was part of the 39% of experts who agreed that health risks occurring at the e-waste site affected “society,” or people outside of the Agbogbloshie site. In addition to the dispersal of toxic fumes, agricultural activities occur onsite, and an expert explained that this “is a means of transferring heavy metals into the food chain.” Experts identified pregnant women, children, and the elderly as a particularly vulnerable group of people.

#### *Problem and benefit analysis*

**Benefit identification.** Through open-ended interviews, experts were asked to identify the top 3 benefits of the Agbogbloshie e-waste site. Five benefits were identified (Table 2). The most common answer was that e-waste recycling was a source of livelihood and income for many people who were previously unemployed or underemployed, as well as their dependents and families. The second most common benefit, identified by 39% of experts, was that e-waste recycling cleaned up the environment by taking care of the waste that would otherwise end up on the street, in

a landfill, or in drains. Experts pointed out that benefits also existed for the surrounding community of Agbogbloshie. One expert recognized that these activities specifically created wealth for the Muslim community: “[E-waste activities] bring tremendous economic facility for the community. [Agbogbloshie] is [mostly] Muslim in a very Christian country. So it’s become their mecca of economic activity. There’s a lot of money being made and supporting of families.” Other benefits identified were the economic gains for the steel metal companies, agreed upon by 22% of experts. Only 1 expert (6%) thought that the Agbogbloshie site brought no benefits.

**Problem identification.** Experts were asked to identify the different problems that arose from e-waste activities as well as their causes and consequences. The main problem identified by experts was the crude methods that the workers used to recycle the e-waste. According to experts, these included burning, manual dismantling, and dumping of excess waste that released toxic chemicals into the water, soil, and air. As seen in Figure 2, these led to or created 4 types of problems: environmental, social, health, and economic.

Many health problems were identified by experts, with 95% of experts agreeing that they mostly stemmed from the crude recycling methods and lack of PPE for workers. Health effects identified by experts included injuries, respiratory problems, hospitalization, lung cancer, general decrease in childhood health, decreased longevity of the affected population, and underdevelopment of the brain, especially in children. One expert communicated that these health effects were yet to be linked to e-waste activities: “In my opinion, some of the deaths in Ghana could be due to [e-waste activities], but we have not actually studied the link in a way that implies causation.” Another expert reflects on what it will take for policy makers to take action: “I think that sometimes the health issues will have to start manifesting before people will take action, but we can’t just keep quiet.” Although no causal link has yet been established between e-waste recycling and health outcomes, experts identified many potential health impacts resulting from exposure to e-waste contaminants and the importance of documenting them.

Of the experts interviewed, 21% reported that there were economic problems resulting from activities at Agbogbloshie. Experts expressed that health problems resulting from these activities indirectly contributed to a large economic burden on the country. As explained by 1 expert, “When people are ill, they don’t go work, so [there is a] loss of economic contribution and opportunity.” Worsening health outcomes for e-waste workers could bring about a loss of productivity. Another expert identified the consequences of crude recycling methods as “incapacitation, lower work output and poor socioeconomic conditions.” The long-term effects would be serious, suggested another expert, because “the government . . . will have spent more on the chronic illnesses than they [themselves] have.” While short-term economic benefits to those profiting from e-waste recycling

**Table 2.** Benefits of e-waste recycling at Agbogbloshie (Accra, Ghana) e-waste site, identified by 19 experts

Benefit	Expert agreement (%)
Source of livelihood	94
Cleans up waste in the city	39
Economic benefit to the community and area	28
Local steel companies gain income	22
Economic gain	11
There are no benefits	6

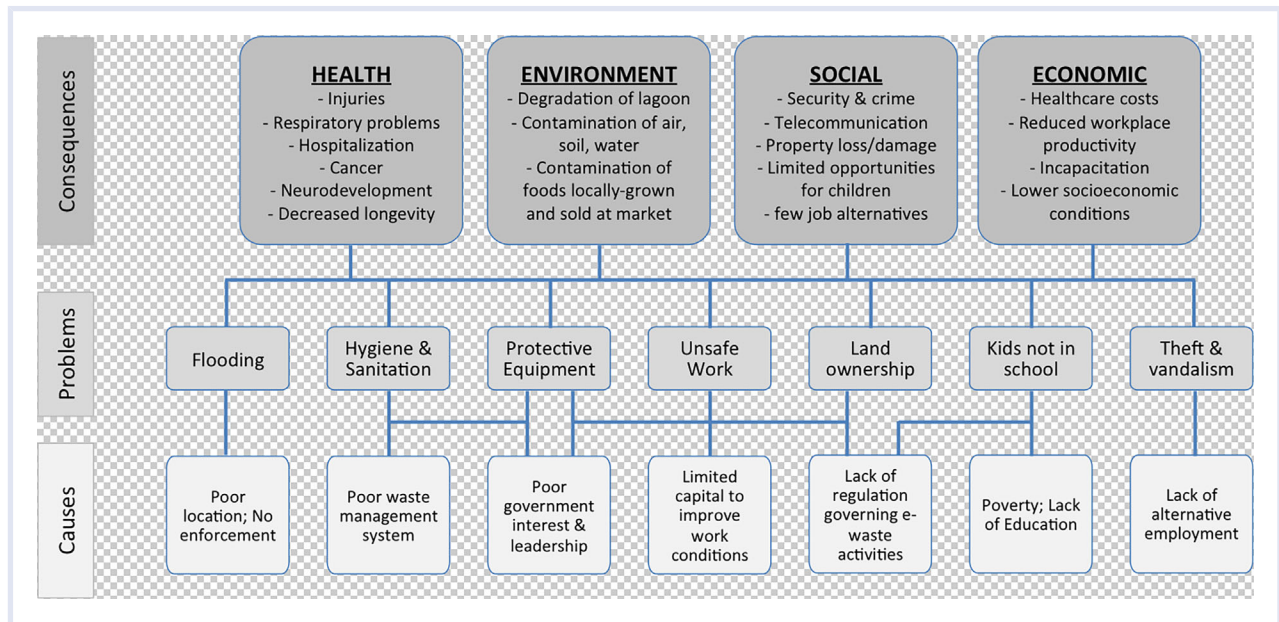


Figure 2. Problem tree analysis from Delphi Round I conducted among experts ( $n = 19$ ).

were reported, the burden on the economy was presented as a serious long-term problem.

According to expert opinion, environmental problems at Agbogbloshe e-waste site were affecting the aquatic environment and all organisms living near the site. Many believed that leaching of the heavy metals into the water, soil, and air from crude methods of recycling was causing pollution. Furthermore, experts mentioned that due to the fact that Agbogbloshe was situated on a natural floodplain, the residents were at a higher risk for damaged property and injuries that resulted from flooding.

In general, experts agreed that many of the e-waste workers' survival depended on their livelihoods. For this reason, scavenging and collection of obsolete electronics was extremely important. According to 2 experts, there had been incidents in which property had been damaged due to e-waste scavengers breaking into people's homes or vandalizing telecommunications networks in order to obtain electronic material. One expert believed that if the issue was not addressed, increased vandalism was imminent. Another expert reported, "slum areas tend to be a den for activities such as drugs and armed robbery. These people don't have permanent jobs...and they have to make a living one way or the other...[this] leads to national security issues as well." Experts agreed that there was also a large effect on children who worked at the site. Besides the previously mentioned health risks, they were not attending school, which would have many repercussions later in life: "Children are [at the site] who are supposed to be in school. There is a deviance. And in that environment, they learn a lot of social vices." Many experts agreed that many negative social consequences could be avoided by addressing the problems at Agbogbloshe.

Expert opinion revealed that poverty was a recurring cause for most of the problems at Agbogbloshe, whether social,

environmental, economic, or health related. The reason that individuals participated in e-waste recycling was for monetary gain, because those involved had little or no alternative for other work. In addition, the lack of funds, proper government recognition, safe and environmentally friendly technology, training, and enforceable legislation were identified as possible causes of the problems by experts. An expert explained that without addressing these causes, the activities at Agbogbloshe would never cease: "Until something is done, people see it as a form of livelihood. There is no alternative right now for recycling electronic waste." With no other available sources of income, finding actions to respond to these issues was presented as important.

#### *Delphi Poll I: Identification of response options*

Following the problem identification, experts were asked to identify 3 solutions that addressed the problems at Agbogbloshe and to rank them in order of impact and feasibility. Through professional judgment, these solutions were compiled into 15 response options, listed in Textbox 1. Weighted scores and unweighted frequencies of expert responses can be seen in Table 3. The top 3 responses with the highest weighted scores for impact were response options 4, 6, and 7 (Textbox 1). The top 3 responses with the highest weighted scores for feasibility were response options 4, 6, and 2 (Textbox 1).

#### *Delphi Poll II: Ranking of response options*

*Mean ratings by benefit and feasibility.* Participants were sent an electronic questionnaire containing the 15 response options and were asked to rank them on the basis of benefit and feasibility. Figure 3 describes the mean ratings of all response options for economic, environmental, social, and health feasibility and benefit. Environmental benefit was

**Text Box 1: Response options to problems at Agbogbloshie (Accra, Ghana) e-waste site, identified by 19 experts from Delphi Round I**

It is recommended that

- 1)...conventions such as Basel and Rotterdam be enforced by the Ghana Revenue Authority (Customs division) and the Ghanaian Environmental Protection Agency (EPA) in order to limit the importation of e-waste into Ghana.
- 2)...the Ministry of the Environment, Science, Technology and Innovation (MESTI) revisit and process the hazardous waste bill that addresses e-waste procurement and management in Ghana.
- 3)...e-waste workers be given appropriate personal protective equipment.
- 4)...e-waste workers be provided with proper infrastructure such as a formal recycling plant, new technology for handling e-waste, and on-the-job training.
- 5)...the Agbogbloshie e-waste site be cleared and the site remediated.
- 6)...there be increased education and sensitization by the Ghanaian EPA, the Ministry of Health, and Green Advocacy on hazards related to e-waste disposal and health and safety at the site, directed toward e-waste workers and the general public.
- 7)...e-waste activities be formalized and that the workers be registered and certified.
- 8)...the e-waste workers be offered alternative income-generating employment.
- 9)...the producers of electronic goods adopt the Extended Producer Responsibility (EPR) in order to take responsibility for the waste that they generate.
- 10)...the Ministry of Health install a health clinic in Agbogbloshie.
- 11)...e-waste workers be involved in the planning process of interventions and be kept informed of any research or program results.
- 12)...the Greater Accra Scrap Dealer's Association (GASDA) be provided with working capital in order to pay for technical training and to scale up operations in order to export scrap metals.
- 13)...there be further research on the health effects from e-waste at Agbogbloshie.
- 14)...there be incentives for the general public to bring their waste to the appropriate drop-off center.
- 15)...the registered steel companies purchase e-waste directly from the e-waste scavengers and disassemble it themselves at their facilities.

highest for all scenarios ( $\mu = 3.37$ ), followed by benefit to people ( $\mu = 3.24$ ). Political feasibility ranked lowest for all response options ( $\mu = 2.50$ ), followed by implementation feasibility ( $\mu = 2.57$ ).

*Greatest impact.* The top 4 most beneficial options to address health and safety at Agbogbloshie were response options 4, 9, 13, and 3 (Textbox 1) and are shown in Figure 4.

*Greatest overall mean.* The top 3 response options that were ranked as the most feasible and beneficial to address health and safety at Agbogbloshie were response options 13, 3, and 2 (Textbox 1). Response options 11 and 6 (Textbox 1) had the same overall mean and both ranked 4th. Results are shown in Figure 5. Although the benefits for these options were not as high as some of the other options, their feasibility ranks were high, allowing them to emerge on top for initiatives that represented beneficial as well as feasible options.

## DISCUSSION

### *Benefit and feasibility*

The overall mean ranks of response options did not vary greatly ( $SD [\sigma] = 0.20$ ) and ranged from 2.53 to 3.23. Despite a lack of a stand-out solution, it was agreed by 100% of

experts that action must be taken at Agbogbloshie or else the situation will continue to worsen. When taking into consideration the feasibility of each response option (Figure 5), and not solely the benefit (Figure 4), the 2 highest ranked solutions differ, showing the importance of measuring feasibility.

As seen in Figure 3, a reported barrier to the implementation of these response options was a lack of political will. This was consistent with interview responses, which identified a lack of government recognition and initiative. One expert stated that there "seems to be total neglect from authorities, political leadership and regulators." This neglect is despite the fact that the government also suffers due to the e-waste activities at Agbogbloshie. One expert explained that these activities are a "big drain on human capacity as a nation because [workers] are not able to develop their meaningful work and contribute to the economy." A socioeconomic study by Prakash et al. (2010) explains that the e-waste refurbishing and recycling industry amounts to around US\$105 and US\$268 million annually, which is not contributed to the Ghanaian national gross domestic product (GDP) because it resides in the informal sector (Prakash et al. 2010). Another expert thinks that these activities are indirectly costing the government by being "a huge drain on the public health system." Government recognition remains an

Table 3. Ranking of response options by 19 experts from Delphi Poll I<sup>a</sup>

Response	Impact		
	Frequency of 1 <sup>st</sup> choice	Unweighted frequency	Weighted score
Enforcement of Basel and Rotterdam conventions	1	4	12
Hazardous Waste Bill be revisited and processed	2	8	20
E-waste workers be given PPE	0	2	4
Provide proper infrastructure and new technology	7	14	46
Clear and remediate Agbogbloshie (Accra, Ghana)	1	7	16
Increased H&S education and sensitization	5	9	31
Formalization of e-waste activities	3	8	25
Alternative income-generating employment	3	5	18
Adoption of EPR	0	1	3
Installation of a health clinic in Agbogbloshie	0	1	3
Participation of e-waste workers in interventions	2	3	11
Working capital for GASDA	1	1	4
Further research	0	1	2
Incentives for the general public for e-waste drop off	0	1	1
E-waste sold directly to steel companies	0	1	3
Rank	Feasibility		
	Frequency of 1 <sup>st</sup> choice	Unweighted frequency	Weighted score
Enforcement of Basel and Rotterdam conventions	1	4	12
Hazardous Waste Bill be revisited and processed	4	9	26
E-waste workers be given PPE	0	2	4
Provide proper infrastructure and new technology	4	12	36
Clear and remediate Agbogbloshie	1	7	17
Increased H&S education and sensitization	6	9	33
Formalization of e-waste activities	1	7	20
Alternative income-generating employment	1	7	19
Adoption of EPR	0	1	3
Installation of a health clinic in Agbogbloshie	1	1	4
Participation of e-waste workers in interventions	1	3	8
Working capital for GASDA	0	1	3
Further research	0	1	2
Incentives for the general public for e-waste drop off	0	1	2
E-waste sold directly to steel companies	0	1	3

EPR = Extended Producer Responsibility; GASDA = Greater Accra Scrap Dealer's Association; H&S = Health and Safety; PPE = personal protective equipment.  
<sup>a</sup>Weighted scores determined by assigning points to different ranks: Rank of "1" = 3 points, rank of "2" = 2 points, and rank of "3" = 1 point.

important barrier in addressing issues within the informal e-waste recycling industry.

#### Highest ranked response options

Although there exists current evidence of contamination of the Agbogbloshie ecosystem due to e-waste processing

activities, experts agreed that there is still a need for further research at the site, and this option emerged as having the highest overall mean rank. Although it may take time to link e-waste activities to specific health outcomes, expert opinion suggested that there may be health issues in the Agbogbloshie population, requiring an urgent study to



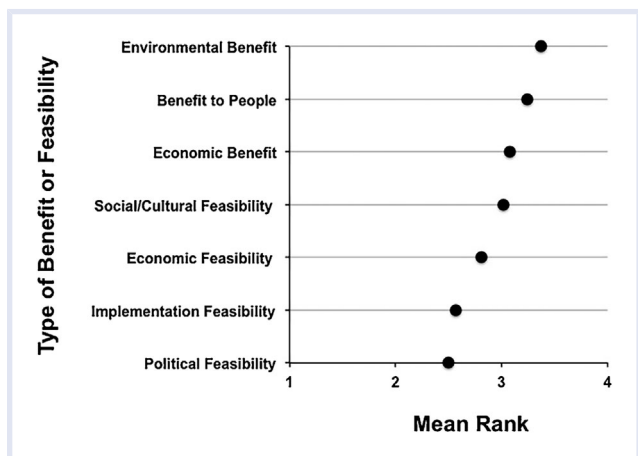


Figure 3. Mean ranking by experts (n = 19) of benefit and feasibility for response options from Delphi Poll II.

establish the extent of the health issues and the appropriate response measures. Accurate scientific evidence is a way to enact change at the government level (Watson 2005), and achieving this change in regards to the e-waste problem means continuing to monitor environmental contaminants and their fate in the environment, as well as the impacts on the health of the workers and community. Oteng-Ababio et al. (2014) recognized the importance of monitoring persistent organic pollutants (POPs) in food originating from Agbogbloshie. Research in nonscientific disciplines is equally important. For example, certain Chinese research institutions and universities have published various articles on the progress of e-waste legislation in the country

and effectiveness studies of certain e-waste policies (e.g., licensing schemes) (Shinkuma and Managi 2010). These articles include suggestions for policy improvement, including the need for proper monitoring and evaluation mechanisms (Yu et al. 2010).

Experts agreed that providing workers with PPE would act as a preventative measure against injuries and inhalation of toxic smoke. The economic, political, and implementation feasibility were lower in this response option than in the “Further Research” option, but it ranked very high for the benefit to people. Lessons of implementation can be learned from an initiative in Manila, Philippines, led by Medecins du Monde (MdM), who distributed PPE to e-waste workers in order to reduce their exposure to harmful recycling practices. The communities in Manila were given gloves, Kevlar sleeves, and goggles. According to an MdM medical advisor, who conducted assessments on PPE use, Kevlar sleeves were not used due to the tropical climate that was causing sweating, leading to skin rashes and itching. Also, improper storing and handling of masks increase the risk of spreading the toxic agents found in e-waste (E. Vicario, San Juan City, Philippines, personal communication). For this reason, MdM did not distribute masks, and stopped distributing sleeves. They will keep trying, however: “we are now in the phase of setting the so-called ‘safe dismantling areas’ (separation of working areas and living areas), and there we want to slowly reintroduce masks and additional PPE like overalls...” (E. Vicario, San Juan City, Philippines, personal communication). Lessons can be learned from this initiative, given that Accra also has a tropical climate; thus providing the workers with PPE that is uncomfortable could lead to a failed initiative. Using a

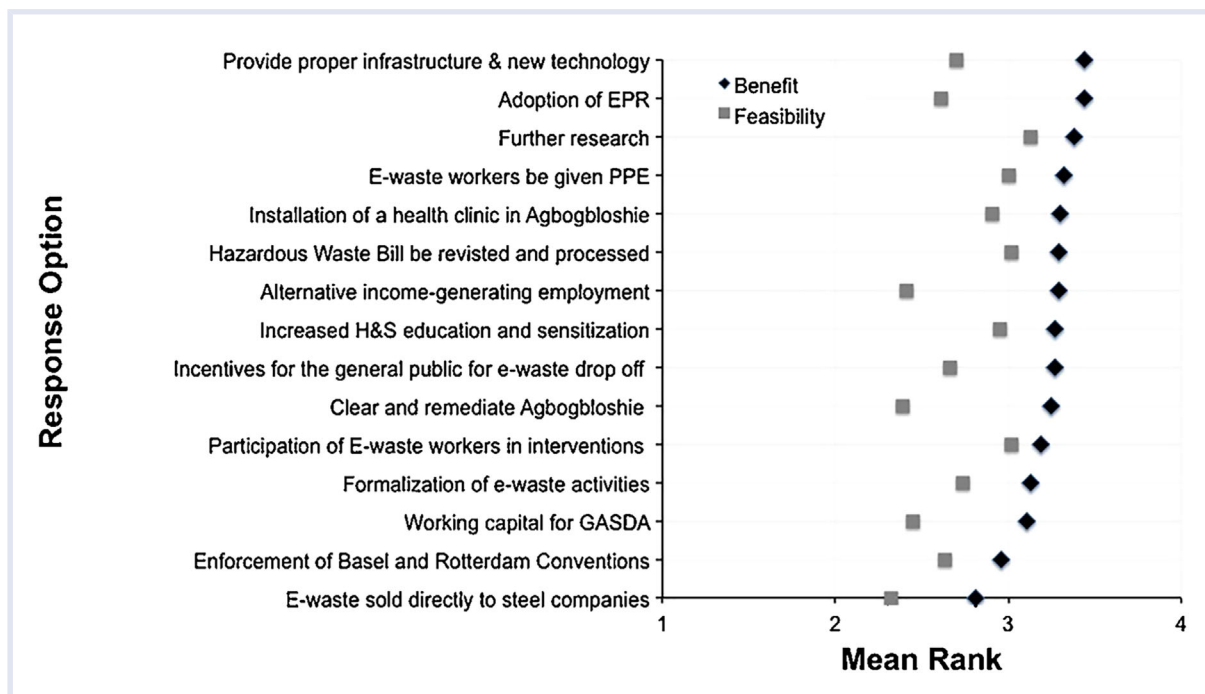


Figure 4. Mean ranking by experts (n = 19) of benefit and feasibility for each response option from Delphi Poll II, sorted by decreasing benefit. EPR = Extended Producer Responsibility; GASDA = Greater Accra Scrap Dealer’s Association; PPE = personal protective equipment.

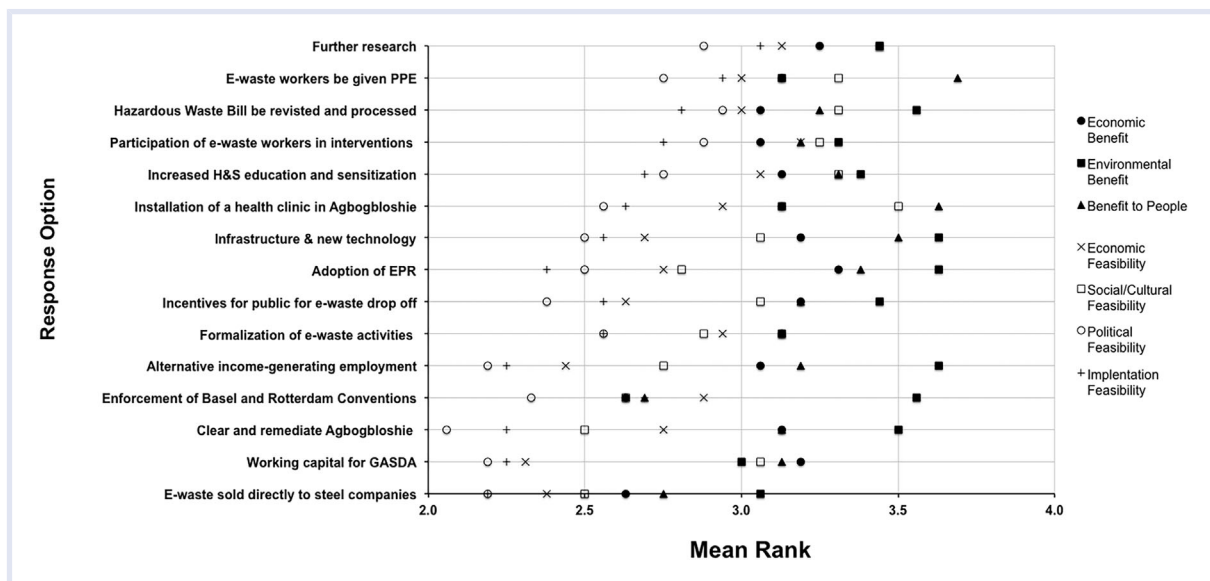


Figure 5. Mean ranking of benefit and feasibility for response options from Delphi Poll II, sorted by decreasing overall mean rank. EPR = Extended Producer Responsibility; GASDA = Greater Accra Scrap Dealer's Association; PPE = personal protective equipment.

participatory approach would be beneficial in this scenario because workers could predetermine what equipment they would and would not wear. The MdM staff also highlighted the importance of safety training and education: "MdM staff has to constantly remind them about the risks [of] expos[ing] themselves and their families! And keeping raising awareness" (E. Vicario, San Juan City, Philippines, personal communication). Experts agreed with this statement, claiming that certain organizations have given out PPE at Agbogbloshie in the past, but that "there is not enough consistency of this initiative and if it is not complemented by training then the workers will not be motivated to utilize it." Response option 6 had the same overall mean rank as response option 11, both having the 4<sup>th</sup>-highest mean rank. Experts considered the sensitization of e-waste workers and the general public as having the potential for high environmental benefit and high social or cultural feasibility (Figure 5). However, research shows that education and awareness creation alone is not likely to change behavior (Yu et al. 2010). Using it alongside other interventions, such as distributing PPE, will increase the chance of intervention success. One expert mentioned that the government might not have the needed funds to provide the protective equipment, which indicates that the funds may need to come from elsewhere. This requires further exploration.

At the time of data collection for the present study, a hazardous waste bill addressing e-waste procurement and management in Ghana had been drafted but not yet passed. In June 2016, the parliament of Ghana passed the Hazardous and Electronic Waste Control and Management Bill (Ankrah 2016). Although this passage is a success for the country, implementation feasibility remains the biggest barrier for this response option. One expert explained that the most important and challenging part of passing the bill is the enforcement of the legislation. This expert stated that confusion can arise over which institution is in charge of

enforcement and management of the funds obtained from the Electrical and Electronic waste levy, defined in the bill (Ankrah 2016). For example, legislation in Ghana currently restricts the importation of secondhand refrigerators and air conditioners. According to expert opinion, it is unclear what responsibilities fall under the mandate of the Customs Excise Prevention Service versus Ghana's EPA in regards to law enforcement at the ports of entry. A similar situation exists in China, where only licensed recyclers are legally allowed to import and export e-waste in and out of the country. Six or more national institutions are involved in the management and monitoring of e-waste in the country, which has been shown to limit the power of each institution involved to enforce their mandate (Yu et al. 2010). Furthermore, although China has issued several regulations that restrict the import of e-waste into the country, the lack of mechanisms for enforcement and monitoring has resulted in the continued existence of illegal imports (Yu et al. 2010). Ghana's Hazardous and Electronic Waste Control and Management Bill is likely to be successful if the enforcement and administration are limited to a few organizations, roles are clearly defined, and monitoring mechanisms are in place.

The experts highlighted the need for e-waste workers themselves to be involved in the process of planning interventions, as well as to be kept informed of any research or project results once completed. This involvement is important in order to establish a relationship of trust and respect with the community, leading to a larger chance of a successful intervention. The MdM e-waste intervention in Manila had a mandate of reducing exposure from e-waste processing through a community development approach. They spent much time communicating with and empowering the community before they were accepted and respected by community members. According to MdM staff, the project involved local leaders, both formal and informal, and they

were informed of the project objectives. The MdM staff made regular visits to understand the community life, and undertook a community assessment, a needs assessment, and a problems and issue analysis, all in partnership with the local leaders and members of the community (E Vicario, e-mail message, September 3, 2015). In addition, locally led "People's Organizations" (POs) were created. They consisted of e-waste dismantlers who were "train[ed] and empowered through capacity building sessions... They have regular activities like executive meetings, monthly planning, and monthly accountancy" (E. Vicario, San Juan City, Philippines, personal communication). This training eventually led to the accreditation of the POs, which enabled access to social programs such as registration to the social security system and to feeding programs. Eventually, the POs were registered with the Department of Labor and Employment (DOLE), which allowed them to access even more programs (E Vicario, e-mail message, September 2, 2015). A similar idea is suggested in a study by Akormedi et al. (2013), in which emphasis is placed on the need to develop sustainable financial and social security for the workers at Agbogbloshie. Involvement of the community in the intervention planning contributed greatly to the success of the MdM intervention, highlighting the importance of community participation in projects at Agbogbloshie.

## CONCLUSION

E-waste recycling activities in Ghana (and elsewhere) are complex. Expert interviews identified that most of the problems at the Agbogbloshie site occur because of crude recycling methods, such as manual dismantling and burning of e-waste, that are leading to health, economic, and social problems as well as environmental contamination. The informal nature of this sector makes it challenging to collect empirical data and to use such information to help improve conditions and formulate policies and programs (Basu et al. 2016). Through expert interviews and the Delphi process for ranking response options, 5 solutions were identified as being most beneficial as well as feasible for the Agbogbloshie e-waste site. Experts agreed that continued research will help further understand the issues ongoing at the site, that PPE should be offered to e-waste workers for the protection of their health and safety, that the hazardous waste bill should be passed and enforced in Ghana to implement stricter laws concerning importation of e-waste, that a participatory approach should be used when designing interventions, and that there should be increased sensitization on hazards related to e-waste disposal for e-waste workers and the general public. The response options identified provide policy makers with solutions prioritized by experts to ensure the health and environmental protection of Agbogbloshie. However, these solutions are in no way exhaustive, and further research into each option is needed in order to ensure appropriate action. For example, 1 notable limitation of our work is the relatively few individuals and institutions with whom we engaged.


Lessons can be learned from similar initiatives undertaken internationally, and continued communication among local and international actors is recommended.

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**Data Accessibility**—Data may be accessed by contacting the corresponding author Niladri Basu (niladri.basu@mcgill.ca).

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