Mapping Informal E-waste Hubs from Academic and News Literature

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Abstract

Globally, workers improperly recycle E-waste in informal hubs, damaging the environment and the health of their community. No one has previously published an extensive list of E-waste hubs, which has caused a disproportionate amount of research in a handful of hubs. Through a content analysis of academic literature and regional news, we mapped 23 hubs worldwide, identified gaps in the topics and locations of E-waste research, and compared the two media sources.

Acknowledgments

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Authorship

Name	Sections Written	Sections Edited	Research Accomplished
Brigid R. Auclair	Introduction Section 2.3.1 Section 3.0 Section 3.2.3 Section 4.2 Section 5.1 Section 5.2	All sections	Analyzed and coded academic articles from 2020, 2017, 2014, 2009 Analyzed and coded articles from Chinese news websites
Gwyneth C. Ormes	Section 2.2 Section 3.1.2 Section 3.2.1 Section 3.2.2 Section 3.2.3 Appendices	All sections	Analyzed and coded academic articles from 2018, 2012, 2011 and 2007-2000 Analyzed and coded articles from Vietnamese and Nigerian news websites Analyzed and coded worldwide NGOs Created and managed database SQL database
David A. Smith	Executive Summary Section 2.0 Sections 2.1 Section 3.0 Section 5.3 Section 3.3 Section 4.2	All sections	Analyzed and coded Academic articles from 2016, 2015, 2008 Analyzed and coded articles from Indian news websites Analyzed and coded regional NGO reports
Nicholas J. Tourtillott	Abstract Introduction Section 2.3.2 Section 3.1 Section 3.3 Section 4.1	All sections	Analyzed and coded academic articles from 2019, 2013, 2010 Analyzed and coded articles from Vietnamese and Ghanaian news websites

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Executive Summary

As consumerism progresses, people discard seemingly obsolete devices and replace them with newer models--creating over 50 million metric tons per year, which is 7.3kg of waste per person (Forti et al., 2020). Electronic waste (E-waste) grows at a rate of 3-5% a year, faster than other waste streams, yet society only properly recycles 20% of this waste (Bel et al., 2019; Kumar et al., 2017). The rest ultimately finds its way into landfills, E-waste hubs or other places within the informal sector. Informal E-waste hubs provide economic stability to those who need it but are harmful to their workers, the community, and the environment around them.

Researchers have not mapped the locations of informal E-waste hubs, which leads to repetitive research that fails to address the diverse locations and complications of E-waste. Our project consolidated and mapped informal E-waste hubs worldwide to address this gap in research. Our team reviewed academic literature over the last 20 years to catalog hubs and aggregate keywords relating to E-waste and the processes surrounding it. We chose news articles from five countries with the greatest number of E-waste hubs in academic literature--China, Ghana, India, Nigeria, and Vietnam. We applied these keywords to find news articles relating to the informal E-waste sector. These two content analyses provided our team with the locations to map informal E-waste hubs, E-waste related keywords, and common research topics for future researchers.

Results

We had two main sections for our research, an academic content analysis, and a news content analysis.

Academic

In our academic search, we found informal E-waste activity in 37 countries, with 75% of research originating from China, India, Ghana, and Nigeria. Appendix A shows our density map of the number of academic articles by country. Guiyu, China appeared in 205 articles or 27.2% of all articles. Academics mentioned Taizhou, China in 116 articles, placing it after Guiyu in the number of mentions. The sixth most researched location was Agbogbloshie, Ghana which appeared in 6.6% of articles and was the most researched location not in China. Chinese E-waste hubs receive significantly more attention in academic literature than other hubs--highlighting the need to research more locations elsewhere since data relating to E-waste may not be the same across different countries. Informal E-waste activity is prevalent across the globe, however, in depth research is not, leading many hubs to go under the radar. So, if policymakers near these less-researched locations take action they are left to make decisions based on data that loosely fits their community which will lead to loose and ineffective policies. Whereas, research on a specific hub will inform a policy tailor-made to help that community.

33.1% of articles were about soil pollution, followed by community health with 16.7% of articles. The ubiquity of soil pollution in academic literature may be due to the lack of ethical restraints researchers face when experimenting on soil rather than human subjects. No articles mentioning Agbogbloshie were about the effect on wildlife or the local waterways, which is significant as Agbogbloshie is close to the Odaw river. These imbalances in the E-waste research are important to fill for policymakers and researchers to have a full understanding of the effects of informal E-waste recycling.

News

Our analysis of news from China, Ghana, India, Nigeria, and Vietnam gathered articles referring to over 123 unique locations, 67 of which were not covered in academic research. 26.5% of the news articles related to E-waste policy and management whereas we only coded 6.7% in our academic review. Additionally, we coded a higher percentage of news articles as 'reports and definitions,' 'E-waste flow,' and 'worker impacts' than academic articles. In contrast to academic papers, the news mentioned soil pollution only seven times. News sites are more focused on the community members, policies that affect the public, and problems within the community.

Future Research Recommendations

Our research reveals gaps in current E-waste research and highlights potential avenues to advance our research. We found that searching through regional news was successful at finding locations of informal E-waste recycling not discussed in academic literature. Future researchers interested in discovering new hubs should consider this process.

Another approach in future research is to verify the locations we identified as informal E-waste hubs. Researchers should pay special attention to sites which either academic literature or the media failed to cover. These lesser researched hubs are likely just as dangerous to surrounding communities as the more well-researched hubs, but academics and local residents may not recognize them as a problem. Along with these lesser-known hubs, there remain gaps in current research of comparatively well-known hubs, and there remain gaps within the broader discussion of E-waste--all of which future researchers can address to create a more accurate discussion of informal E-waste.

Our research suggests that literature on informal E-waste tends to focus on a few select sites and topics. We recommend that research and media about informal E-waste hubs consider a broader range of locations and topics, to increase the global understanding of this phenomenon.

1 Introduction

E-waste (Electronic Waste) increases at a rate of 3-5% per year--three times faster than other waste streams-- and only about 20% of it is properly recycled (Balde et al. 2017; Kumar et al., 2017). The remaining 80% goes undocumented and likely ends up in landfills or informal E-waste hubs (Balde et al. 2017). E-waste has grown due to increasing numbers of people using and buying technology in general, as well as the planned obsolescence of electronics. Companies continue to create improved models for devices every year because the demand for new technology is high. More people upgrade and discard outdated and/or broken technology and have little regard as to where it ends up. This cycle between companies and consumers leads to an increasing amount of electronic waste (Bel et al., 2019). Often, E-waste ends up in informal recycling locations where workers repair broken electronics or dismantle them into components to extract valuable materials that surrounding businesses buy. Second-hand stores purchase repaired electronics or working parts for resale and manufacturers may buy the raw metals since it is cheaper than extracting ore. Informal E-waste hubs lack government documentation and avoid taxes used in tracking traditional businesses.

Unlike formal recycling locations that are specifically designed to process E-waste in a safe and responsible manner, these informal hubs are unequipped to handle safely the dangerous materials present in E-waste. As workers dismantle E-waste, the hazardous materials involved can seep into the environment (Wong, C. et al., 2007). In informal hubs, workers use rudimentary and hazardous processes to dismantle E-waste, such as open burning, coal-fired grill heating, and leaching using acid baths (Wong, M. et al., 2007; Nnorom et al., 2008). Because the

businesses are informal, they lack environmental regulations, which leads to the use of dangerous recycling methods, exposing workers to toxic chemicals that can have serious effects on their health and to other unsafe working conditions. However, many of these communities rely on the economic benefits these hubs offer through the recycling of precious materials and sale of repaired electronics. The valuable metals extracted from E-waste are more abundant in these hubs than in naturally occurring ore veins (Kumar et al., 2017).

Researchers must first know where a hub exists to apply their findings, but current research lacks a published catalog of informal E-waste hubs. These hubs are difficult to identify because they skirt taxes and government regulations, thus requiring creative means to identify. Academics have studied a handful of well-known informal hubs interested in understanding their processes and effects, such as in Guiyu, China, and Agbogbloshie, Ghana. However, a disproportionate amount of research has focused on these sites, leaving others hardly acknowledged by academics or journalists. Our project will allow future researchers to be able to address the problems of E-waste by understanding where this informal recycling is happening.

This project centralizes and maps informal E-waste hub research to aid future endeavors regarding these hubs and the complex issues surrounding them. The following objectives guided our research. First, we reviewed the current academic literature of informal E-waste hubs to compile a list of known E-waste hub locations, identify search terms and discover gaps within the current E-waste discussion. Next, we analyzed regional news in five countries which researchers mentioned the most in academic literature to conduct a creative and novel method of finding informal E-waste hubs. Lastly, we mapped our catalog of informal E-waste hubs and

provide recommendations and resources for future researchers to address gaps in the current E-waste discussion.

2 Background

E-waste (Electronic Waste) or WEEE (Waste Electrical and Electronic Equipment) are both terms describing waste items ranging from discarded cell phones to refrigerators. The United Nations University provides a simple definition for E-waste, as "anything with a plug, electric cord or battery (including electrical and electronic equipment)," but not all academics or policymakers agree with this definition (Bel et al., 2019). Policies and research encompass differing items under the term of E-waste. After consumers discard these products, E-waste travels to a formal recycling plant, an unspecified informal recycling hub, or a landfill. Before starting our project, we first had to understand the complex issue of informal E-waste hubs, specifically what the harmful and beneficial effects they may have on their workers and the communities that house them.

2.1 Metrics of E-Waste

To grasp why informal hubs develop it is important to understand the growth, value, and policies of E-waste. E-waste grows at a rate of two million metric tons a year and does not appear to be stopping, which leads to a greater need for understanding this global problem (Forti et al., 2020). E-waste makes up 70% of the hazardous waste in landfills and grows at a rate three times faster than other waste streams (Holgate, 2018). People increase the growth of E-waste not only by discarding broken items but by replacing old, yet functional, technology with newer models. These new technologies can be as simple as a new iPhone model or as complex as switching from CRT screens to LCD screens. Global legislation of E-waste often falls under the

Basel Convention, an unclear and lenient international agreement that sets guidelines on the trade and management of E-waste.

2.1.1 Quantity of E-waste

The estimated weight of E-waste created is 53.6 million tons per year, which is 7.3 kg of waste per person (Forti et al., 2020). These discarded items often have a lifespan of less than eight years (Kumar et al., 2017). E-waste encapsulates a broad group of devices from telephones to heat transfer equipment. About 50 percent of E-waste by weight is personal devices while the rest is other items such as, refrigerators, televisions, medical devices, and other large electronic appliances. (Bel et al., 2019). This wide grouping of items can make it hard to track or identify E-waste and where it all ends up. Figure 2.1 further expands on this breakdown of E-waste and separates the known locations of E-waste after users discard them. Of the 80 percent not collected for formal recycling, the rest's location is a mystery. This unaccounted-for E-waste often ends up in informal hubs and dumpsites.

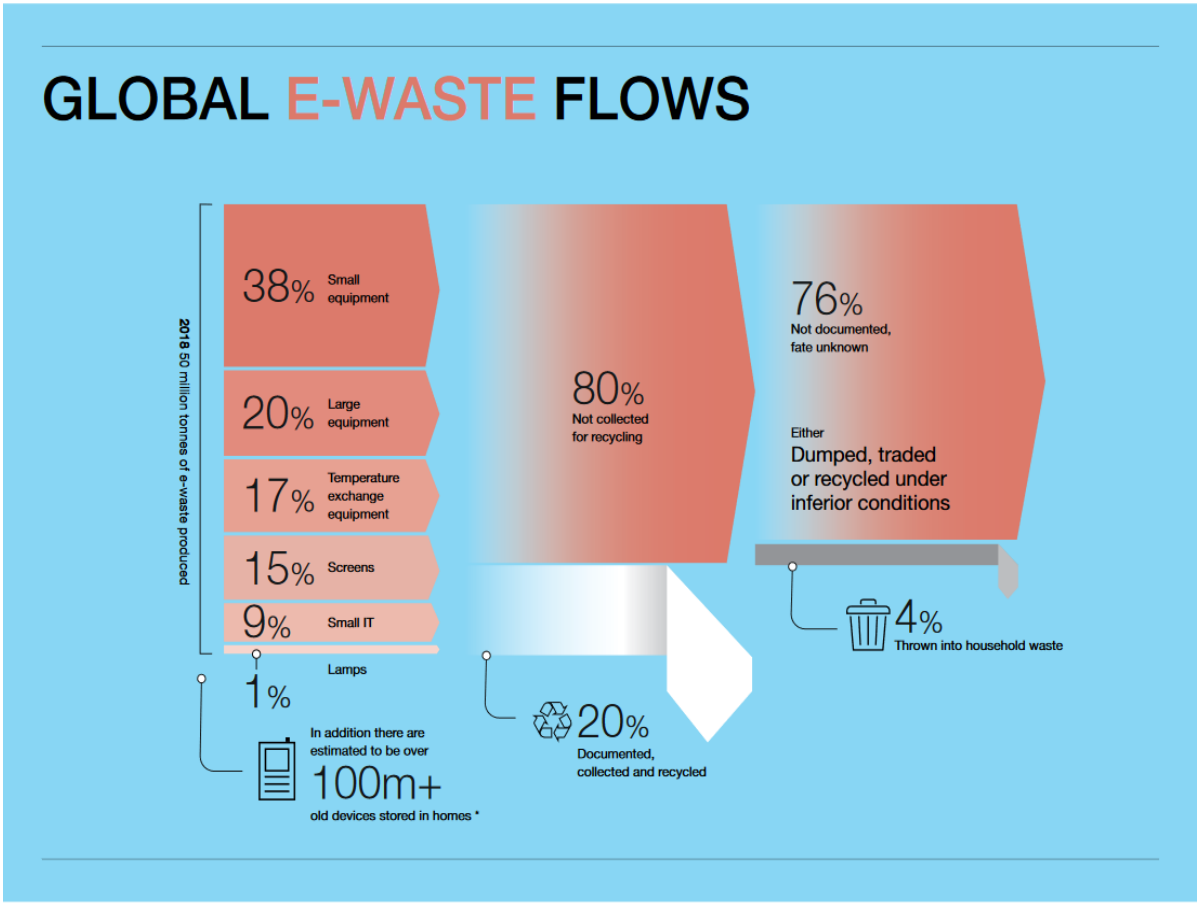


Figure 2.1 Composition and flow of E-waste

(Bel et al., 2019)

2.1.2 Value of E-waste

The life cycle of the materials tends to be thought of traditionally in a linear fashion, from production to consumption to waste. However, this model fails to capture the full value of E-waste since the technology still holds value in its raw material even if its current form is no longer useful (Lepawsky et al., 2011). The industry of informal E-waste recycling contradicts the assumption that discarded products no longer have value. Informal E-waste recycling is a

lucrative industry for all parties involved, perpetuating the recycling and resale of E-waste byproducts. As the supply of E-waste byproducts begin to rise, businesses are more willing to accept E-waste, manufacturers can rely on these materials for production, and technology focused second-hand stores will begin to grow and buy more refurbished devices. The UN estimates the value of E-waste to be $62.5 billion, which is more than the Gross Domestic Product (GDP) of most countries (Balde et al., 2017).

This estimated value of E-waste is due to the presence of over 60 different metals like silver, copper, gold, and palladium which workers can extract from electronic devices (Namias, 2013). *The Journal of Renewable and Sustainable Energy Reviews* published a study which evaluates the sources of income based on the raw materials workers scavenged from the waste and found gold, copper, palladium and other precious metals represented a majority of the revenue at these sites (Cucchiella et al., 2015). These metals are more plentiful in E-waste than in naturally occurring ore veins. Stripped materials from discarded E-waste can be resold almost immediately while extracting raw materials requires more costly processes in order to be resold, which can provide workers in developing countries with a valuable source of income and technology. Workers at one such hub expressed the sentiment that if the government cracked down on informal recycling activities, they would continue to work there for the money illegally, suggesting a desperate need for income in these communities (Ejiogu, 2013). In these areas there are no central governing rules to accompany these sites; each person operates for their own benefit.

2.1.3 The Basel Convention

The Basel Convention is the major international treaty on the flow of hazardous materials, including E-waste. It limits the flow of E-waste from countries in the Organization of Economic Cooperation and Development (OECD) to non-OECD nations (Lepawsky et al., 2015). The pollution haven hypothesis fuels this policy, by stating that cheap labor and lax environmental regulations lead to OECD countries dumping E-waste on non-OECD nations (Davis, Akese & Garb, 2019). Additionally, most of the signing countries implemented legislation to control imports and exports of this hazardous waste but the treaty has been unsuccessful as both legal and illegal shipping of hazardous waste still occurs. Most of the Americas lack legislation banning the international trade of E-waste, including the United States, which is not a signer of the Basel Convention (Patil 2020).

2.2 Environmental and Health Impacts of Informal E-waste Recycling

There are many different toxic chemicals and hazardous materials involved in the disposal of E-waste; the majority of them are heavy metals and flame retardants. Some of the most common and dangerous heavy metals found in E-waste are lead (Pb), cadmium (Cd), and mercury (Hg). Informal E-waste hubs lack the tools required to dismantle electronic components safely. Thus, these toxic metals leak into the environment and damage people's health.

The processes used in informal E-waste hubs release pollutants into the surrounding environment, affecting everyone. Heavy metals and chemicals used in the recycling process make their way into the water, soil, and air causing contamination and serious damage. For

example, when workers dismantle printed circuit boards, they use an acidic liquid to try and recover the copper in it. This wastewater is highly toxic, and if it flows into a river or the soil, it damages the environment (Shinkuma & Thi Minh Huong, 2009). People in the surrounding areas often feel that the water is unusable due to the contamination. In Guiyu, a town in China with a major informal E-waste hub, people are afraid to drink the water and claim that if they use it to wash their clothes it dyes the fabrics yellow (Watson, 2013).

Wastewater runoff, as well as other metals, contaminates the soil and the crops grown there. A study by Quan et al. (2015) found that there were higher levels of heavy metals, such as Ni, Cu, Zn, Cd, Pb, Sn and Sb, around exposed areas. Once these metals are present in the environment, they enter the food chain through contaminated waterways and soil. The biomagnification of these toxic substances causes many health effects within the individuals exposed to this pollution.

In the bloodstream, Pb, Cd, and other heavy metals cause elevated liver function and induce anemia in patients (Chen et al., 2018). Hospitalized patients who resided in a region of China in close proximity to a hub had statistically higher concentrations of Pb and Cd in their blood compared to a reference population who did not live near a hub (Chen et al., 2018). Researchers also found that nearly 48% of individuals studied within the chosen region had developed chronic liver disease, suggesting exposure to the toxic metals released by the E-waste recycling process (Chen et al., 2018). These effects are closely linked to each other because the liver, in simplistic terms, acts as a filter for the blood, so high levels of these toxic metals within the blood will logically have dangerous implications for these vital physiological functions.

Children are at a higher risk of adverse health effects from these metals as their bodies are still developing and these toxins can damage that development. A study found that heavy metals can lead to reduced cognitive and language skills in children (Liu et al., 2018). While heavy metals have a variety of adverse health effects, the dismantling of E-waste releases numerous other pollutants into the environment. Human exposure to these pollutants, both organic and inorganic, have equally dangerous health effects that responsible recycling of E-waste could limit.

2.3 Informal E-waste Hubs

To define informal E-waste hubs, we first define an informal industry. Informal industries operate in a legal grey area without laws that apply to typical businesses, through loopholes or poorly enforced rules (Lepawsky & McNabb, 2009). Gerhaxi (2004) defines the most common economic factors of informal sectors as: (1) the status of labor, (2) avoidance of income tax, (3) size of the business, and (4) evasion of regulation. Understanding these factors within the broad definition of informal industries helped us develop our definition of informal E-waste hubs.

Collecting, harvesting, and resale summarize the typical E-waste recycling process. Often, workers physically dismantle parts with rudimentary tools, strip metals in open-pit acid baths, and remove components from printed circuit boards (Wong, M. et al., 2007, Nnorom et al., 2008). Other techniques include stripping wires, smashing circuit boards with a hammer, and dismantling televisions and computers with blowtorches (Mahesh et al. 2019). Beyond dismantling products, a large part of the industry also includes repairing broken technology that is still in good condition. Certain intermediate dealers and local industries accept electronic by-

products which encourage the local growth of recycling E-waste. Figure 2.2 uses an example of the E-waste flow in Dhaka to illustrate the relationships in the informal E-waste sector.

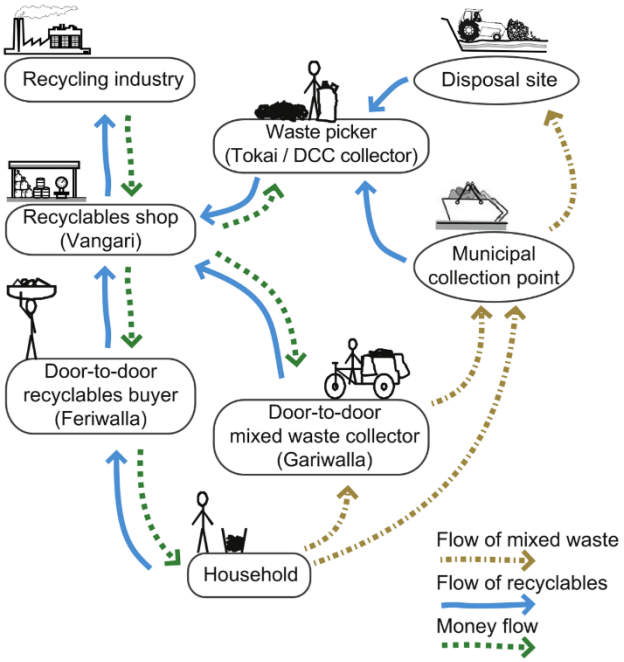


Figure 2.2 Represents the flow of E-waste between key players in the informal recycling sector

(Matter et al. 2013)

The relationship between informal and formal sectors is important to recognize as they are not independent, but instead either have a complementary or competitive relationship specific to each area (Chi et al, 2011). As an example, informal E-waste recyclers often sell to second-hand stores or manufacturers, which are formal businesses. Formal businesses in the surrounding area often determine the flow of E-waste because buyers control demand for these products and some surrounding manufacturers contribute to the supply of E-waste in the area. Without a reliable source of E-waste or buyers to accept these products, an informal E-waste hub cannot

form. Businesses' willingness to buy recycled materials determines the value of E-waste. The relationships of informal E-waste hubs to their community and the interconnectedness to their economy builds the foundation of their success. The agglomeration of businesses support each other and continue the cycle of informal E-waste recycling.

3 Methods

We consolidated and mapped informal E-waste hub research worldwide through a content analysis of informal E-waste hubs in academic literature and regional media sources. To do this analysis we reviewed 20 years of academic literature to compile a list of researched E-waste hubs and identified common keywords and themes throughout the literature. We listed all of the academic articles used in Appendix K. We also analyzed regional news and relevant NGO reports relating to E-waste in countries most prevalent in academic literature--China, India, Ghana, Nigeria, and Vietnam--to investigate previously cataloged locations and find new ones. We listed all the news articles used in Appendix L and the NGO reports in Appendix M. We looked for the same themes as in the academic literature and used selected search terms based on the keywords we had previously identified. Using this information, we created a definition to categorize a location as a hub and mapped these informal hubs. We also included the first year writers mention the location and the most common theme on the map.

3.1 Review Current Literature of E-waste Hubs

Our first objective was to conduct a content analysis of academic E-waste literature over the last 20 years to identify known informal E-waste hubs. We chose 20 years as our timeframe as we found few relevant articles before 2000. We read an article's title for relevance to quickly sort out articles that referred to formal E-waste research or did not explicitly identify locations involving informal E-waste recycling. We then reviewed the abstract and body of the relevant

articles for: information on informal E-waste hub locations, the most common research topics relating to them, and the various terms that researchers use to describe them.

Many search engines aggregate academic papers and provide rich search functionality. Beyond recognizing keywords, many allow sorting by area, date range, and journal, and link similar articles. We decided to use Scopus because it provided a manageable sample size of relevant academic literature and allowed us to filter by year of publication. We conducted this review specifically on academic articles from January 1st, 2000 to June 1st, 2020. We searched the title, abstract, and keywords with the term [“E-waste” OR “E waste” OR “Electronic Waste” OR “WEEE” OR “Waste Electrical and Electronic Equipment”]. This search produced 7,992 articles, which we analyzed for locations and themes common to informal E-waste research. Though Scopus is not as far-reaching as Google Scholar, the team determined Google Scholar would be time-intensive and likely not return superior results. Additionally, a quick test of Google Scholar found 77,300 articles when using the same search term and date range as Scopus, which was not manageable for our team to analyze.

Content analysis is a research method used to quantify and analyze words, themes, or concepts in text. It turns qualitative data (i.e. text and phrases) into quantifiable data, which allows us to make clear interpretations about the broader E-waste discussion. Researchers translate the language into codes, or categories, with a particular theme (Columbia University, 2019). Coding identifies commonly used themes, phrases, and concepts with any form of written communication surrounding a desired topic--in our case that is informal E-waste hubs. Content analysis informs researchers on international differences in communication, behavioral or

emotional factors surrounding a topic, relationships between the different codes determined in the analysis, and general patterns of communication that surround their particular topic of interest (Columbia University, 2019). In the context of our project, content analysis was a vital tool in cataloging our information on informal E-waste hubs. It allowed us to determine the patterns of communication used by media and academic literature when referring to E-waste sites and identify gaps within the current state of informal E-waste hub research.

We worked with a fluid set of codes to categorize texts that we analyzed, allowing us to adapt our broad conceptual categories into final codes for our database, based on common research topics. We started by sorting relevant articles into broader codes such as environmental impacts, health impacts, the flow of E-waste, informal recycling, and management of waste sites. We then placed them into a formal database using these final codes:

Agricultural Impacts	E-waste Policy & Management	Worker & Community Surveys
Air Pollution	Miscellaneous	Water Pollution
Child Health	Neonatal & Pregnancy Health	Wildlife Health
Community Impacts	Reports & Definitions	Worker Impacts
E-waste Flow	Soil Pollution	

This method provided our team with a way to track patterns in the general concepts surrounding informal E-waste hub literature, while still allowing us to adapt our approach as appropriate.

We recorded our codes alongside the location, citation, and year of publication in a Structured Query Language (SQL) database. This database allowed our team to associate an article with the locations it mentioned and its assigned codes, which gave us the ability to

perform complex data analysis. Appendix J provides the database relational model and some more details on each of the seven tables. Our full database is available at our GitHub: https://github.com/gormes/WPI-Ewaste.

3.2 Analyze NGO Reports and Regional News

After reading through the academic papers relating to E-waste, we compiled a list of researched informal hubs, included in Appendix C. We reviewed the data from our academic content analysis to find the countries with the largest number of reports of E-waste hubs. Within these countries, we reviewed NGO reports and regional news to analyze common topics outside of scholarly articles, catalog new locations, and refine our understanding of large hubs. Our team also coded the news articles and NGO reports in our SQL database by applying the existing framework of analysis we used for academic literature. Using the same content analysis system allowed us to compare the discussion of E-waste sites in academia and the media, and to integrate both sources of literature into the same catalog of informal E-waste hubs.

3.2.1 Regional News Sources

We looked at regional news sources online to find information on informal E-waste hubs. We chose to consider only online sources because of language barriers and our inability to travel. We reduced our search to news in China, India, Ghana, Nigeria, and Vietnam. To find these sources we searched Google using country codes, which filter out news sources not from the specified country. We searched using the name of the hub location, the word news, and the appropriate country code in Google to create the list of sources in Appendix H (i.e “Guiyu News

site:.cn" or "Agbogbloshie E-waste News site:.gh"). Using keywords, we gathered from academic literature we searched these sources for articles pertaining to an informal E-waste hub. We selected 6 keywords which we determined journalists were the most likely use in the news. We based this decision on how technical the term was and how often it was used in academic articles. The full list of keywords can be found in Appendix G. This method allowed our team to find regional colloquialisms journalists use when discussing these sites in addition to locations of informal E-waste hubs.

3.2.2 Translating Sources

One of the problems we anticipated was translating the news sources we found for each country. For example, E-waste is the commonly used term in English speaking countries, but we found many different terms used to describe E-waste in our content analyses, which Appendix G contains. Accurate translations were crucial to our project since many of the keywords we found were colloquialisms. One limitation of Google Translate or other automatic translators is they often produce a word for word translation. This method can often lose the underlying meaning of a phrase or the nuance of a specific word, potentially relevant in future research.

3.2.3 Reviewing NGO Reports

We also reviewed NGO reports from eight global E-waste NGOs as well as regional environmental NGOs in China, India, Ghana, Nigeria, and Vietnam, all of which are in Appendix I. These reports provide an in-depth view of informal E-waste in a specific area. We searched Google for environmental NGOs and noted ones that were mentioned in our news

reviews. For each NGO, we performed a content analysis on every report they published on E-waste to identify locations, themes, and keywords--including them in our database. This data supplemented the academic and news information on informal E-waste hubs.

3.3 Mapping Locations of Informal E-waste Hubs

From our research, we created two types of maps, a global density map and an interactive Google MyMap to display the cataloged locations. The density maps provide the global distribution of informal E-waste research. This map sorts references to informal E-waste locations based on the countries, instead of listing the most exact locations. The interactive map displays the location of the informal E-waste hubs and areas we cataloged, along with the number of academic, NGO, and news articles that refer to it. Additionally, each location has the most mentioned code and the year writers first mention the location. For our team to place a location on the interactive map, it had to have either over two academic references, one academic reference and at least three media or NGO reports, or at least five total media and NGO sources. Corroborating sources limited the number of locations but provided our team with confidence to deem locations informal E-waste hubs. To verify that a location on the map was correct, we referenced maps from academic articles which we included in Appendix B. The location was then combined with others within eight kilometers. We listed the locations that were combined in Appendix E. If the location's area was under 52 kilometers squared, we classified it as a 'Hub' and if not, we classified it as an 'Area'. We based this classification on Guiyu, China which in our research was the most mentioned hub in academic articles.

We chose this combination of maps because a worldwide map of all locations would easily become unreadable, if we included all uncorroborated sources. A large portion of our data simply alluded to the existence of a hub within a region, rather than providing an exact location. Appendix A contains screenshots of our interactive map and the density maps divided into continents. Our interactive map is accessible at: https://www.google.com/maps/d/edit?mid=1Bwom1VnJ9YykJTd28F1qjiop3HrEn6w-&usp=sharing.[1]

[1] Disclaimer: Our maps have been prepared for illustrative purposes only. The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of the authors or Worcester Polytechnic Institute concerning the geo-political situations or the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. We chose these boundaries based on the environmental regulations the region adheres to.

4 Results and Analysis

Through a content analysis of academic literature, regional media, and environmental NGO reports, we have found 1,791 references to informal E-waste hubs in 52 countries. We then mapped 23 unique hubs along with the number of times scholars or reporters refer to a given informal hub, which we listed in Appendix A. We also analyzed the topics and locations referred to in academic literature and news to identify gaps in the current discussion of E-waste and compare the similarities between these two sources. We found that the academic literature and the news media focus on different topics, specific environmental concerns for academic articles versus general reports for news media. These two forms of literature are similar in that they both lack breadth in the locations and topics discussed. We section our results below into those about the current discussion and the geographic patterns of informal E-waste hubs that we mapped.

4.1 The State of Informal E-waste Discussion

In our content analysis of the discussions surrounding informal E-waste practices, we found that academic literature largely focused on soil pollution, and the media focused on policies and management as shown in Figures 4.1 and 4.2.

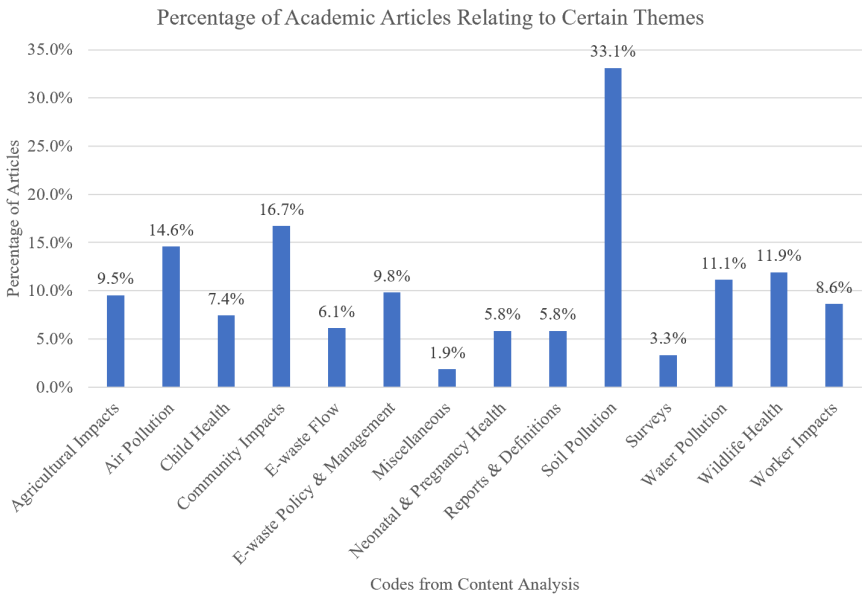


Figure 4.1[2] Distribution of academic articles across codes

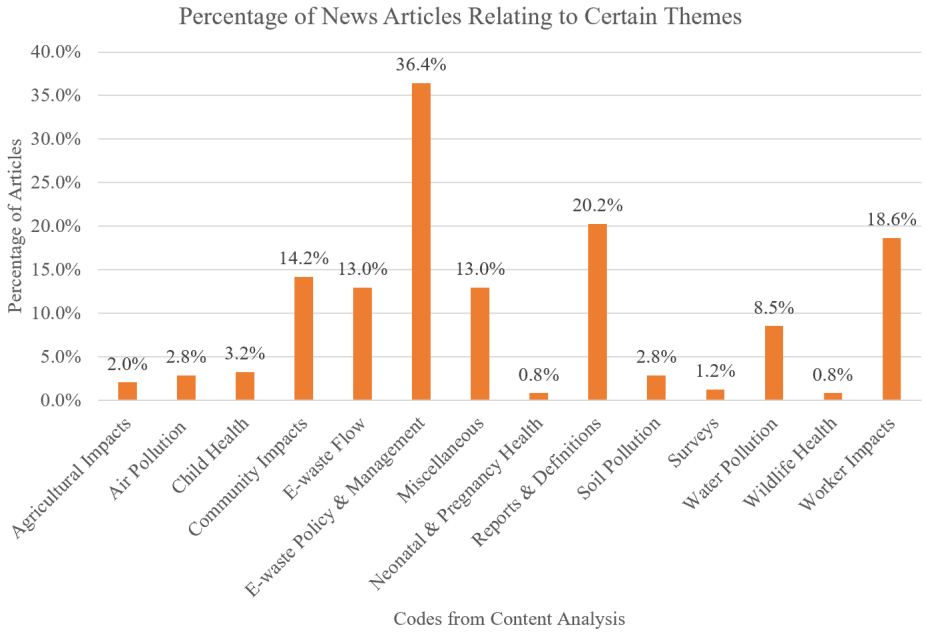


Figure 4.2[2] Distribution of news articles across codes

[2] For figures 4.1 and 4.2, articles can be coded into multiple topics based on the main themes of the paper. For full counts of articles per code see Appendix F.

These trends demonstrate how academic research prioritizes environmental and health effects while the media tends to report on the political aspects of E-waste. Both emphasize the negative symptoms of E-waste rather than the broader issues that fuel the creation of these hubs, such as a lack of formal recycling locations, or even the benefits they may bring to a community, such as economic stability.

We found researchers often study a handful of particular locations when referring to informal E-waste while discussing others less frequently. The location mentioned most frequently in academic papers was Guiyu, China. The top five locations worldwide were all in China, with the sixth location as Agbogbloshie, Ghana. Figure 4.3 lists the most common and specific locations across academic literature, as well as their number of times mentioned in our media search.

Location[3]	Number of Mentions in Academic Literature	Number of Mentions in News Media	Total Mentions Between Both Sources
Guiyu, China	205	34	239
Taizhou[4], China	116	1	117
China	68	4	72
Qingyuan Province, China	58	1	59
Longtang Town, China	52	0	52
Agbogbloshie, Ghana	50	53	103

Figure 4.3 Counts of most specific locations named in academic literature and news media [This figure continues in Appendix D]

Guiyu was the most common location across Chinese news articles. Since most of the academic literature focuses on Guiyu or other locations in China, there are many other sites around the rest of the world that are under-researched. In the future, these sites need to be more of a focus especially as China has implemented stricter regulations including limitations on E-waste importation, a formalization of the E-waste sector, and initiatives to clean the pollution left by these sites. As China limits imports of electronic waste, the destinations will change to other countries instead. Identifying these hubs faster will help policymakers develop a solution before

[3] Some of these locations may overlap one another. We chose to include the most specific place mentioned in the article rather than assume which hub the authors referred to. This means that this Appendix will include countries, provinces/states, and towns all together. Appendix C contains only the hubs.

[4] Zhejiang Province

the problem gets out of control. Each site has unique community and environmental effects. There is no easy replacement for informal E-waste hubs that remediate their negative effects, so it is important to assess each individually and build a tailored solution. This data also reinforces the need to catalog existing E-waste sites, since articles generally discuss few locations and tailored solutions cannot be made without research specific to a site.

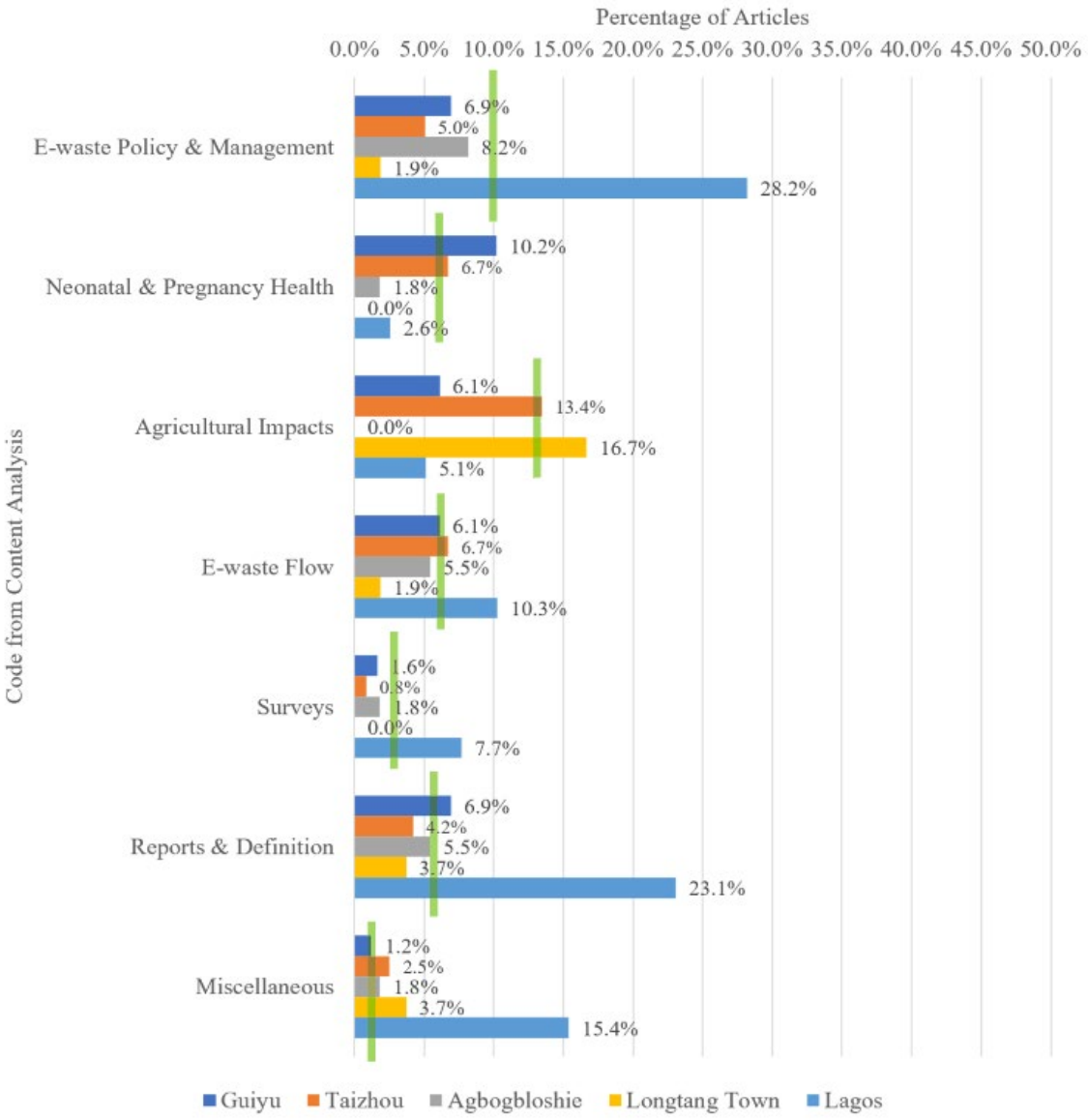
4.1.1 The Academic Discussion on Informal E-waste

Academic research into informal E-waste practices indirectly fuels the discussion of the mounting global issue of E-waste in news by informing policymakers, whose work draws the attention of journalists. The academic literature provides depth in only the most niche topics and fails to reflect the complete breadth of the issue. These research articles often highlight the negative impacts of E-waste, guiding policy makers to act, while ignoring the benefits these sites bring to socially underserved communities.

Our content analysis of informal E-waste academic articles highlighted the specificity of current research. While researchers mentioned 23 unique hubs over the 20-year period we reviewed, they mentioned 19 hubs fewer than five times. In contrast, researchers mentioned Guiyu over 200 times. Our team has interpreted this finding to reflect research perpetuates itself. Well-researched hubs are more likely to receive academic attention because research breeds notoriety, which then leads to more research into this specific location. In contrast, other less-researched hubs often go unnoticed and may benefit from similar attention. While the research done on these sites remains crucial to understanding E-waste, scientists should be cautious in generalizing this information to all informal E-waste locations. Given the broad definition of E-

waste, it is likely that the contents of different sites vary, and thus their effects vary. Thus, it is important that scientists strive to verify and replicate such findings across the globe in other E-waste communities, to validate these studies.

The literature discussed soil pollution at these sites to an overwhelming degree of 33% while only 7% of articles discussed child health. The ubiquity of soil pollution in academic literature may be due to the lack of ethical restraints researchers face when experimenting on soil rather than human subjects. Thus, it remains important to broaden the scope of studies researchers conduct because current E-waste research fails to reflect all aspects of the issue. To that point, researchers should broaden the locations they study in order to verify their findings across multiple hubs as well as verify research studies in less notorious hubs. Figure 4.4 below compares the codes among the most researched places to the average of all our research.


Percentage of Articles
0.0% 5.0% 10.0% 15.0% 20.0% 25.0% 30.0% 35.0% 40.0% 45.0% 50.0%
Code from Content Analysis
E-waste Policy & Management
6.9%
5.0%
8.2%
1.9%
28.2%
Neonatal & Pregnancy Health
10.2%
6.7%
1.8%
0.0%
2.6%
Agricultural Impacts
6.1%
13.4%
0.0%
16.7%
5.1%
E-waste Flow
6.1%
6.7%
5.5%
1.9%
10.3%
Surveys
1.6%
0.8%
1.8%
0.0%
7.7%
Reports & Definition
6.9%
4.2%
5.5%
3.7%
23.1%
Miscellaneous
1.2%
2.5%
1.8%
3.7%
15.4%
Guiyu
Taizhou
Agbogbloshie
Longtang Town
Lagos

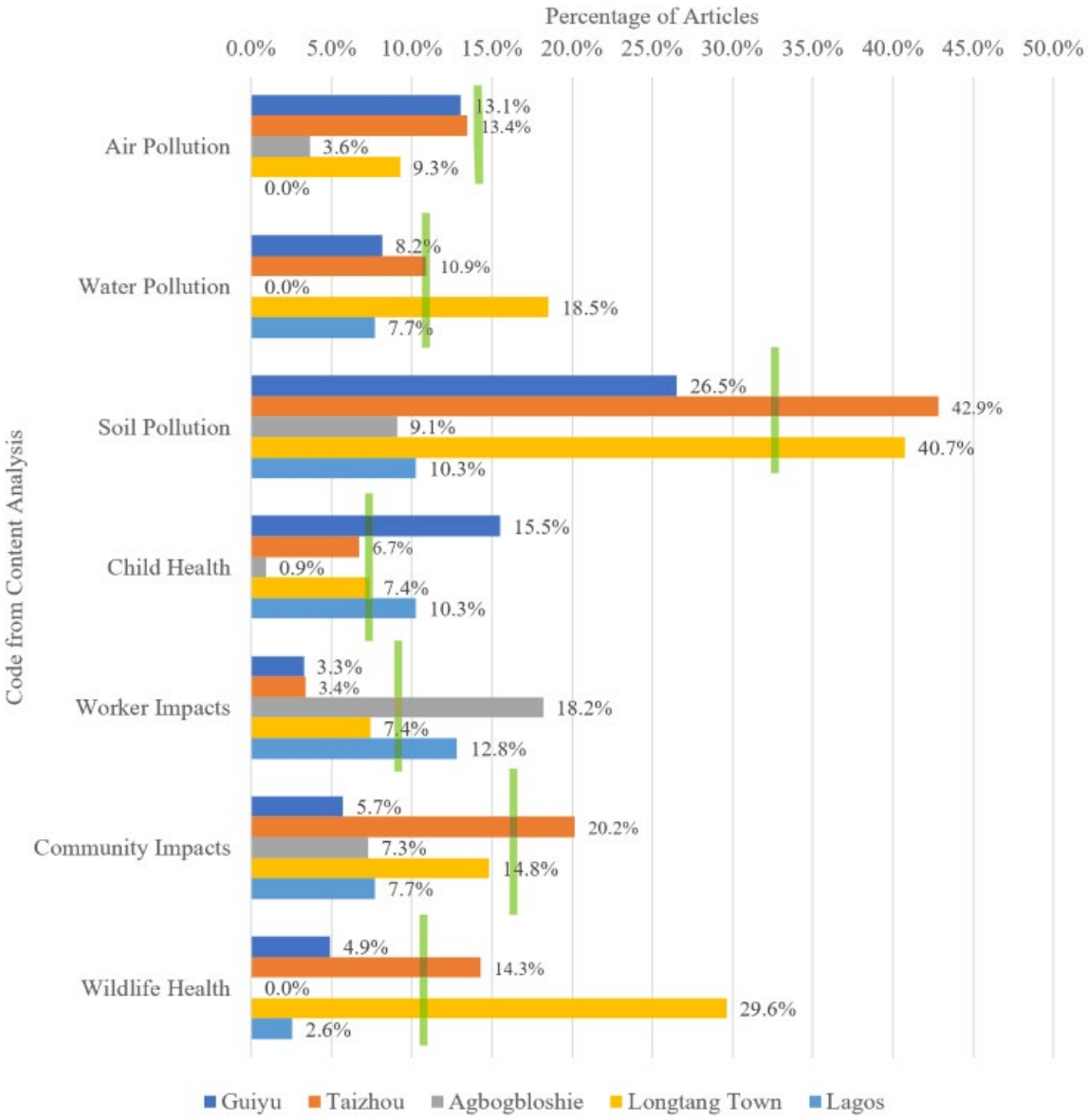


Figure 4.4 Comparison of the percentage articles referencing common themes between well-researched informal E-waste areas and the overall average

[The green bars represent the average across all academic articles]

Figure 4.4 illustrates how researchers tend to investigate certain topics at specific hubs.

Articles about Agbogbloshie tend to be more focused on worker impacts than articles about other

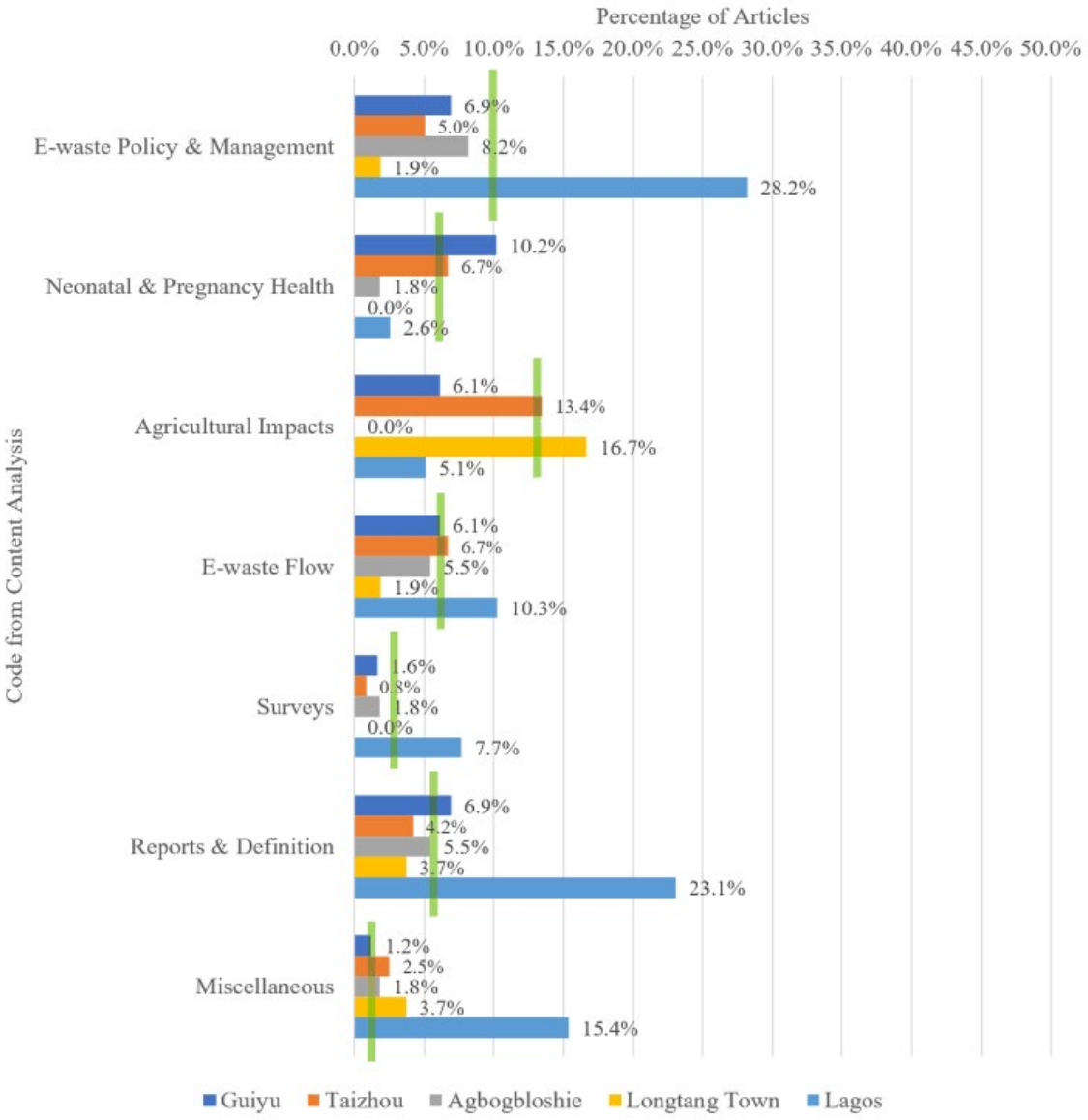
locations. No articles discussing the effects on the wildlife or local waterways mention Agbogbloshie. This is a clear gap in the research at Agbogbloshie. Researchers studying informal E-waste hubs delve into different demographics. For example, articles about Guiyu focused on child health more than average. The emphasis on places like Guiyu or Agbogbloshie may leave communities around less researched hubs uneducated about health and environmental dangers that informal E-waste recycling brings.

4.1.2 Regional Media Discussion on Informal E-waste

Similar to the discussion in academic literature on informal E-waste, the media discussion around these locations has a limited scope. 37.5 percent of Chinese articles referred to Guiyu, making it the most widely mentioned location in China, along with Dong Mai Village at 20 percent in Vietnamese articles, Agbogbloshie at 82.5 percent in Ghanaian articles, Lagos at 30.6 percent in Nigerian articles, and Moradabad at 20.3 percent in Indian articles. We found journalists mentioned 46 locations in their articles that researchers did not address. However, 111 locations were only mentioned in academic literature with 66 of those from the countries above. Taizhou, the second most mentioned site in academic literature, only appeared once in our media review. This variation between sources reflects inconsistencies in both realms of E-waste discussion that did not acknowledge the many locations of informal E-waste recycling.

This lack of breadth also extends to the themes journalists use to discuss informal E-waste when reporting on it. For example, E-waste Policy & Management was the most common topic of discussion at 36.4 percent (Figure 4.5), which points to a focus on the political efforts to clean up these informal sectors while leaving readers uninformed to the environmental dangers

that spur these reforms. Interestingly, Chinese news never reports on E-waste related air or soil pollution despite being topics scientists frequently discuss in their research. Also, we found the lack of articles discussing worker impacts, such as the economic benefits or health effects of working in these hubs, in Ghanaian and Nigerian news surprising, since researchers extensively explored those topics in academic literature. Additionally, Chinese and Ghanaian news articles were about water pollution less than average. This pattern continues from academic literature where articles about Guiyu are about water pollution less than average and articles about Agbogbloshie never discuss water pollution. We find this lack of water pollution coverage alarming, because both sites are near major bodies of water. Figure 4.5 below illustrates these trends and others.


Percentage of Articles
0.0% 5.0% 10.0% 15.0% 20.0% 25.0% 30.0% 35.0% 40.0% 45.0% 50.0%
Code from Content Analysis
E-waste Policy & Management
6.9%
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1.9%
28.2%
Neonatal & Pregnancy Health
10.2%
6.7%
1.8%
0.0%
2.6%
Agricultural Impacts
6.1%
13.4%
0.0%
16.7%
5.1%
E-waste Flow
6.1%
6.7%
5.5%
1.9%
10.3%
Surveys
1.6%
0.8%
1.8%
0.0%
7.7%
Reports & Definition
6.9%
4.2%
5.5%
3.7%
23.1%
Miscellaneous
1.2%
2.5%
1.8%
3.7%
15.4%
Guiyu
Taizhou
Agbogbloshie
Longtang Town
Lagos

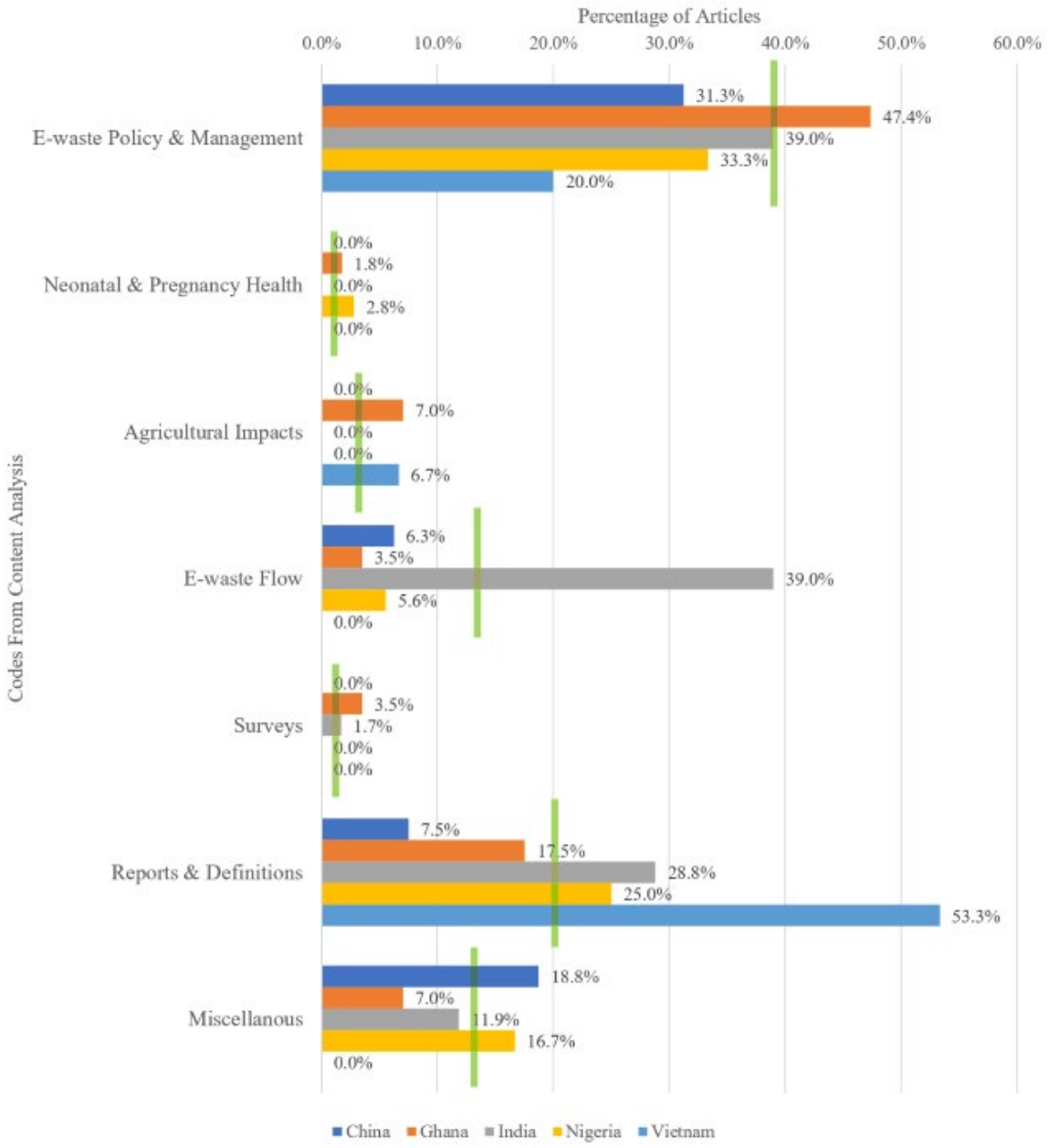

Figure 4.5 Comparison of the percentage articles referencing common themes between media country and the overall average

[The green bars represent the average across all news articles]

During our news search we found various terms used to describe E-waste including E-trash, E-scrap, E-waste, and electronic waste. We found specific regional colloquialisms in India like, ‘‘kabaad’’(recyclables), “kabadi ki dukan” (scrap shops), and “kabadiwala” (scrap man), and in Ghana, “bola taxis” (waste collection service) and “kaya borla” (informal waste collectors). These colloquialisms may limit readers from identifying E-waste activity in other regions of the world because there is not a uniform way of referring to E-waste in the media.

4.1.3 NGO Discussion on E-waste

We examined 18 NGOs, listed in Appendix I, to deepen our understanding of where informal E-waste hubs are in the world. While some NGO reports we reviewed were helpful--giving detailed explanations of informal E-waste hubs--most were not. Worldwide NGOs proved to be more useful than environmental NGOs country wide. In total, we found only 76 locations in 42 articles. These NGOs mentioned Agbogbloshie, Guiyu, and Hong Kong the most. Toxic Link and Pure Earth were the most informative NGOs, giving us new hubs and an in depth look at certain hubs. Our team found these NGOs to contain more in-depth information on informal E-waste hubs than news and academic articles, but this result was a rare occurrence. The majority of their information was irrelevant to our search. We attribute this inconsistency of reports to a failure in our search for NGOs, or due to the specific nature of NGOs--many of them focus on narrow topics which are not explicitly E-waste. We could not include some NGOs we found in our news search in our study of NGOs because we could not access their websites or reports.

4.2 Geographic Patterns

From the density map in Appendix A, we can see that informal E-waste research is more prevalent in Asia and Africa. The pollution-haven hypothesis suggests that E-waste would be shipped to about 130 developing nations of the world. If the pollution-haven hypothesis were true, we would expect to see E-waste research within all of these countries. We highlighted informal E-waste research within 49 developing countries, which would suggest that we have disproved this widely debated theory. However, our team does not make this claim, because our findings only capture locations where informal E-waste hub research is taking place. It is likely that researchers have not studied every hub and we cannot conclude that no published research of informal E-waste hubs indicates the absence of a hub in that country.

We also created an interactive map of hub locations, screenshots of which are shown in Appendix A. The majority of these hubs are near port cities and major bodies of water. This proximity to waterways likely indicates some of the E-waste in this location is being shipped from other parts of the globe. This geographic trend would support the theory that a large amount of E-waste arrives to these informal hubs from other countries, which we can further support through the various news articles we analyzed that indicated E-waste was being smuggled into the country. However, this proximity to water could also be due to the massive populations of port cities. The hubs around New Delhi, India, and other major Asian cities could indicate that massive populations create larger amounts of E-waste. Our team believes it is likely the E-waste in these informal hubs originates from both hypotheses, but to what degree E-waste is from imports versus created domestically we do not know.

5 Conclusions and Recommendations

Our project cataloged and mapped informal E-waste hubs research, through the analysis of academic literature and regional media, to bridge the gap of limited known hub locations. We demonstrate informal E-waste hub research locations globally through a global density map. Additionally, we mapped unique hubs present in China, India, Ghana, Vietnam, and Nigeria. Future researchers should investigate gaps in knowledge surrounding more well-known hubs, further regional news sources, and hubs invisible to academics.

5.1 Current E-waste Research and News Coverage

Current academic research focuses primarily on soil pollution and other environmental effects around informal E-waste hubs. In contrast, researchers have paid very little attention to the health impacts on newborns and pregnant mothers living near these hubs. This unequal amount of research is likely due to the lack of ethical restraints scientists face when testing soil samples versus infants or pregnant women. Looking at the effects on newborns and their mothers proves important because they remain an at-risk demographic group and the effects of heavy metals may be more detrimental to their development than to other groups of people.

Also, few articles analyzed the flow of E-waste to informal E-waste hubs. While there is research on a global scale about the flow it often does not drill down to find the final locations of E-waste. It remains important to conduct research into the flow of E-waste to identify how it reaches these hubs so that policymakers can create solutions to address the source of the E-waste rather than remediate the harmful effects informal hubs bring. As it stands, policymakers propose

measures that treat the symptoms of these hubs and they do so with the aid of broad legislation based on studies from other communities. They need to make these solutions on a case by case basis. There is no simple solution that will work for all E-waste hubs in the world, as they vary in size and waste contents. By knowing their site more specifically, policymakers can create tailored solutions to address the needs of their community. We recommend that future research explore these gaps in E-waste research.

Both academic literature and Chinese news articles mention Guiyu, China the most often. 205 academic articles mentioned Guiyu-- many of which look at the health and environmental effects of this informal hub. In comparison, there were 32 Chinese news articles that mentioned Guiyu and almost all of them explained how the government was working to clean up and formalize these workshops to reduce the negative health effects. It is possible that the attention of researchers, NGOs, and journalists spurred the Chinese government's reform efforts in Guiyu. To that point, other Chinese hubs exist but receive less attention in academic literature and Chinese media, so they are left to continue their harmful practices. Additionally, increasing the coverage of informal E-waste hubs in other nations, would likely urge those governments to make similar reforms.

Another location that came up often in academic literature and news articles was Agbogbloshie, Ghana. 50 academic articles and 46 Ghanaian news articles mentioned this location. Similar to news articles about Guiyu, many news articles about Agbogbloshie stated that the government was working to formalize and regulate this hub. In contrast, however, these efforts seemed to be less successful than in China. To that point, no articles stated that Ghana

was eliminating imports of electronic waste as China did in their cleanup efforts. We found that the majority of Ghanaian news articles about policies and management of E-waste discussed plans to create a formal recycling plant in Agbogbloshie. However, it seems that these efforts have been unsuccessful as there were articles within the last few years that explained how people tend to continue recycling informally even with the addition of formal recycling plants nearby and that damage to nearby waterways persists. In academic literature about Agbogbloshie, research avoided discussions of water pollution despite the close proximity to the Odaw river and instead focused on worker impacts and policies/management. When researchers neglect the effects Agbogbloshie has on its local waterways policymakers and residents may not be spurred to take action, leaving their waters polluted.

5.2 Recommendations for Future Research

We developed recommendations for future research into studying informal E-waste hubs and future projects to explore E-waste. Our results identified gaps in the knowledge of informal E-waste hubs. including locations that lack thorough academic analysis, and broader gaps within the current research topic surrounding E-waste. Future researchers can access our database at https://github.com/gormes/WPI-Ewaste to see more specific data on locations and their research topics.

5.2.1 Verifying Lesser-Known Hubs & Filling Research Gaps

Future researchers should verify the sites we claim are informal E-waste hubs--paying close attention to the sites that governments have claimed to cleanup and those with less articles. One way to verify a location as an informal hub is to travel to the location and

personally investigate the site. We lacked this ability and as such could not verify the existence of hubs at these locations ourselves. Thus, we recommend that future researchers improve on our findings by verifying the existence of an informal E-waste hub.

Another effective method of verification that does not require personal travel is to communicate directly with the residents of an identified location or the authors of a relevant article. We could not effectively apply this method either, due to language barriers and a lack of time. This method may prove useful for future researchers in verifying suspected hubs and finding unreported informal E-waste hubs within nations that have not been researched at all.

We also recommend that future research into E-waste address the current gaps we identified. Researchers have explored many informal sites less thoroughly, such as Abokobi, Ghana and Xiaoshijiazhuang Village, China which academic literature has never mentioned, but we identified through our media search. Along with these lesser-known sites, there remain gaps in current research of comparatively well-known locations, such as a lack of research into water pollution in Agbogbloshie, and the health effects on pregnant mothers and newborns in Longtang Town. These areas of research may aid others in understanding the effects of informal E-waste recycling and whether they vary between different locations.

5.2.2 Continuing our News Research

We found our news search to be a useful method, however, there remains room for improvement. Many articles provided no new information--instead, they simply referred to the same event or were copies of articles on another website. While it did highlight locations left unacknowledged by academia, those findings were rare. This finding could be because we chose

to analyze news in countries where researchers have identified major E-waste hubs already. It could be that these sites then draw attention away from smaller hubs within that country so this method may prove even more useful in countries without heavily researched informal E-waste sectors or no research at all.

Our team decided to focus our search for news media on China, India, Ghana, Nigeria and Vietnam because they appeared the most frequently in academic articles. We recommend future researchers apply our methods to other news sites to search for informal hubs in other countries. Ideally, their approach would address limitations we faced like language barriers and online accessibility.

5.3 Final Thoughts

As E-waste grows so does informal E-waste recycling. Many of these informal E-waste hubs lack proper reporting within academic literature and the regional media. Our project consolidated a list of these locations from academic papers, news articles and NGO reports. We found that most of the research and reporting generally focused on a handful of locations and topics which could lead to enacting policies that fail to address the unique problems each location faces. We gathered these findings from a novel method of searching regional news for evidence of informal E-waste hubs. Future researchers should refine our creative methodology, investigate less infamous locations, and expand upon research topics to create a more balanced understanding of informal E-waste hubs.

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Appendix A: Density and Regional Maps

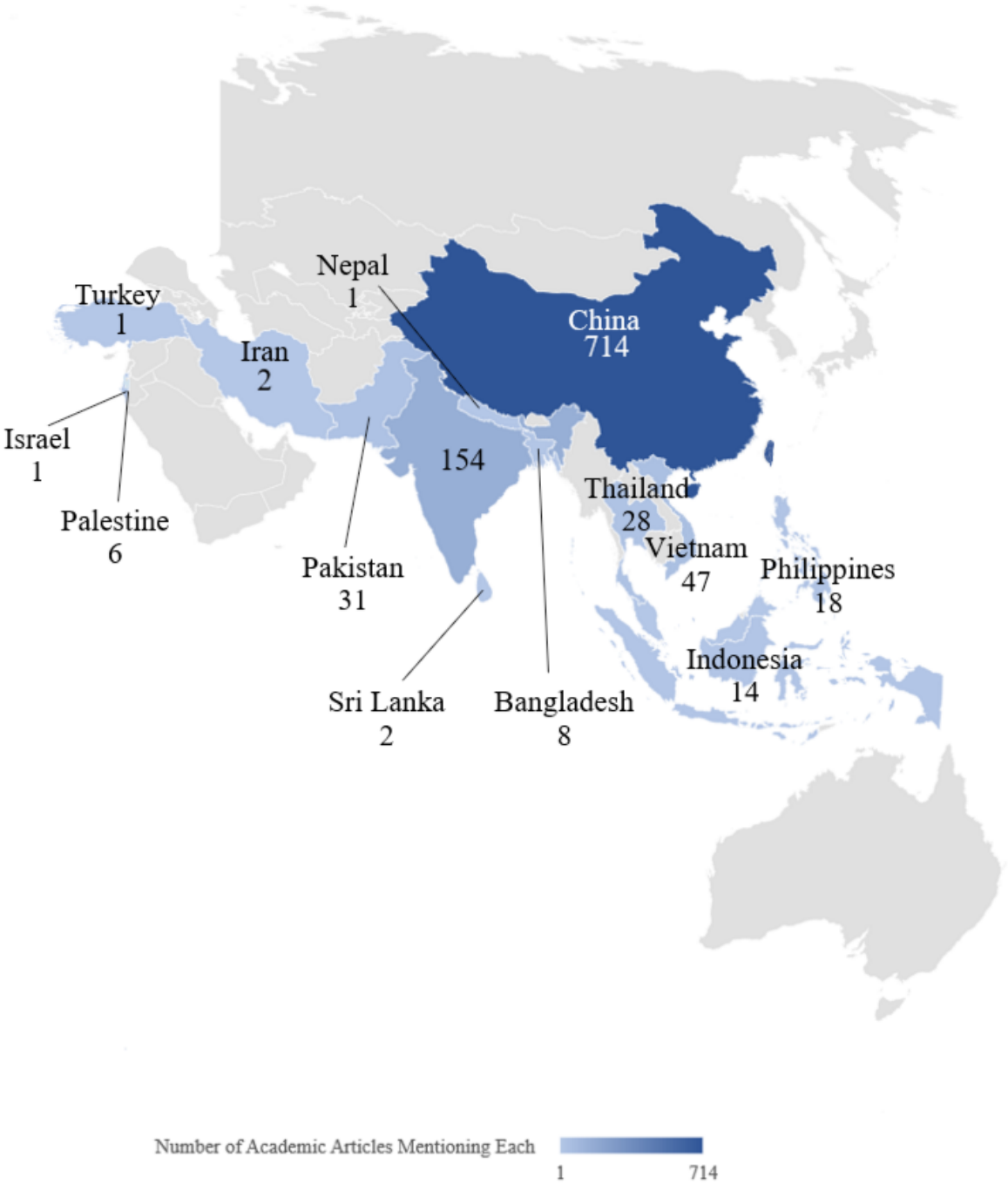
This Appendix contains both worldwide density maps of informal E-waste hubs from academic literature and individual maps of informal E-waste hubs in China, India, Ghana, Nigeria, and Vietnam. The country maps have been created in Google My Maps. To view an interactive version visit:
https://www.google.com/maps/d/edit?mid=1Bwom1VnJ9YykJTd28F1qjiop3HrEn6w-&usp=sharing

Disclaimer: Our maps have been prepared for illustrative purposes only. The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of the authors or Worcester Polytechnic Institute concerning the geo-political situations or the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. We chose these boundaries based on the environmental regulations the region adheres to.
The following maps describe the country-wide count of academic articles that mention the locations of informal E-waste hubs.

Mentions of Informal E-waste in Each Country in North and South America From Academic Articles, News Articles, and NGO Reports

Mentions of Informal E-waste in Each Country in Europe and Africa
From Academic Articles, News Articles, and NGO Reports

Mentions of Informal E-waste in Each Country in Asia From Academic Articles, News Articles, and NGO Reports

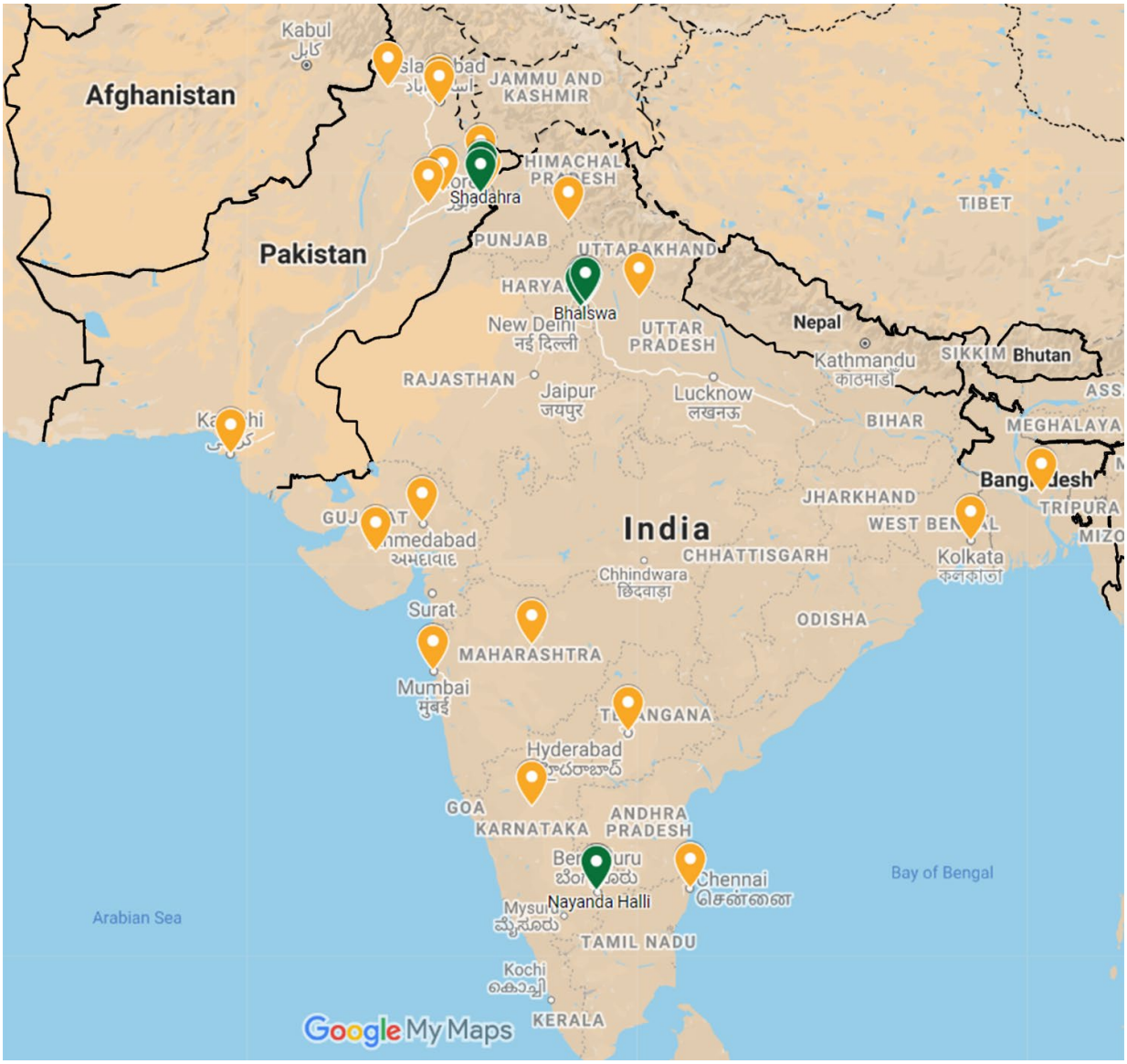


The following maps present the location of informal E-waste hubs from each country found in academic articles, NGO reports, and regional news.

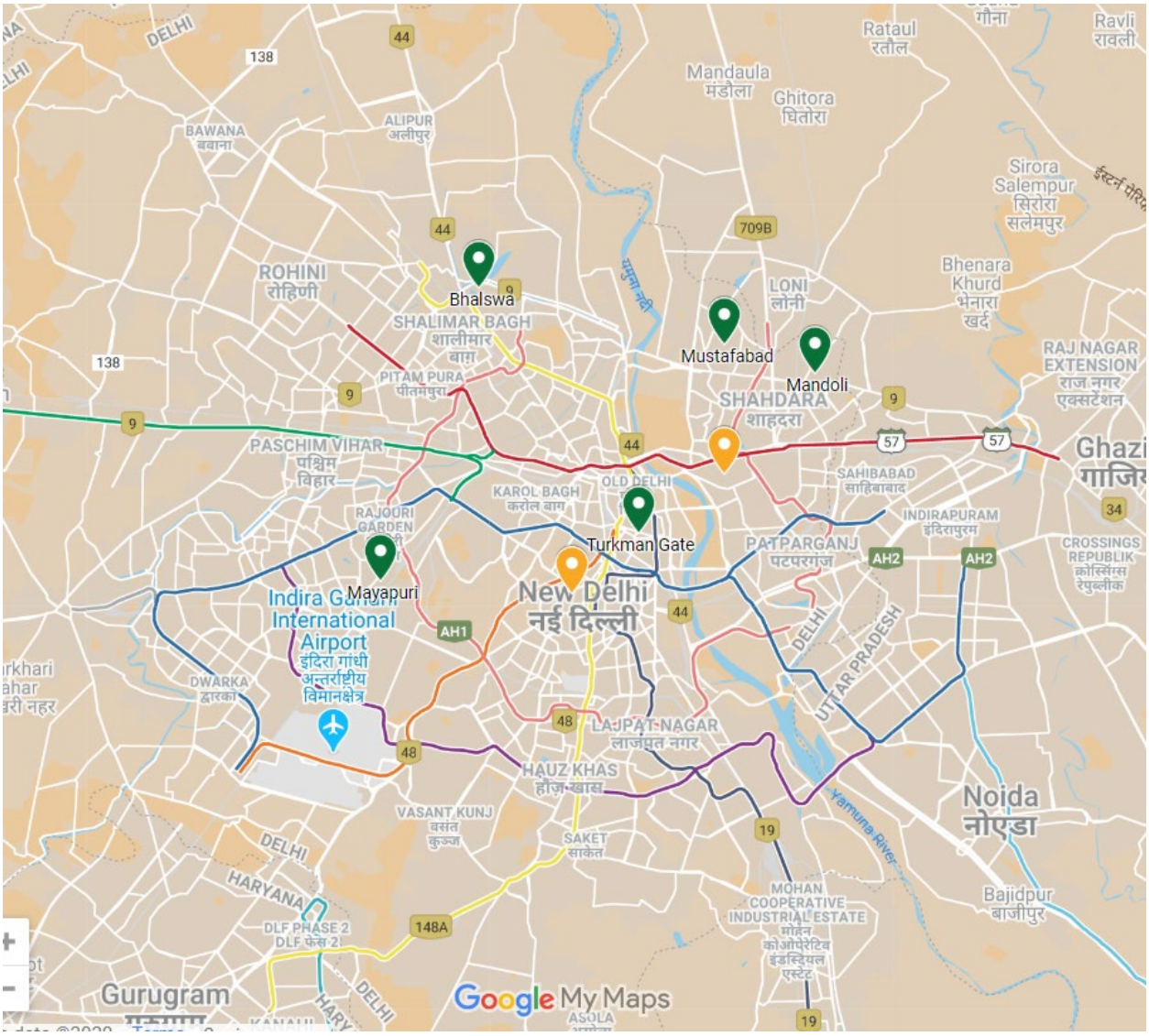
Key: Informal E-waste Hub: Informal E-waste Area:

Informal E-waste Hubs in China

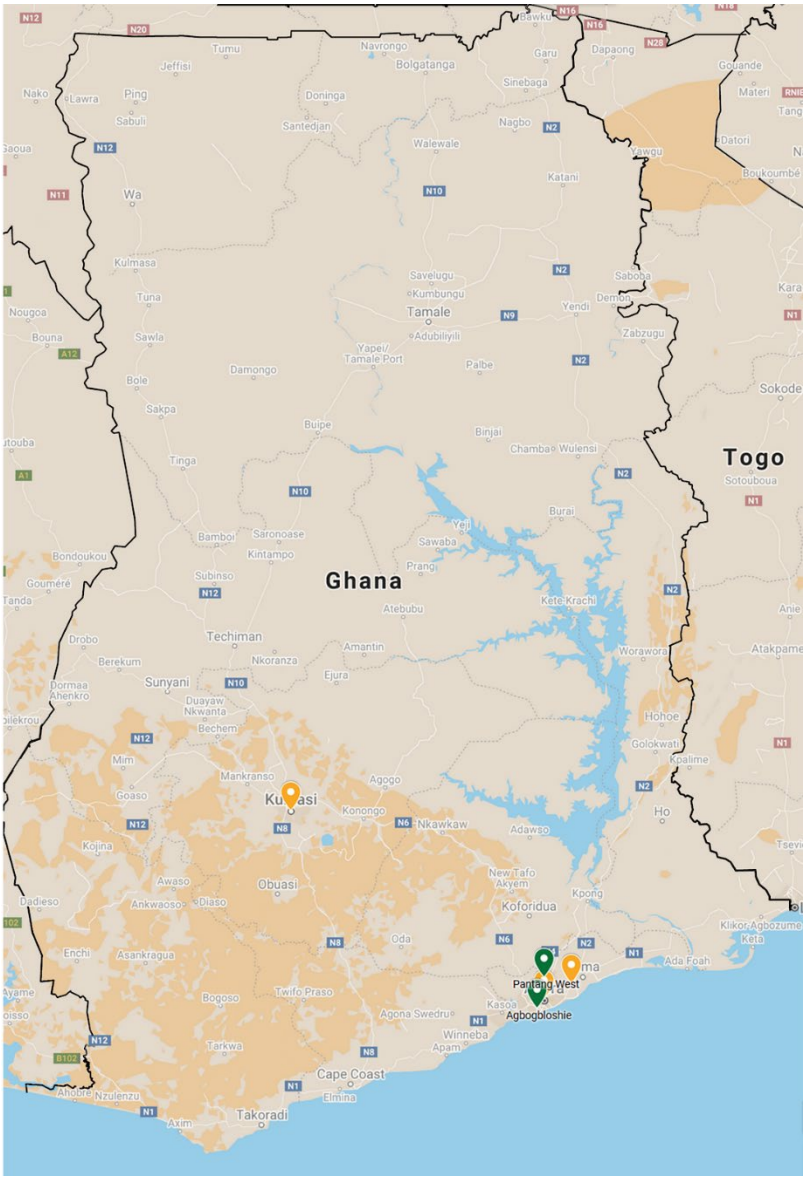
Informal E-waste Hubs in India



New Delhi Area, India

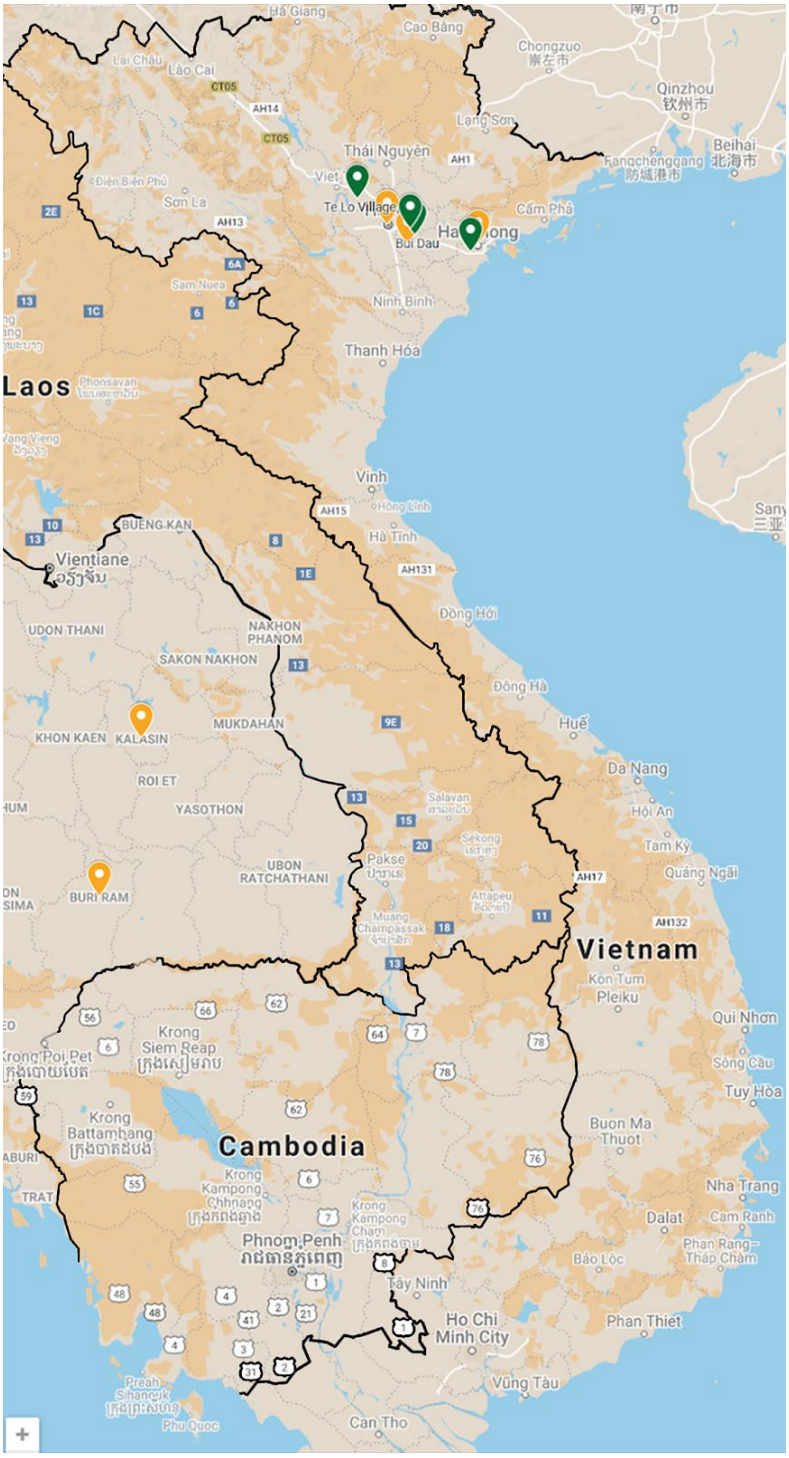


Informal E-waste Hubs in Ghana



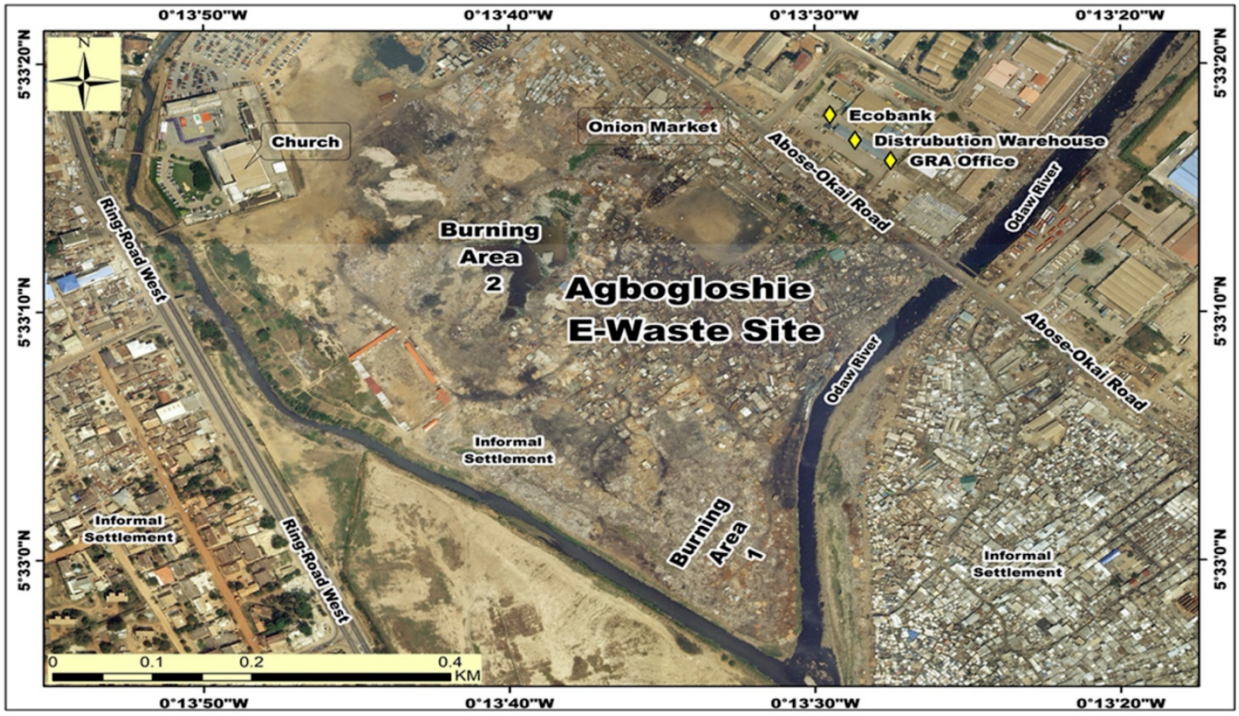
Informal E-waste Hubs in Nigeria

Informal E-waste Hubs in Vietnam



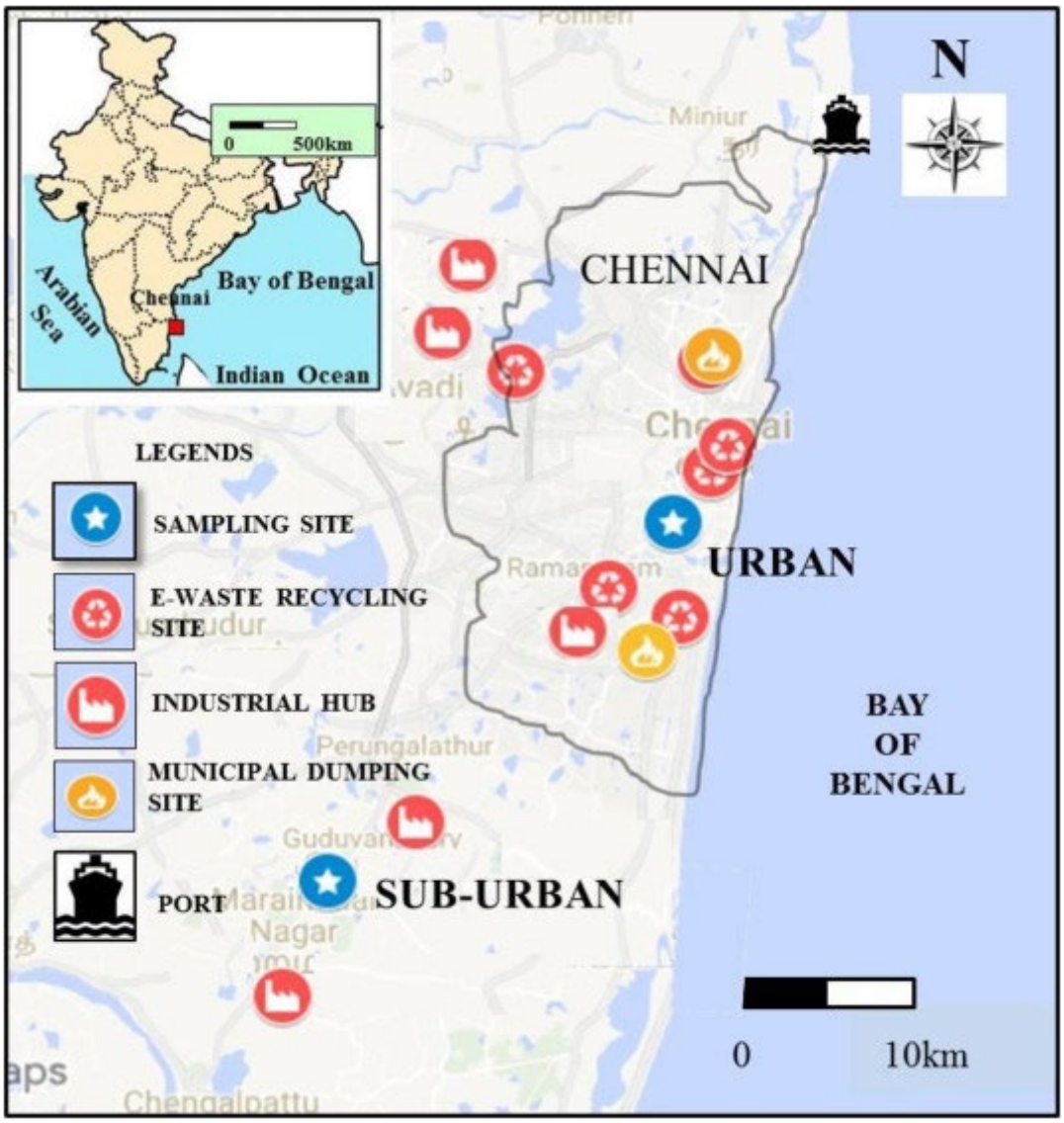
Appendix B: Additional Maps from Academic Literature

This appendix contains maps found in our academic literature search that clarified our understanding of larger hubs and helped us locate smaller hubs that were not as easy to determine just using Google Maps. This is not a complete list of every map from our academic literature review but rather a list of those we found most useful and informative. Each map has a citation below it.

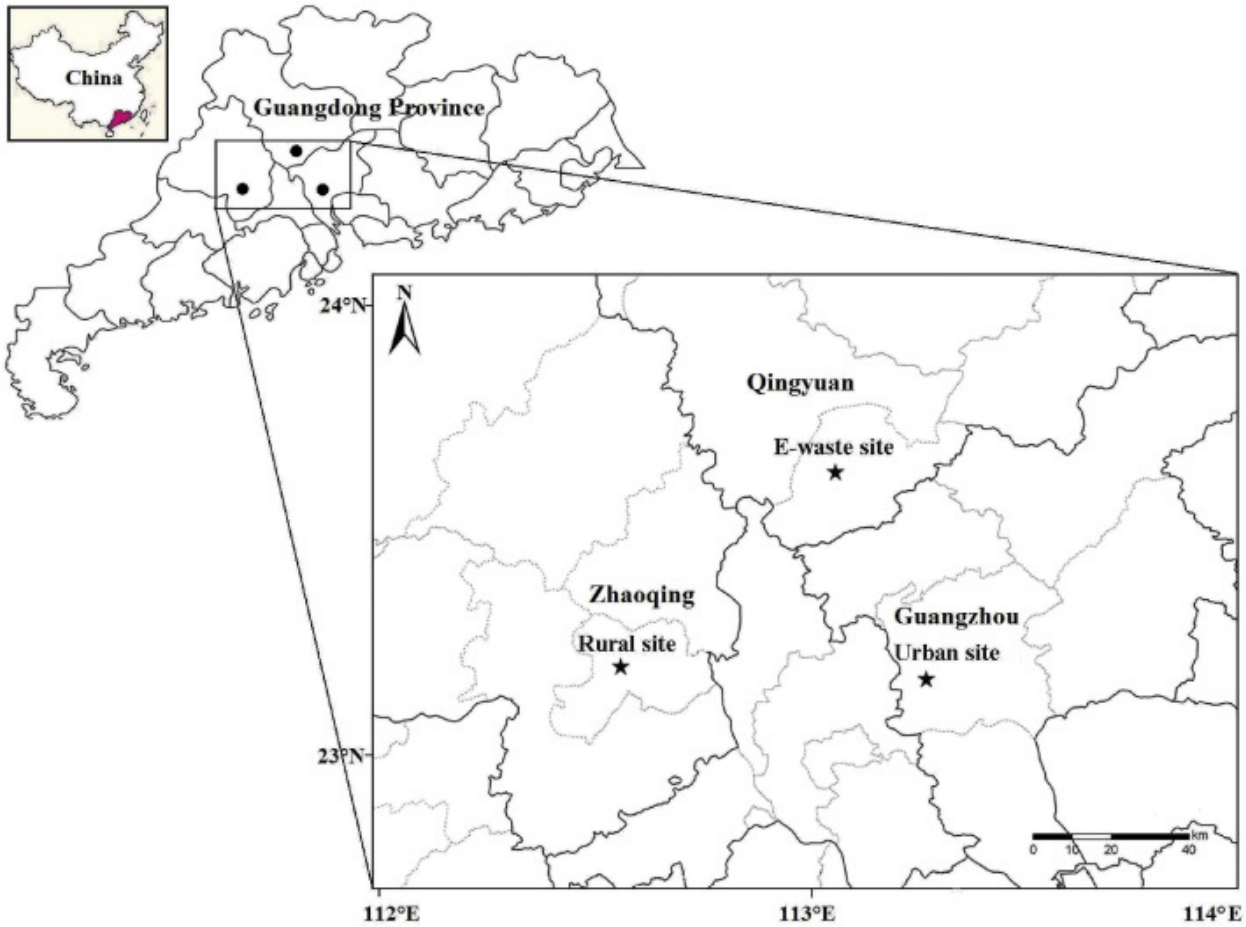


(a)

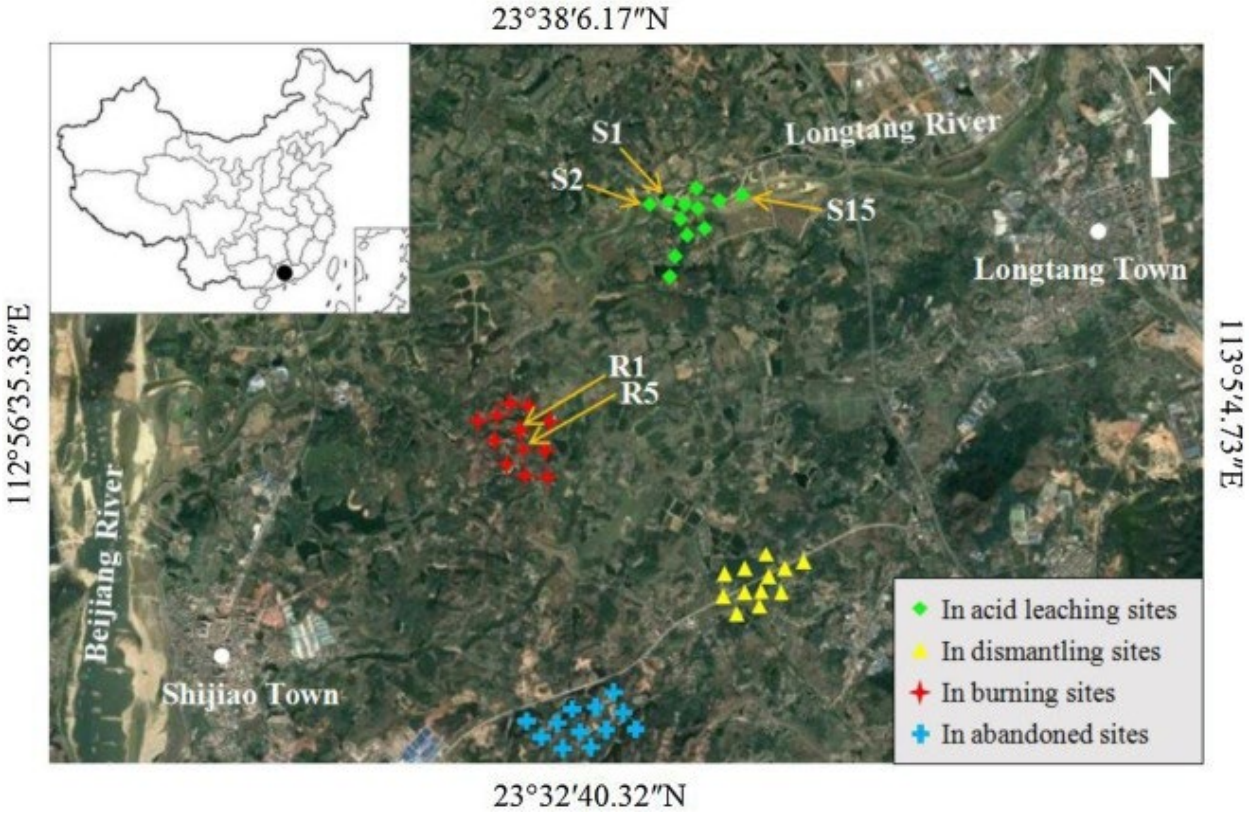
Nti, A. A. A., Arko-Mensah, J., Botwe, P. K., Dwomoh, D., Kwarteng, L., Takyi, S. A., Tettey, P., Basu, N., Batterman, S., Robins, T., & Fobil, J. N. (2020). Effect of Particulate Matter Exposure on Respiratory Health of e-Waste Workers at Agbogbloshie, Accra, Ghana. *International Journal of Environmental Research and Public Health*, 17(9), 3042 https://doi.org/10.3390/ijerph17093042



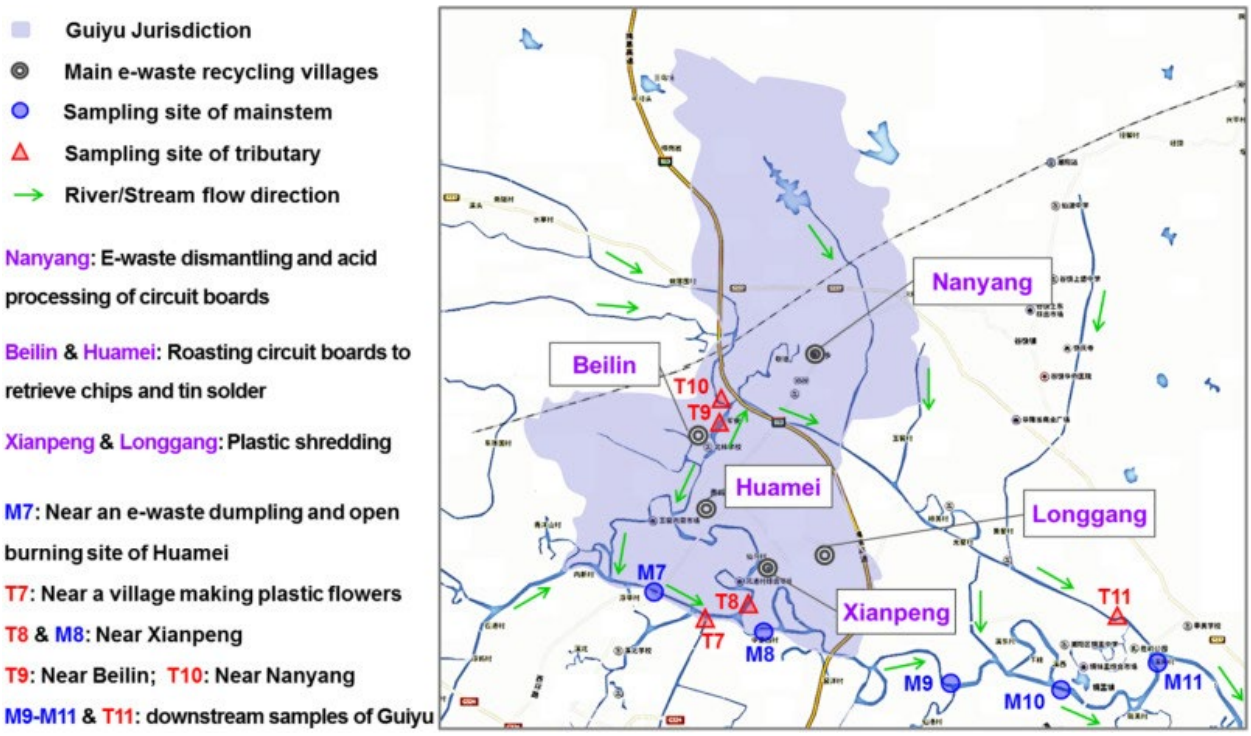
Prithiviraj, B., & Chakraborty, P. (2020). Atmospheric polychlorinated biphenyls from an urban site near informal electronic waste recycling area and a suburban site of Chennai city, India. *Science of the Total Environment,* 710, 135526. https://doi.org/10.1016/j.scitotenv.2019.135526



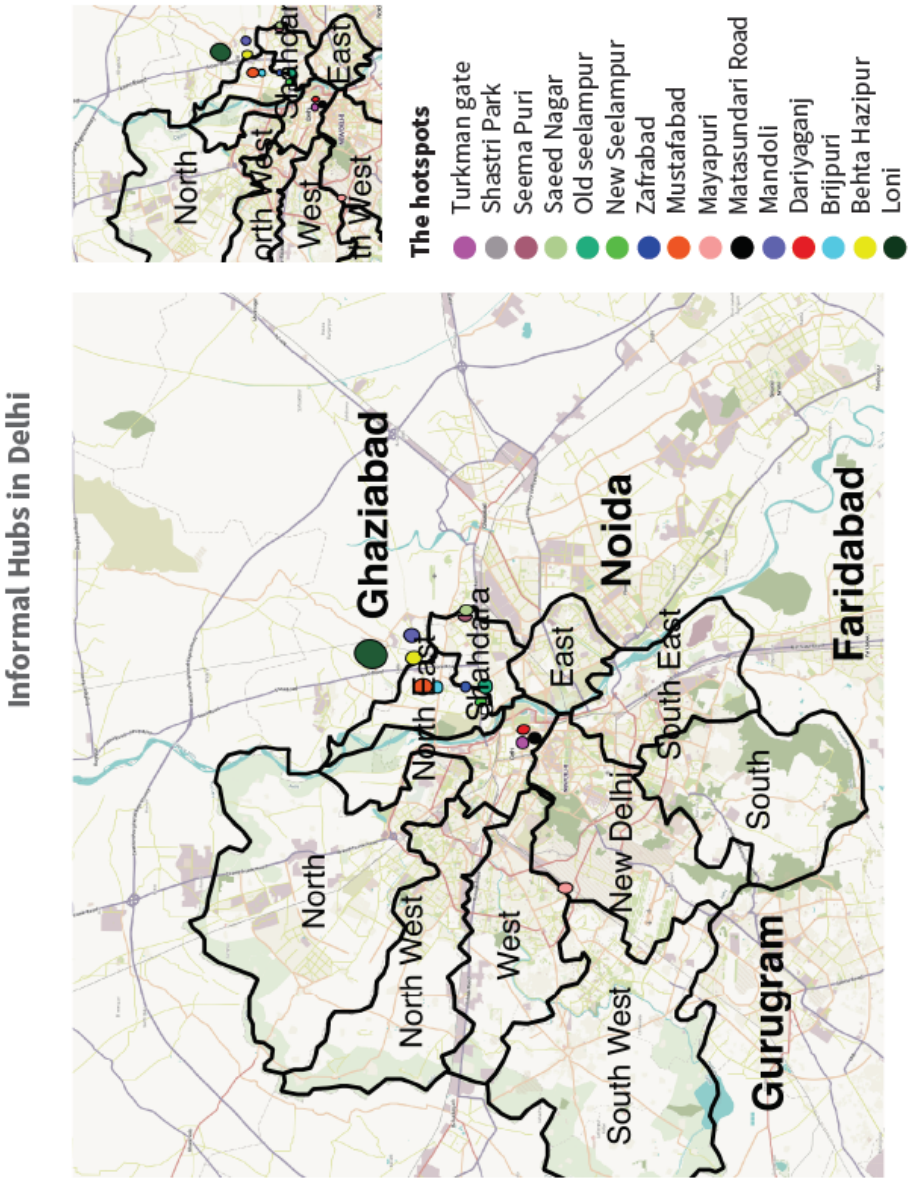
Mo, L., Zheng, X., Zhu, C., Sun, Y., Yu, L., Luo, X., & Mai, B. (2019). Persistent organic pollutants (POPs) in oriental magpie-robins from e-waste, urban, and rural sites: Site-specific biomagnification of POPs. *Ecotoxicology and Environmental Safety*, 186, 109758. https://doi.org/10.1016/j.ecoenv.2019.109758



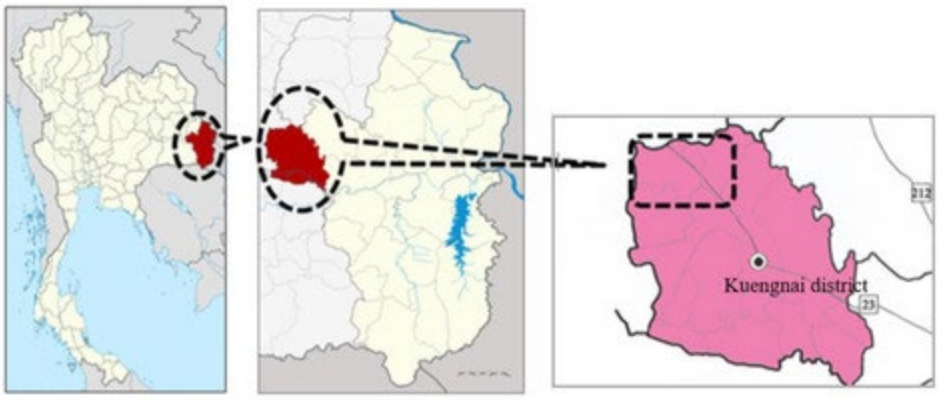
Han, Y., Tang, Z., Sun, J., Xing, X., Zhang, M., & Cheng, J. (2019). Heavy metals in soil contaminated through e-waste processing activities in a recycling area: Implications for risk management. *Process Safety and Environmental Protection*, 125, 189–196. https://doi.org/10.1016/j.psep.2019.03.020



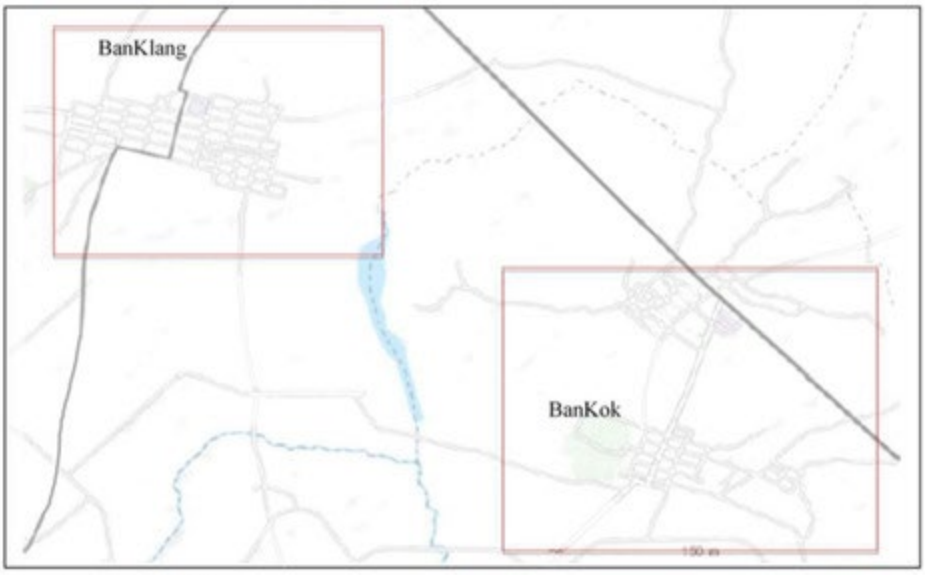
Li, H., Guardia, M. J. L., Liu, H., Hale, R. C., Mainor, T. M., Harvey, E., Sheng, G., Fu, J. Peng, P. (2019). Brominated and organophosphate flame retardants along a sediment transect encompassing the Guiyu, China e-waste recycling zone. *Science of The Total Environment*, 646, 58–67. https://doi.org/10.1016/j.scitotenv.2018.07.276



Toxic Link. (2018). *Informal E-waste Recycling in Delhi: Unfolding/Impact of two years of E-waste (Management) Rules 2016.* http://www.toxicslink.org/docs/Informal%20E-waste.pdf

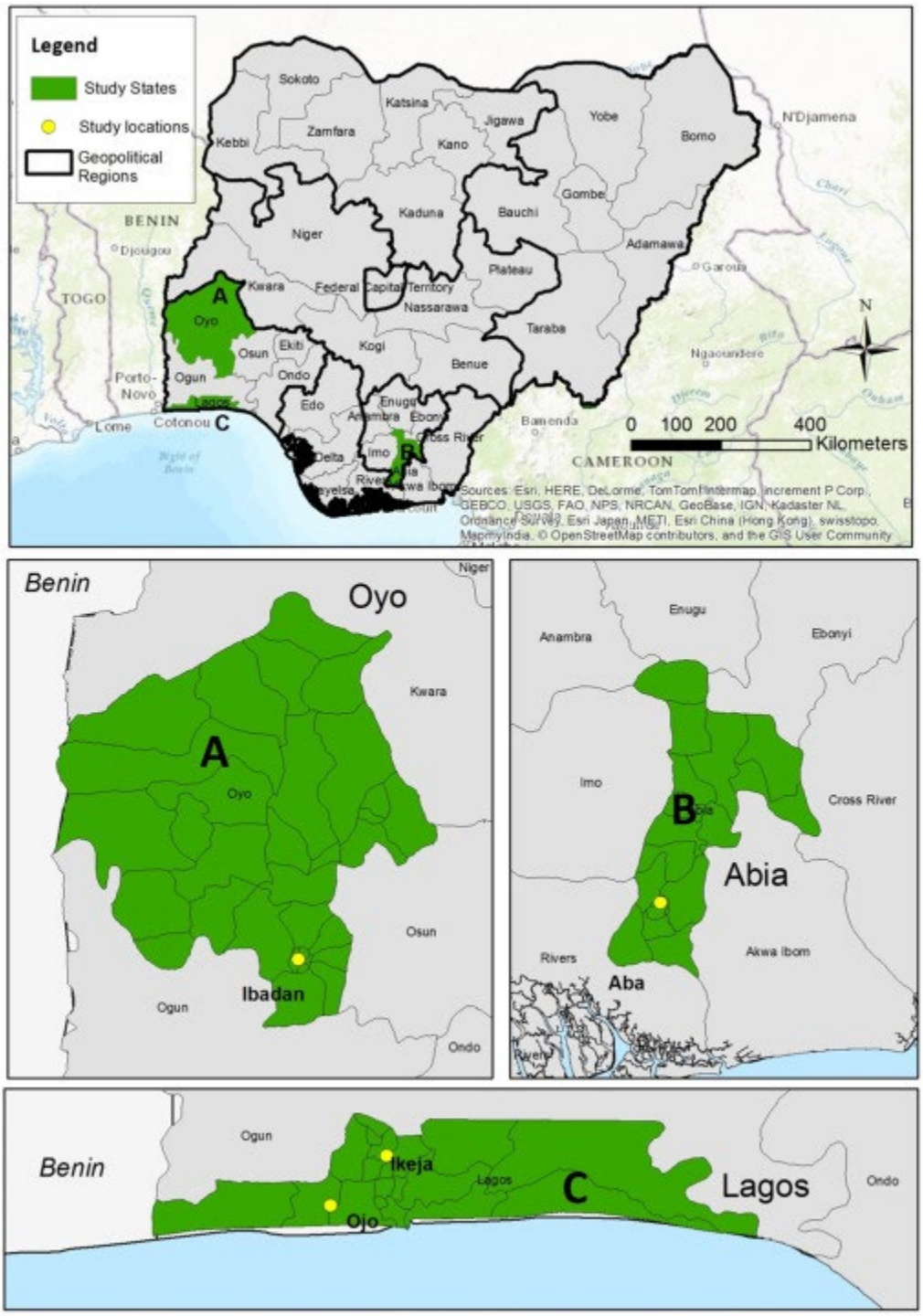


Map of Thailand Map of Ubon Ratchathani province Map of Kuengnai district

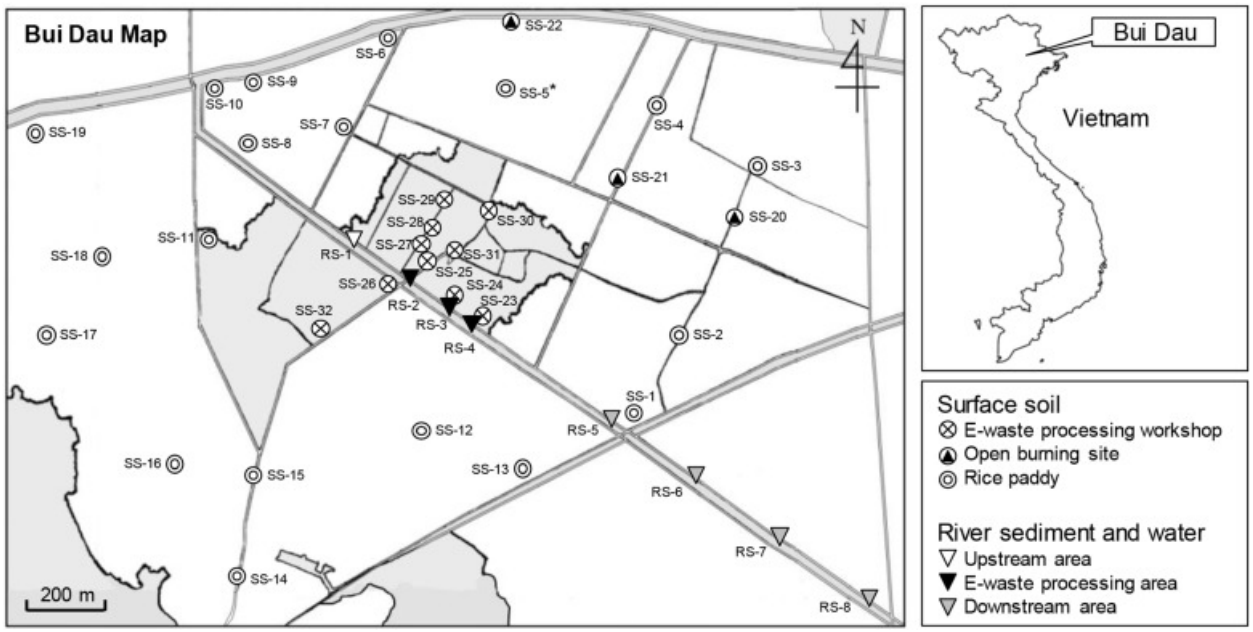


Map of BanKok and BanKlang

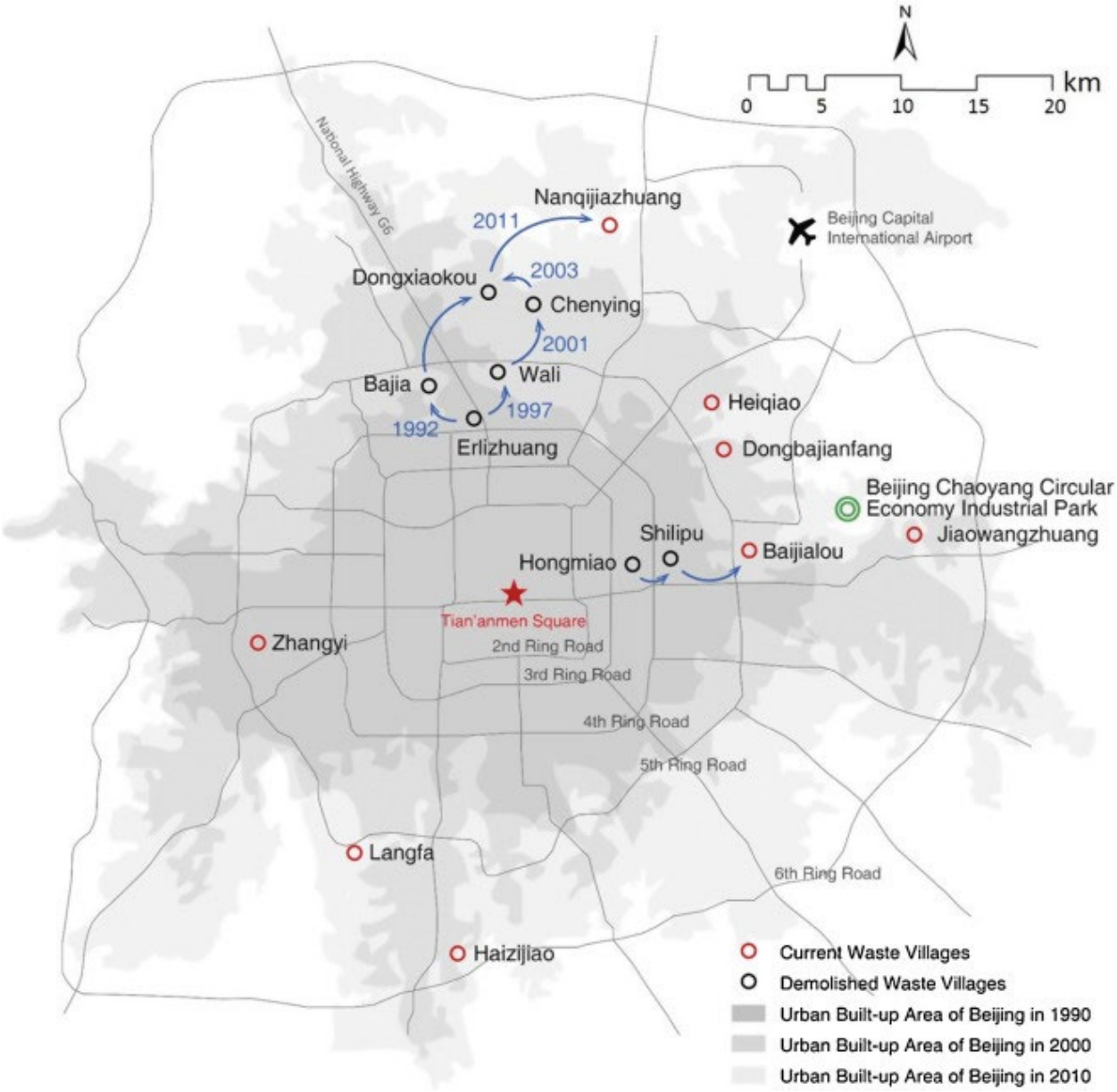
Kuntawee, C., Tantrakarnapa, K., Limpanont, Y., Lawpoolsri, S., Phetrak, A., Mingkhwan, R., & Worakhunpiset, S. (2020). Exposure to Heavy Metals in Electronic Waste Recycling in Thailand. *International Journal of Environmental Research and Public Health,* 17(9), 2996. https://doi.org/10.3390/ijerph17092996



Ohajinwa, C. M., van Bodegom, P. M., Vijver, M. G., & Peijnenburg, W. J. G. M. (2018). Impact of informal electronic waste recycling on metal concentrations in soils and dusts. *Environmental Research,* 164, 385–394. https://doi.org/10.1016/j.envres.2018.03.002

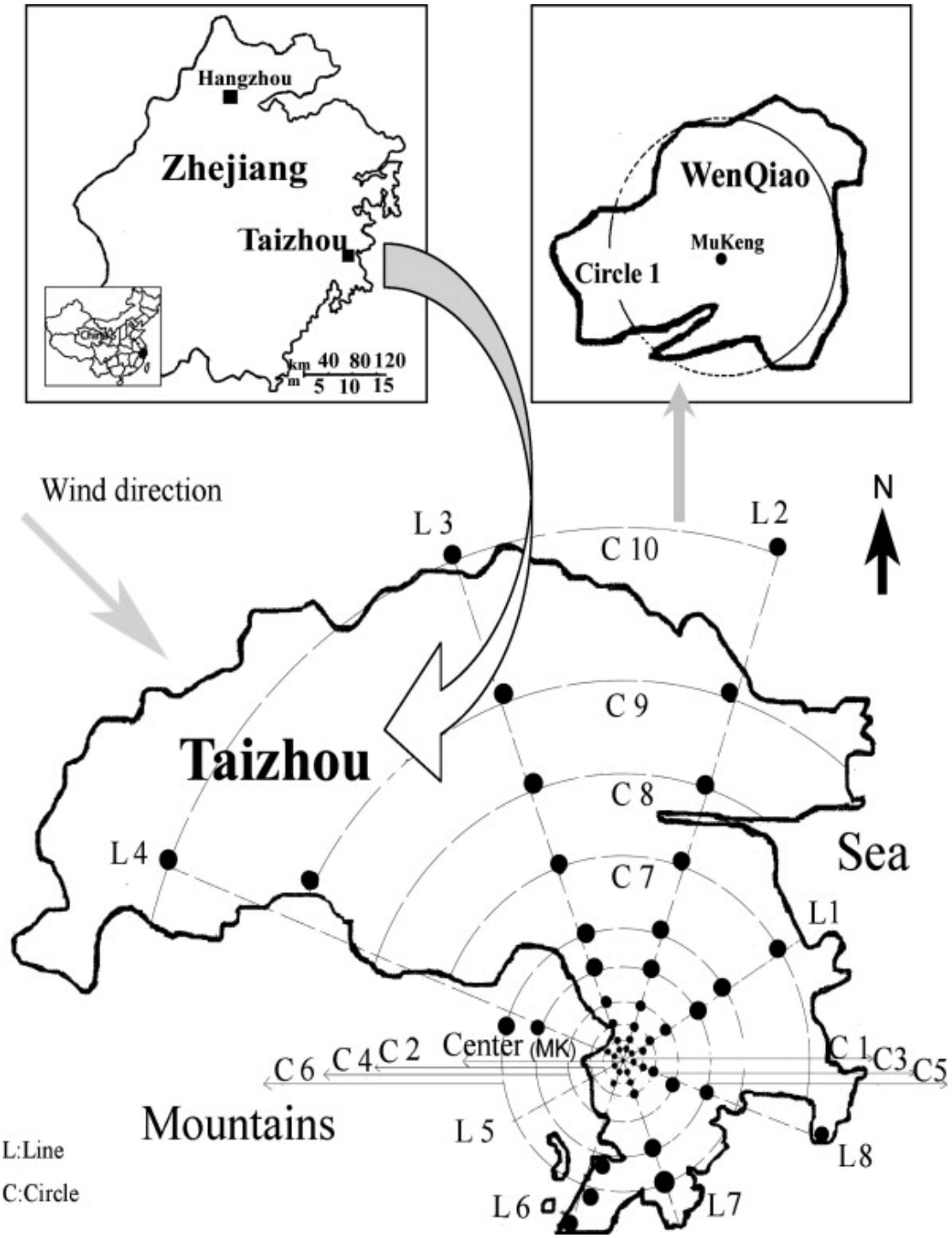


Uchida, N., Matsukami, H., Someya, M., Tue, N. M., Tuyen, L. H., Viet, P. H., Takahashi, S., Tanabe, S., & Suzuki, G. (2018). Hazardous metals emissions from e-waste-processing sites in a village in northern Vietnam. *Emerging Contaminants*, 4(1), 11–21. https://doi.org/10.1016/j.emcon.2018.10.001



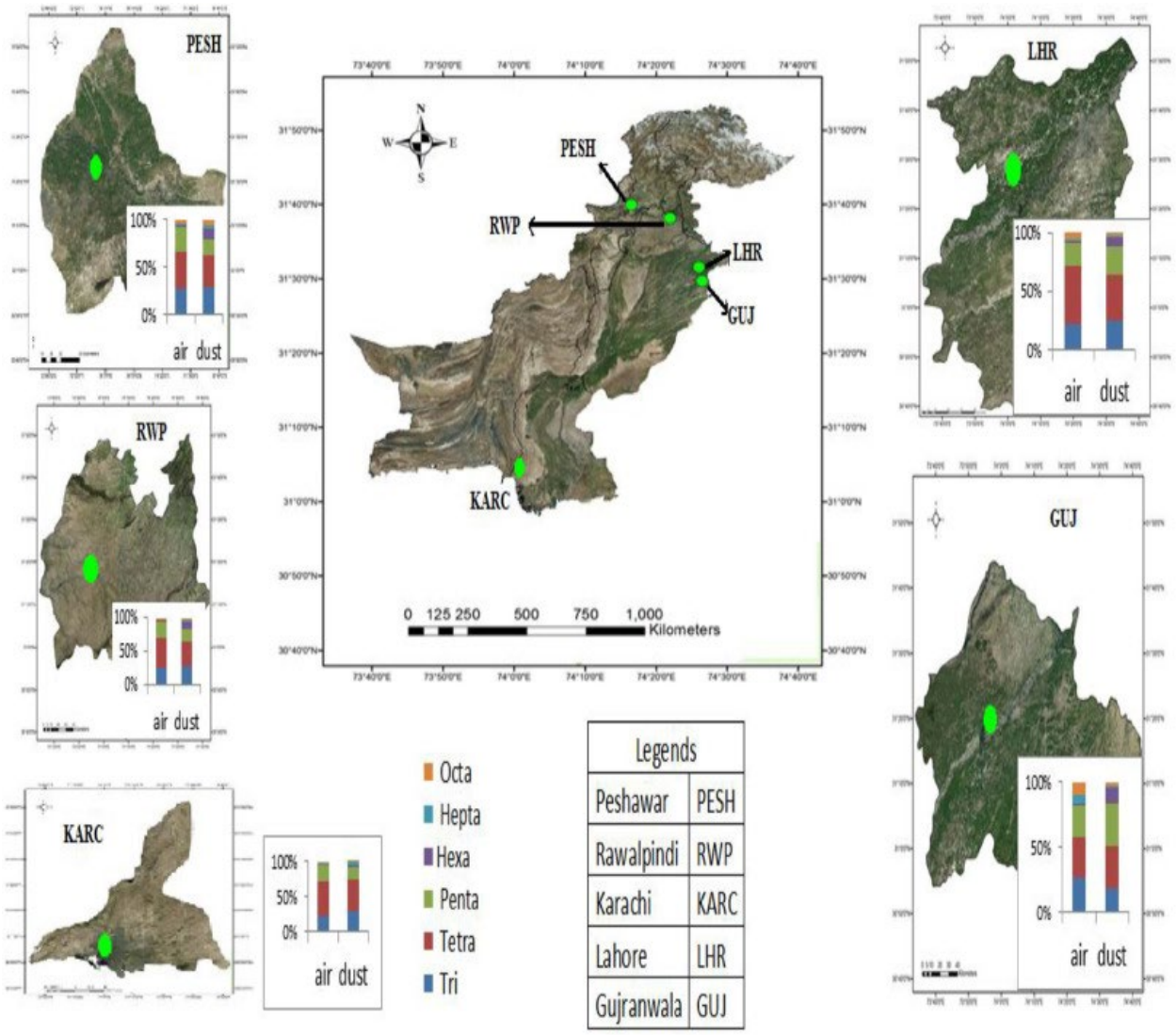
Tong, X., & Tao, D. (2016). The rise and fall of a “waste city” in the construction of an “urban circular economic system”: The changing landscape of waste in Beijing. *Resources, Conservation and Recycling*, 107, 10–17. https://doi.org/10.1016/j.resconrec.2015.12.003

Wang, C., Lin, Z., Dong, Q., Lin, Z., Lin, K., Wang, J., Huang, J., Huang, X., He, Y., Huang, C., Yang, D., & Huang, C. (2012). Polybrominated diphenyl ethers (PBDEs) in human serum from Southeast China. *Ecotoxicology and Environmental Safety,* 78, 206–211. https://doi.org/10.1016/j.ecoenv.2011.11.016

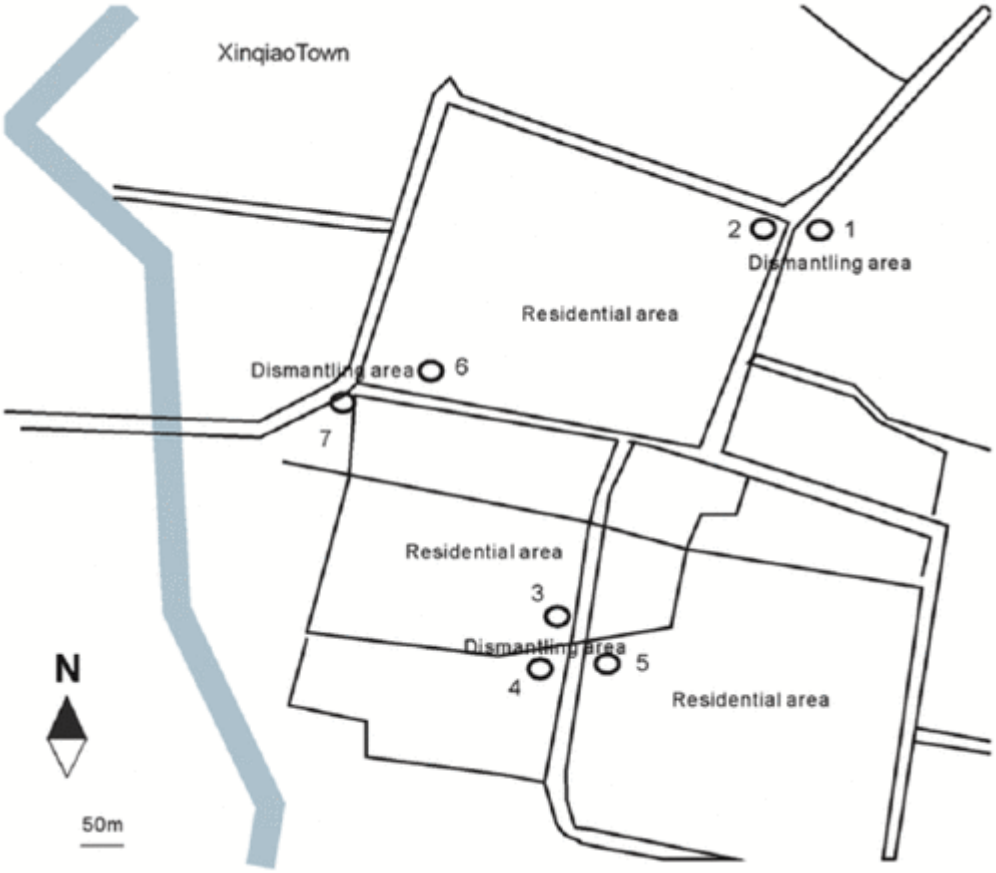


Zhao, Y.-X., Qin, X.-F., Li, Y., Liu, P.-Y., Tian, M., Yan, S.-S., ... Yang, Y.-J. (2009). Diffusion of polybrominated diphenyl ether (PBDE) from an e-waste recycling area to the surrounding

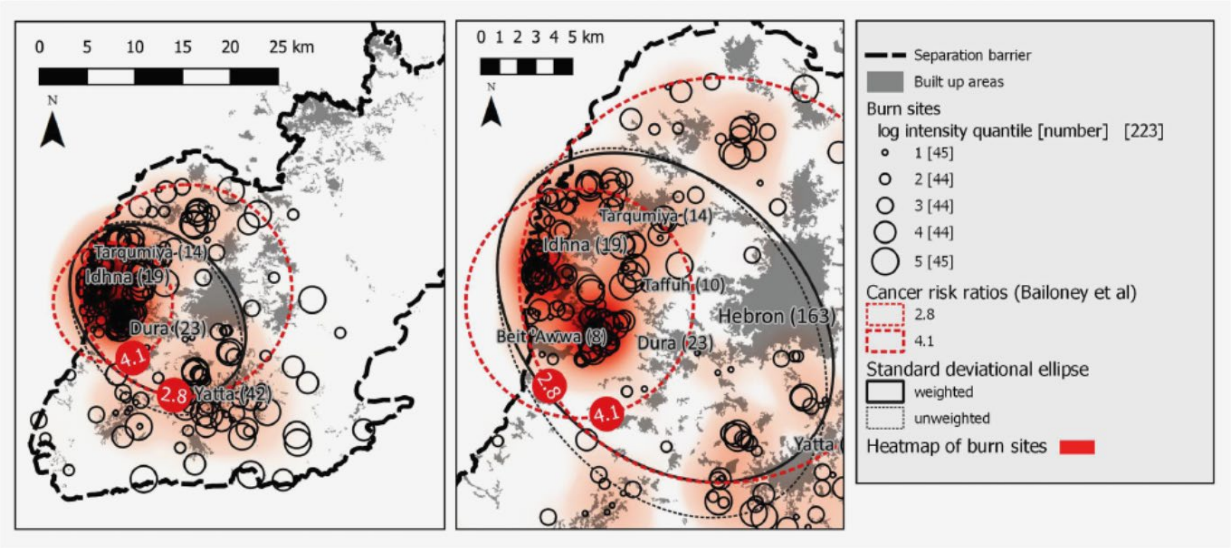
regions in Southeast China. *Chemosphere,* 76(11), 1470-1476. https://doi.org/10.1016/j.chemosphere.2009.07.023



Waheed, S., Khan, M. U., Sweetman, A. J., Jones, K. C., Moon, H.-B., & Malik, R. N. (2020). Exposure of polychlorinated naphthalenes (PCNs) to Pakistani populations via non-dietary sources from neglected e-waste hubs: A problem of high health concern. *Environmental Pollution*, 259, 113838. https://doi.org/10.1016/j.envpol.2019.113838



Gu, W., Bai, J., Yuan, W., Ma, E., Zhang, C., & Wang, J. (2019). Pollution analysis of soil polycyclic aromatic hydrocarbons from informal electronic waste dismantling areas in Xinqiao, China. *Waste Management & Research*, 37(4), 394–401. https://doi.org/10.1177/0734242X19826369



Davis, J.-M., & Garb, Y. (2018). A strong spatial association between e-waste burn sites and childhood lymphoma in the West Bank, Palestine. *International Journal of Cancer*, 144(3), 470475. https://doi.org/10.1002/ijc.31902

Appendix C: List of Informal E-waste Hubs Found and Breakdown Between Academic, News, and NGO Sources

This table lists every hub and related articles we found throughout our research. We have determined this list of hubs by identifying locations with at least two academic mentions, five news/NGO mentions, or one academic and three news/NGO, and which locations were less than 52 km^2, the size of Guiyu, China. We have combined locations that were 8km or less apart and have assigned them one name. Appendix E lists combined locations and alternate spellings of some locations. The second, third, and fourth columns are the number of articles from each type of source that mention the hub or its combined locations. The fifth column is the total number of mentions. The last column lists the citation reference numbers which correspond to a citation of an article. Appendices J, K, and L list each citation and its citation reference number.

Article Location	Academic	News	NGO	Total	Citations
Aba	3	0	0	3	79, 342, 481
Agbogbloshie	50	55	7	112	4, 6, 19, 29, 32, 39, 44, 46, 56, 59, 66, 71, 90, 94, 96, 104, 123, 124, 130, 143, 158, 162, 165, 191, 199, 200, 205, 231, 260, 271, 313, 317, 322, 333, 347, 348, 351, 353, 375, 401, 448, 457, 459, 488, 495, 504, 540, 668, 676, 743, 811, 814, 862, 879, 883, 884, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 918, 919, 920, 921, 922, 923, 924, 926, 929, 930, 931, 932, 933, 935, 936, 938, 939, 951, 985, 1067, 1070, 1076, 1085, 1095, 1096, 1097
Bhalswa	2	3	1	6	101, 354, 1014, 1022, 1040, 1094
Bui Dau	17	4	0	21	23, 28, 80, 127, 131, 149, 152, 228, 240, 383, 403, 413, 465, 480, 483, 497, 746, 949, 950, 967, 970
Dong Mai Craft Village	2	5	1	8	180, 483, 880, 881, 882, 946, 948, 1079
Dongxiaokouzhen	2	6	0	8	119, 508, 802, 809, 821, 831, 837, 853
Guiyu	206	35	6	247	4, 7, 8, 10, 15, 16, 18, 22, 42, 51, 53, 60, 65, 68, 72, 74, 78, 81, 87, 102, 103, 107, 108, 110, 111, 114, 115, 116, 118, 121, 125, 126, 128, 132, 133, 138, 140, 147,

					148, 150, 153, 154, 155, 156, 157, 160, 163, 169, 175, 177, 178, 190, 192, 195, 202, 209, 215, 219, 229, 243, 250, 258, 262, 263, 264, 265, 268, 269, 272, 273, 281, 282, 284, 297, 307, 317, 323, 326, 327, 335, 340, 341, 346, 352, 360, 362, 368, 369, 373, 382, 384, 405, 407, 412, 414, 420, 421, 424, 426, 433, 434, 436, 438, 439, 440, 442, 445, 450, 457, 461, 464, 467, 483, 486, 487, 488, 489, 491, 504, 506, 509, 523, 525, 527, 530, 532, 533, 534, 538, 547, 550, 551, 552, 553, 554, 555, 556, 557, 558, 560, 567, 568, 569, 570, 571, 572, 573, 574, 576, 580, 581, 583, 592, 593, 594, 596, 603, 605, 606, 608, 610, 613, 615, 617, 620, 622, 623, 629, 632, 633, 636, 642, 646, 647, 651, 652, 658, 661, 664, 667, 675, 678, 682, 688, 690, 691, 692, 699, 700, 701, 703, 705, 707, 711, 712, 715, 716, 717, 721, 723, 732, 734, 735, 737, 738, 803, 805, 812, 813, 818, 820, 822, 824, 826, 827, 828, 830, 832, 834, 835, 836, 841, 843, 845, 846, 848, 851, 852, 856, 858, 859, 861, 863, 866, 868, 876, 896, 926, 1035, 1058, 1060, 1080, 1081, 1105, 1111, 1112, 1114
Idhna	2	0	0	2	145, 422
Ikeja	3	16	0	19	302, 683, 685, 941, 944, 955, 957, 958, 959, 960, 961, 962, 965, 973, 974, 975, 980, 981, 986
Liushi	2	0	0	2	648, 693
Mandoli	7	5	1	13	76, 101, 318, 354, 366, 654, 669, 1022, 1025, 1031, 1040, 1051, 1062
Manila	2	1	0	3	347, 594, 816
Mayapuri	2	3	0	5	101, 354, 1018, 1022, 1040
Mukeng Village	2	0	0	2	528, 585
Mustafabad	1	4	0	5	354, 1014, 1022, 1040, 1051
Nayanda Halli	2	0	0	2	188, 354
Pantang West	2	0	0	2	46, 184
Shadahra	2	0	0	2	20, 402
Shershah Colony	2	0	1	3	20, 55, 1111
Trang Minh Village	3	3	0	6	428, 465, 483, 949, 950, 967

Turkman Gate	1	4	0	5	354, 1022, 1040, 1045, 1051
Xinqiao	2	0	0	2	202, 257

Appendix D: List of Locations Found and Breakdown Between Academic, News, and NGO Sources

This table lists every location and related details we found throughout our research. We have combined some locations and assigned them one name. Appendix E lists locations with those they have been combined with along with alternate spellings of some locations. The second, third and fourth columns are the number of articles from each type of source that mention the article. The fifth column is the total number of mentions. The last column lists the citation reference numbers which correspond to a citation of an article. Appendices J, K, and L list each citation and its citation reference number.

Article Location	Academic	News	NGO	Total	Citations
Aba	3	0	0	3	79, 342, 481
Abokobi	0	1	0	1	901
Abuja	0	2	0	2	953, 956
Accra	17	6	0	23	103, 136, 150, 211, 221, 228, 244, 336, 337, 440, 468, 486, 488, 490, 671, 672, 740, 844, 885, 917, 922, 927, 934
Agbogbloshie	50	55	7	112	4, 6, 19, 29, 32, 39, 44, 46, 56, 59, 66, 71, 90, 94, 96, 104, 123, 124, 130, 143, 158, 162, 165, 191, 199, 200, 205, 231, 260, 271, 313, 317, 322, 333, 347, 348, 351, 353, 375, 401, 448, 457, 459, 488, 495, 504, 540, 668, 676, 743, 811, 814, 862, 879, 883, 884, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 918, 919, 920, 921, 922, 923, 924, 926, 929, 930, 931, 932, 933, 935, 936, 938, 939, 951, 985, 1067, 1070, 1076, 1085, 1095, 1096, 1097
Ahmedabad	2	0	0	2	190, 308
Aja	0	1	0	1	959
Alang	0	1	0	1	1013
Angola	1	0	0	1	46
Apapa	0	1	0	1	959
Ashaiman	2	0	0	2	46, 165

Astanaanyar	1	0	0	1	174
Bac Kan	0	1	0	1	881
Bac Ninh	0	1	0	1	968
Badplaas/eManzana	1	0	0	1	64
Bajos de Haina	0	0	1	1	1072
Bamako	1	0	0	1	594
Ban Kok	1	0	0	1	9
Bandung	1	0	0	1	109
Bangkok	4	0	0	4	4, 45, 1102, 1103
Bangladesh	2	1	0	3	480, 501, 928
Bareilly	0	2	0	2	1023, 1054
Beijing	6	3	1	10	105, 458, 508, 666, 713, 725, 810, 839, 864, 1113
Bekasi Regency	1	0	0	1	109
Bengaluru	24	13	2	39	89, 101, 103, 113, 144, 150, 188, 309, 376, 431, 440, 457, 483, 486, 488, 506, 524, 546, 592, 618, 625, 652, 737, 746, 867, 1000, 1001, 1002, 1003, 1004, 1005, 1007, 1008, 1016, 1024, 1026, 1028, 1098, 1112
Bhalswa	2	3	1	6	101, 354, 1014, 1022, 1040, 1094
Bhopal	1	0	0	1	492
Billstrasse	0	1	0	1	955
Binh Duong Province	1	1	0	2	109, 969
Binhai	1	0	0	1	40
Bogata	1	0	0	1	594
Brazil	3	1	0	4	122, 596, 619, 926
Bui Dau	17	4	0	21	23, 28, 80, 127, 131, 149, 152, 228, 240, 383, 403, 413, 465, 480, 483, 497, 746, 949, 950, 967, 970
Buri Ram Province	2	0	0	2	194, 280
Cairo	1	0	0	1	594
Caloocan	3	0	0	3	109, 228, 482
Cambodia	0	0	2	2	1091, 1092
Cape Town	1	0	0	1	276
Carolina	1	0	0	1	64
Cavite Province	2	0	0	2	109, 482
Central Macedonia	1	0	0	1	1106
Chandigarh	5	0	0	5	245, 247, 343, 345, 546
Changping District	1	0	0	1	508

Changzhou	1	0	0	1	146
Chaoyang District	1	1	0	2	508, 836
Chaozhou	1	0	0	1	560
Chendian Village	0	1	0	1	836
Chennai	14	4	2	20	27, 50, 76, 113, 129, 188, 190, 233, 253, 321, 453, 457, 565, 618, 1001, 1024, 1026, 1049, 1111, 1112
Chenzhou	1	0	0	1	65
Chidambaram	1	0	0	1	618
Chile	1	0	0	1	139
China	68	4	5	77	34, 36, 61, 69, 70, 92, 94, 105, 122, 187, 189, 198, 203, 204, 206, 210, 212, 218, 223, 224, 225, 236, 246, 248, 274, 286, 287, 290, 296, 299, 334, 338, 356, 357, 358, 359, 361, 364, 365, 379, 380, 381, 387, 388, 391, 392, 395, 396, 397, 415, 417, 430, 446, 496, 498, 507, 515, 548, 586, 591, 596, 617, 619, 644, 665, 714, 731, 926, 928, 963, 976, 1087, 1088, 1091, 1092, 1099, 1110
Chongqing	2	0	0	2	645, 673
Colombia	1	0	1	2	122, 1083
Conakry	0	0	1	1	1075
Dai Bai Village	1	0	0	1	23
Dakar Neighborhood of Thiaroye-Sur-Mer	0	0	1	1	1068
Dali	3	0	1	4	140, 407, 532, 1112
Dandora	0	1	0	1	854
Dar es Salaam	0	1	0	1	982
Daxing District	1	1	0	2	119, 815
Delhi	24	10	3	37	89, 101, 103, 113, 188, 201, 233, 237, 253, 318, 440, 453, 457, 483, 486, 490, 516, 564, 565, 566, 594, 652, 670, 737, 1001, 1009, 1022, 1024, 1026, 1029, 1034, 1048, 1049, 1052, 1061, 1111, 1112
Depok	1	0	0	1	214
Dhaka	5	0	1	6	26, 150, 252, 319, 490, 1061
Dibut	1	0	0	1	226
Dikapinisan	1	0	0	1	226
Diotorin	1	0	0	1	226

Dominican Republic	0	0	2	2	1091, 1092
Dong Mai Craft Village	2	5	1	8	180, 483, 880, 881, 882, 946, 948, 1079
Dong Nai Province	1	1	0	2	109, 969
Dongbajianfang	1	0	0	1	119
Dongxiaokouzhen	2	6	0	8	119, 508, 802, 809, 821, 831, 837, 853
Douala	1	0	0	1	261
Durban	1	0	0	1	452
Dwarka	0	1	0	1	1047
East of Jerusalem	1	0	0	1	230
Egypt	1	0	1	2	650, 1083
Eldoret	0	0	1	1	1069
Elukwatini Settlement	1	0	0	1	64
Enugu	1	0	0	1	696
Faisalabad	3	0	0	3	190, 402, 410
Fengjing Town	10	0	0	10	40, 115, 202, 291, 405, 411, 584, 588, 626, 729
Fengtai District	0	1	0	1	801
Firozabad	0	2	0	2	1022, 1026
Foshan	1	0	0	1	489
Fujian Province	1	0	0	1	567
Fuxing Island	0	1	0	1	872
Gazipur	0	0	1	1	1094
Ghana	10	7	1	18	82, 85, 94, 249, 496, 596, 617, 619, 643, 823, 926, 928, 963, 964, 976, 977, 1083, 1100
Ghazipur	0	1	0	1	1015
Grahamstown	0	1	0	1	903
Guangdong Province	16	3	1	20	94, 176, 208, 217, 241, 285, 489, 567, 590, 616, 649, 684, 687, 695, 738, 741, 825, 829, 833, 1113
Guangzhou	15	2	1	18	114, 133, 235, 242, 454, 485, 561, 577, 596, 597, 598, 688, 689, 697, 720, 846, 849, 1111
Guiyang	0	1	0	1	819
Guiyu	206	35	6	247	4, 7, 8, 10, 15, 16, 18, 22, 42, 51, 53, 60, 65, 68, 72, 74, 78, 81, 87, 102, 103, 107, 108, 110, 111, 114, 115, 116, 118, 121, 125, 126, 128, 132, 133, 138, 140, 147, 148, 150, 153, 154, 155, 156, 157,

					160, 163, 169, 175, 177, 178, 190, 192, 195, 202, 209, 215, 219, 229, 243, 250, 258, 262, 263, 264, 265, 268, 269, 272, 273, 281, 282, 284, 297, 307, 317, 323, 326, 327, 335, 340, 341, 346, 352, 360, 362, 368, 369, 373, 382, 384, 405, 407, 412, 414, 420, 421, 424, 426, 433, 434, 436, 438, 439, 440, 442, 445, 450, 457, 461, 464, 467, 483, 486, 487, 488, 489, 491, 504, 506, 509, 523, 525, 527, 530, 532, 533, 534, 538, 547, 550, 551, 552, 553, 554, 555, 556, 557, 558, 560, 567, 568, 569, 570, 571, 572, 573, 574, 576, 580, 581, 583, 592, 593, 594, 596, 603, 605, 606, 608, 610, 613, 615, 617, 620, 622, 623, 629, 632, 633, 636, 642, 646, 647, 651, 652, 658, 661, 664, 667, 675, 678, 682, 688, 690, 691, 692, 699, 700, 701, 703, 705, 707, 711, 712, 715, 716, 717, 721, 723, 732, 734, 735, 737, 738, 803, 805, 812, 813, 818, 820, 822, 824, 826, 827, 828, 830, 832, 834, 835, 836, 841, 843, 845, 846, 848, 851, 852, 856, 858, 859, 861, 863, 866, 868, 876, 896, 926, 1035, 1058, 1060, 1080, 1081, 1105, 1111, 1112, 1114
Gujarat State	2	1	0	3	516, 656, 1013
Gwalior	1	0	0	1	113
Hai Phong City	2	1	0	3	109, 483, 968
Haizijiao	1	0	0	1	119
Hajipur	0	1	0	1	1025
Hangzhou	1	0	0	1	601
Hanoi	2	2	0	4	109, 483, 966, 968
Harbin	1	0	0	1	620
Haryana State	1	0	0	1	347
Hebei Province	0	1	0	1	829
Hebron	3	0	0	3	275, 422, 504
Ho Chi Minh City	1	1	0	2	109, 966
Hong Kong	8	9	5	22	61, 293, 489, 498, 652, 688, 704, 705, 800, 808, 842, 873, 874, 875, 877, 878, 928, 1060, 1087, 1088, 1091, 1092
Huangjitian	1	0	0	1	390
Huating Town	0	1	0	1	870

Hunan Province	2	0	0	2	489, 567
Hung Yen Province	5	1	0	6	4, 109, 180, 480, 483, 968
Hyderabad	3	0	0	3	75, 101, 188
Ibadan	5	0	0	5	77, 79, 316, 342, 481
Ibiwe Residential Area	1	0	0	1	302
Ibrahimpur	1	0	0	1	654
Idhna	2	0	0	2	145, 422
Ikeja	3	16	0	19	302, 683, 685, 941, 944, 955, 957, 958, 959, 960, 961, 962, 965, 973, 974, 975, 980, 981, 986
Ikorodu	0	1	0	1	959
India	13	5	0	18	94, 122, 187, 198, 279, 332, 496, 498, 596, 617, 619, 714, 731, 926, 928, 963, 976, 977
Indonesia	1	0	0	1	94
Islamabad	2	0	0	2	402, 410
Ivory Coast	0	2	0	2	928, 936
Jaipur	1	0	0	1	546
Jakarta	5	0	1	6	5, 109, 259, 494, 1061, 1108
Jamaica	0	0	1	1	1073
Jiangning District	1	0	0	1	512
Jiangsu Province	1	0	0	1	405
Jinghai District	4	0	0	4	330, 475, 517, 627
Jinsha Township	1	0	0	1	390
Jinshan District	0	1	0	1	871
Jogeshwari	1	0	0	1	188
Kalasin Province	2	0	0	2	456, 483
Kalyan Puri	0	1	0	1	1014
Kamoke	3	0	0	3	20, 402, 410
Kanpur	1	0	0	1	686
Karachi	4	1	1	6	190, 202, 402, 410, 1043, 1112
Karnataka State	2	2	0	4	347, 516, 1037, 1042
Karu	0	1	0	1	956
Kathmandu	1	0	0	1	460
Kenya	2	0	2	4	122, 594, 1091, 1092
Khok-Sat-At	1	0	0	1	43
Khong Chai District	1	0	0	1	83
Kiandutu Slums	0	0	1	1	1069

Kingtom	1	0	0	1	19
Kisumu	0	0	1	1	1069
Kodungaiyur	0	1	0	1	1053
Koforidua	1	0	0	1	46
Koko	0	2	0	2	945, 975
Kokompe	1	0	0	1	165
Kolkata	8	4	1	13	101, 113, 188, 233, 253, 453, 457, 594, 1001, 1021, 1035, 1046, 1061
Krishna Vihar	1	1	0	2	503, 1036
Kumasi	2	2	1	5	44, 62, 927, 934, 1085
Lagos State	22	15	2	39	4, 37, 65, 77, 79, 91, 103, 172, 324, 325, 339, 419, 440, 447, 481, 486, 488, 504, 514, 611, 675, 714, 844, 925, 937, 941, 942, 943, 952, 954, 964, 972, 976, 978, 979, 987, 1035, 1063, 1112
Lahore	4	0	0	4	190, 202, 402, 410
Laizhou	1	0	0	1	24
Lajpat Nagar	0	2	1	3	1014, 1022, 1094
Lalkuan	1	0	0	1	185
Lengshui Village	0	1	0	1	840
Liaoning Province	0	1	0	1	822
Lima	0	0	1	1	1074
Linyi	1	0	0	1	116
Lishui	0	1	0	1	868
Liujiamatou	0	1	0	1	850
Liushi	2	0	0	2	648, 693
Longtangzhen	53	0	2	55	4, 12, 22, 30, 31, 41, 58, 65, 73, 108, 112, 121, 135, 164, 170, 183, 202, 227, 292, 294, 303, 305, 312, 323, 344, 374, 385, 398, 399, 405, 406, 407, 423, 441, 442, 443, 444, 449, 470, 484, 523, 526, 578, 602, 616, 634, 637, 653, 702, 715, 724, 739, 745, 1064, 1112
Ludhiana	1	0	0	1	345
Luqiao District	22	0	0	22	14, 47, 99, 119, 400, 405, 411, 451, 588, 600, 614, 631, 639, 651, 659, 660, 674, 679, 698, 718, 719, 739
Macau	1	0	0	1	599
Madurai	1	0	0	1	539
Maharashtra State	2	0	0	2	347, 656
Makassar	1	0	0	1	494

Malaysia	2	0	0	2	329, 714
Mandoli	7	5	1	13	76, 101, 318, 354, 366, 654, 669, 1022, 1025, 1031, 1040, 1051, 1062
Manila	2	1	0	3	347, 594, 816
Mansarovar Park	0	2	0	2	1014, 1022
Manshiet Nasser	1	0	1	2	349, 1084
Maroua	1	0	0	1	298
Matou	1	0	0	1	
Mawanella	1	0	0	1	390
Mayapuri	2	3	0	5	141
Medan	1	0	0	1	101, 354, 1018, 1022, 1040
Meerut	0	2	0	2	494
Meishu	1	0	0	1	1022, 1026
Metro Manila	3	0	0	3	626
Mexico	7	0	2	9	109, 314, 652
Minna	1	0	0	1	61, 88, 122, 311, 569, 596, 619, 1091, 1092
Mojokerto	0	1	0	1	49
Montevideo	2	0	2	4	838
Moradabad	3	13	0	16	139, 347, 1066, 1070
Morocco	2	0	1	3	188, 304, 457, 857, 1020, 1023, 1032, 1033, 1038, 1039, 1044, 1045, 1050, 1054, 1056, 1057
Mukeng Village	2	0	0	2	122, 643, 1086
Multan	1	0	0	1	528, 585
Mumbai	8	6	2	16	202
Mustafabad	1	4	0	5	4, 89, 188, 190, 233, 253, 453, 457, 1001, 1012, 1019, 1026, 1027, 1049, 1061, 1111
Muzaffarnagar	1	0	0	1	354, 1014, 1022, 1040, 1051
Naameh	0	1	0	1	188
Nagpur	1	0	0	1	855
Nairobi	1	0	2	3	251
Nakhon Si Thammarat Province	2	0	0	2	173, 1061, 1065
Nanjing	1	0	0	1	48, 1104
Nanshan	1	0	1	2	256
Navi Mumbai	0	0	1	1	626, 1060
Nayanda Halli	2	0	0	2	1061
Nigeria	11	8	0	19	188, 354

Ningbo	2	0	0	2	94, 331, 496, 504, 594, 596, 617, 619, 643, 665, 914, 926, 928, 936, 963, 964, 976, 977, 1107
Nis	0	0	1	1	559, 560
Noida	1	0	0	1	1061
Nyamathi	0	0	1	1	188
Obuasi	1	0	0	1	1069
Ogun State	3	0	0	3	46
Ojo	5	4	0	9	419, 447, 514
Pakistan	4	2	4	10	63, 84, 302, 342, 683, 944, 955, 975, 1041
Pallikarnai	0	1	0	1	496, 596, 619, 731, 926, 928, 1087, 1088, 1091, 1092
Pamesta	0	0	1	1	1053
Panlang District	1	0	0	1	1071
Pantang West	2	0	0	2	607
Patna	0	0	1	1	46, 184
Penang	1	0	0	1	1078
Peru	4	0	1	5	489
Pesarean	0	0	1	1	122, 596, 619, 670, 1083
Peshawar	2	0	1	3	1082
Phatthalung Province	4	0	0	4	20, 410, 1060
Philippines	4	2	2	8	48, 54, 1101, 1104
Ping Che	0	0	2	2	4, 94, 488, 496, 926, 963, 1087, 1088
Pondicherry	1	0	0	1	1060, 1090
Port au Prince	1	0	0	1	539
Pune	1	0	1	2	594
Puning	0	2	0	2	493, 1061
Punjab Province	2	0	0	2	803, 848
Qingdao	0	1	0	1	345, 372
Qingyuan	60	1	1	62	807
Quang Ninh	0	1	0	1	2, 4, 11, 21, 22, 35, 51, 60, 81, 86, 87, 98, 100, 106, 117, 120, 121, 140, 159, 164, 168, 181, 193, 195, 238, 239, 254, 278, 306, 307, 327, 350, 404, 405, 408, 455, 462, 473, 474, 476, 489, 500, 510, 519, 520, 620, 621, 630, 635, 653, 664, 690, 700, 708, 709, 710, 715, 716, 746, 804, 1064, 1109
Rampur	1	0	0	1	967

Rawalpindi	2	0	0	2	13
Republic of Congo	0	1	0	1	20, 402
Saharanpur	1	0	0	1	928
Saheed Nagar	0	1	0	1	188
Sangrampur	1	0	0	1	1040
Seelampur	3	10	1	14	188
Semarang	0	0	1	1	347, 354, 742, 1006, 1011, 1014, 1022, 1025, 1040, 1042, 1044, 1045, 1051, 1093
Senegal	1	0	0	1	1089
Shadahra	2	0	0	2	122
Shahjahanpur	0	2	0	2	20, 402
Shangdong Province	2	0	0	2	1023, 1054
Shanghai	4	1	0	5	370, 567
Shantou	6	3	1	10	67, 320, 405, 567, 817
Shenzhen	1	1	0	2	25, 347, 371, 378, 393, 738, 829, 848, 865, 1111
Shershah Colony	2	0	1	3	727, 847
Shijiaozhen	7	1	0	8	20, 55, 1111
Shiqiao Village	0	1	0	1	33, 135, 164, 202, 405, 634, 637, 868
Shizuishan	0	1	0	1	818
Sivakasi	1	0	0	1	824
Soi Suea Yai Uthit	2	0	0	2	618
Songkhla Province	2	0	0	2	142, 746
South Africa	3	1	1	5	48, 1104
Sri Lanka	1	0	0	1	122, 197, 496, 976, 1083
Suame	1	0	1	2	480
Surabaya	1	0	0	1	46, 1085
Surulere	0	1	0	1	494
Suzhou	2	0	0	2	959
Sylhet	1	0	0	1	575, 725
Tabriz City	1	0	0	1	319
Taiwan	1	0	2	3	579
Taizhou	116	1	2	119	61, 1091, 1092
Takoradi	1	0	0	1	4, 17, 22, 25, 51, 52, 65, 74, 81, 95, 102, 103, 108, 114, 115, 116, 140, 151, 152, 159, 161, 166, 167, 182, 195, 213, 216, 222, 234, 266, 283, 288, 295, 301, 307, 315, 323, 327, 328, 355, 363, 367, 389, 405, 411, 416, 418, 425, 427, 429,

					435, 437, 440, 463, 466, 469, 471, 472, 477, 483, 486, 488, 489, 499, 506, 511, 513, 518, 521, 529, 531, 532, 535, 536, 541, 542, 543, 544, 545, 549, 560, 562, 563, 567, 576, 581, 592, 600, 604, 608, 609, 612, 620, 624, 632, 638, 640, 642, 651, 652, 657, 662, 663, 675, 680, 681, 694, 705, 706, 721, 722, 726, 728, 730, 733, 736, 806, 1112, 1114
Tamil Nadu State	1	1	0	2	46
Tanzania	1	1	0	2	516, 1055
Te Lo Village	1	2	0	3	643, 914
Tehran	1	0	0	1	483, 950, 967
Tel-Aviv-Yafo	0	1	0	1	255
Tema	1	2	0	3	1010
Teng County	1	0	0	1	46, 901, 927
Thai Nguyen	0	1	0	1	489
Thailand	5	1	3	9	881
Thranh Tri District	0	1	0	1	61, 94, 220, 483, 488, 963, 1090, 1091, 1092
Tianjin	14	1	0	15	968
Tikri Kalan	0	1	0	1	4, 133, 207, 232, 270, 310, 377, 486, 517, 560, 567, 595, 616, 641, 822
Tiruchirappalli	1	0	0	1	1030
Tixmehauc	1	0	0	1	101
Togo	0	1	2	3	502
Tondo	1	0	0	1	936, 1091, 1092
Tongshan County	1	0	0	1	186
Topsia	0	1	0	1	607
Tori Bossito	0	1	0	1	1017
Trang Minh Village	3	3	0	6	983
Trang Province	2	0	0	2	428, 465, 483, 949, 950, 967
Tu Son	0	1	0	1	48, 1104
Turkey	1	0	0	1	970
Turkman Gate	1	4	0	5	594
Uganda	2	0	0	2	122, 643
United Arab Emirates	0	0	2	2	1091, 1092
Uttar Pradesh State	1	0	0	1	101
Van Mon	1	0	0	1	23
Vellore	0	0	1	1	1077

Vietnam	9	2	0	11	61, 69, 94, 196, 386, 394, 488, 496, 498, 928, 963
Vinh Phuc Province	1	1	0	2	109, 971
Wenling	14	0	0	14	38, 97, 118, 134, 137, 171, 289, 400, 405, 432, 478, 479, 522, 744
Wenzhou	2	0	0	2	513, 560
West Bank	1	0	0	1	267
West Bengal State	1	0	0	1	516
Wujin District	2	0	0	2	93, 179
Xiaoshijiazhuang Village	0	2	0	2	860, 861
Xiatao	1	0	0	1	588
Xiazheng	1	0	0	1	607
Xinqiao	2	0	0	2	202, 257
Xinqiu District	1	0	0	1	607
Yaba	0	1	0	1	959
Yen Phong	0	2	0	2	947, 970
Yogyakarta	1	0	0	1	57
Yuantanzhen	1	0	0	1	405
Yuecheng District	1	0	0	1	155
Yuen Long	0	0	1	1	1060
Yuhang District	1	0	0	1	698
Zambia	1	0	0	1	594
Zarfarabad	1	0	0	1	101
Zhangye	1	0	0	1	119
Zhejiang Province	17	1	1	19	116, 176, 277, 300, 409, 537, 567, 582, 587, 589, 601, 628, 651, 655, 677, 684, 687, 829, 1111
Zhenhai District	1	0	0	1	739
Zhongtanxiang	1	0	0	1	508
Zhuhai	1	0	0	1	350
Ziyazhen	4	0	0	4	474, 505, 517, 532

Appendix E: Key of Locations That Have Been Combined or Have Multiple Names

This appendix lists locations that have been combined into one, along with alternate names that refer to the same place.

Location	Locations that were Combined
Suame	Aboabo, Suame Magazine
Ojo	Alaba International Market
Fengjing Town	Anrong Village
Luqiao District	Baifengqiao, Baifengao, Baijialou, LQ area
Longtangzhen	Baihe Village, Jinsha Village, Longtang Town
Chongqing	Baimutan Village
Bengaluru	Bangalore
Mandoli	Behta Hazipur, Loni, Rahul Garden
Guiyu	Beilin Village, Treasure Town, Yaosuwei village
Mustafabad	Brijpuri, Usmanpur, Wazirabad
Bui Dau	Cam Xa Commune, My Hao, Phan Boi
Idhna	Deir Samet, Beit Awwa
Mumbai	Deonar
Manshiet Nasser	El-Imam El-Shafie Market, Dewei'a, Garbage City, Mokattam
Nayanda Halli	Goripalya, Gandhi Nagar
Dongbajianfang	Heiqiao
Ibiwe Residential Area	Isihor Residential Area
Seelampur	Jafrabad, New Seelampur, Old Seelampur, Kantinagar Area, Brijgang
Mansarovar Park	Karkardooma
Mayapuri	Kirti Nagar
Daxing District	Langfa
Jogeshwari	Malad
Shadahra	Misri shah

Hong Kong	New Territories
Hanoi	Ngu Xa Village, Trieu Khuc Village
Wujin District	Niutang, Dagomba Line
Ibadan	Ogunpa
Ikeja	Ojodu-Berger, Ladipo Market, Egbeda, Ikeja Computer Village, Olusosun, Opebi, GRA Ikeja, Oshodi, Computer Village, Owode Market
Lajpat Nagar	Okhla, Tughlakabad
Agbogbloshie	Old Fadama, (Soddom and Gamora), Abosseyokai, Gallaway
Lalkuan	Pantnagar
Pallikarnai	Perungudi
Qingyuan	Qingcheng District
Bhalswa	Shastri Park, Buradi, Bhalaswa, Jahangirpuri, Shashtri Park
Topsia	Tangra, Dhapa, Park Circus, Tiljala
Mata Sundari Road	Turkman Gate, Daryagan
Dongxiaokouzhen	Dongxiaokou Town
Kamoke	Kamoke-Gujranwala
Minna	Kansuwan gwarri
Khok-Sat-At	Khoh-Sa-Aat
Pantang West	Pantang Village
Shijiaozhen	Shijiao Town, Shijia
Hebron	South West Hebron
Soi Suea Yai Uthit	Sue Yai Utit
Tel-Aviv-Yafo	Tel-Aviv
Teng County	Tengxian
Tondo	Payatas
Yuantanzhen	Yuantan
Zhongtanxiang	Yuxingwang market, in the west of Zhongtan Village
Ziyazhen	Ziya, Ziya Town

Appendix F: Code Counts Across Academic, NGOs and News Media

The following chart shows the number of articles from academic sources, news sources, and NGO reports that refer to the codes on the left. The codes are from our content analysis and if you are interested in learning which articles relate to each code that excel spreadsheet is on our github (https://github.com/gormes/WPI-Ewaste).

Code	Academic	News	NGO	Total Counts
Agricultural Impacts	72	5	0	77
Air Pollution	110	7	0	117
Child Impacts	56	8	2	66
Community Impacts	126	35	1	162
E-waste Flow	46	32	0	78
E-waste Policy & Management	74	90	0	164
Miscellaneous	14	31	0	45
Neonatal & Pregnancy	44	2	0	46
Reports & Definitions	44	50	42	136
Soil Pollution	250	7	0	257
Surveys	25	3	1	29
Water Pollution	84	21	0	105
Wildlife Health	90	2	0	92
Worker Impacts	65	46	0	111

Appendix G: Keywords Identified Across an Academic and Media Review

The following list are terms we found in our literature review that were used to describe informal E-waste hubs, processes used in informal recycling, informal E-waste workers, and E-waste. We also included region-specific terms.

Site Descriptors	Process Descriptors	Worker Descriptors
• Scrap yards • Craft village [Especially in Vietnam] • Workshops • Informal recycling sites • E-waste dismantling sites • E-waste plant • Junkshops • E-waste village • E-waste recycling "center" • Electronic graveyard • E-waste blackspot • Grey zone • Dumpsite and Landfill [in conjunction with terms for E-waste]	• Informal • Dismantling • E-scrapping • Scrap recycling • Electronic scrap recycling • Open burning	• Wastepicker • waste-picker • Scavenger • Ragpicker • Informal backyard recycler

E-waste Vocabulary	Region-Specific Terms
• E-waste • E waste • eWaste • Electronic waste • Electrowaste • WEEE (waste electrical and electronic equipment) • Waste and • e-scrap • E scrap • Electronic scrap • E-squander	• Colombia or other Spanish speaking countries: Residuos de Aparatos Eléctricos y Electrónicos (RAEE) [instead of WEEE] • Egypt: “Sar’eha” (literally translates to scavengers) or “Robabekia men” (E-waste workers) • Ghana: “bola taxis” (waste collection service) and “kaya borla” (informal waste collectors) • India/Delhi: ‘‘kabaad’’(recyclables), “kabadi ki dukan” (scrap shops), “kabadiwala” (scrap man)

• E squander • Used electronic products • Used electronics • EEE • E-trash • E trash • Junk gadgets	

Appendix H: News Websites Used in Our Media Search

The following sources are the news websites we reviewed in our news media search. We used the search terms "E-waste," "electronic waste," "craft village," "scrap yard," "WEEE," "informal recycling sites," and "wastepicker" on each. We looked for articles mentioning informal E-waste hubs locations to enrich our understanding of the sector in each of these five countries. Each source is organized by their source country, although some websites report on worldwide news and mention informal E-waste hubs from outside the country. The sites marked with worldwide news are not solely focused on their source country. The sources that have been struck through provided no relevant results within our search terms.

China:

- China Daily: http://www.chinadaily.com.cn/index.html (There is both a Chinese and World Edition)
- China Dialogue: https://www.chinadialogue.org.cn/
- People's Daily: https://peoplesdaily.pdnews.cn/ (Worldwide news)
- ~~ECNS: http://www.ecns.cn/~~
- China.org: http://www.china.org.cn/ (Worldwide news)
- China Development Brief: http://www.chinadevelopmentbrief.cn/
- En.people: http://en.people.cn/index.html (Worldwide news)
- SHINE: https://www.shine.cn/ (Worldwide news)
- Global Times: https://www.globaltimes.cn/index.html
- China Economic Net: http://en.ce.cn/
- NewsGD.com: http://www.newsgd.com/
- South China Morning Post (Hong Kong) https://www.scmp.com/search/E-waste

India:

- India Today: https://www.indiatoday.in/
- One India: https://www.oneindia.com/
- Aajtak: https://aajtak.intoday.in/
- Business Insider India: https://www.businessinsider.in/
- BangaloreMirror: https://bangaloremirror.indiatimes.com/
- Deccan Herald: https://www.deccanherald.com/
- The Wire: https://thewire.in/ (Worldwide news)
- ~~News Nation: https://english.newsnationtv.com/~~
- The Economic Times: https://economictimes.indiatimes.com/
- DownToEarth.org.in: https://www.downtoearth.org.in/

- Citizen Matters: https://citizenmatters.in/E-wastemanagementdehradunillegalrecycling14918
- DT Next: https://www.dtnext.in/
- The Hindu: https://www.thehindu.com/
- ~~Ani: https://www.aninews.in/ (Worldwide news)~~
- NDTV: https://www.ndtv.com/
- ~~Scroll.in https://scroll.in/~~

Ghana:

- Graphic Online: https://www.graphic.com.gh/ (Worldwide news)
- Bizcommunity: https://www.bizcommunity.com.gh/AllIndustries
- Ghanian Times: https://www.ghanaiantimes.com.gh/
- My Joy: https://www.myjoyonline.com/
- Ghana Web: https://www.ghanaweb.com/GhanaHomePage/
- Modern Ghana:https://www.modernghana.com/
- ~~Ghana News Agency: https://www.gna.org.gh/home~~
- Business Ghana: https://www.businessghana.com/site/

Nigeria:

- The Guardian: https://guardian.ng/ (Worldwide news)
- TodayNG: https://www.today.ng/ (Worldwide news)
- ~~Legit: https://www.legit.ng/~~
- Daily Post: https://dailypost.ng/
- ~~Business Day: https://businessday.ng/~~
- Pulse: https://www.pulse.ng/
- This Day: https://www.thisdaylive.com/
- The Punch: https://punchng.com/
- Premium Times: https://www.premiumtimesng.com/
- NairaMetrics: https://nairametrics.com/
- Vanguard: https://www.vanguardngr.com/

Vietnam:

- Vietnam News: https://vietnamnews.vn/
- ~~Hanoi Times: http://hanoitimes.vn/~~
- Vietnam Net Global: https://vietnamnet.vn/en/
- ~~Nhan Dan: https://en.nhandan.org.vn/~~
- ~~The Voice of Vietnam: https://vovworld.vn/enUS/news/405.vov (Worldwide news)~~

- ~~Vietnam Investment Review: https://www.vir.com.vn/~~
- Vietnam Economic News: http://ven.vn/

Appendix I: List of NGOs Reviewed

The following sources are a list of NGOs focused on E-waste or the environment that we reviewed. We looked through each to find a report mentioning informal E-waste hub locations. We separated the organizations into categories by their region of focus.

Worldwide

- Basel Action Network
- Global Alliance of Wastepickers
- Solving the E-waste Problem
- International Pollutants Elimination Network
- Pure Earth
- Sustainable Recycling Industries
- International E-waste Management Network
- Greenpeace

China

- Friends of Nature
- Green Beagle Environmental Institute

India

- The Energy and Resources Institute
- Chintan Environmental Research and Action Group
- Toxic Link
- SAAHAS

Ghana

- Green Advocacy Ghana

Nigeria

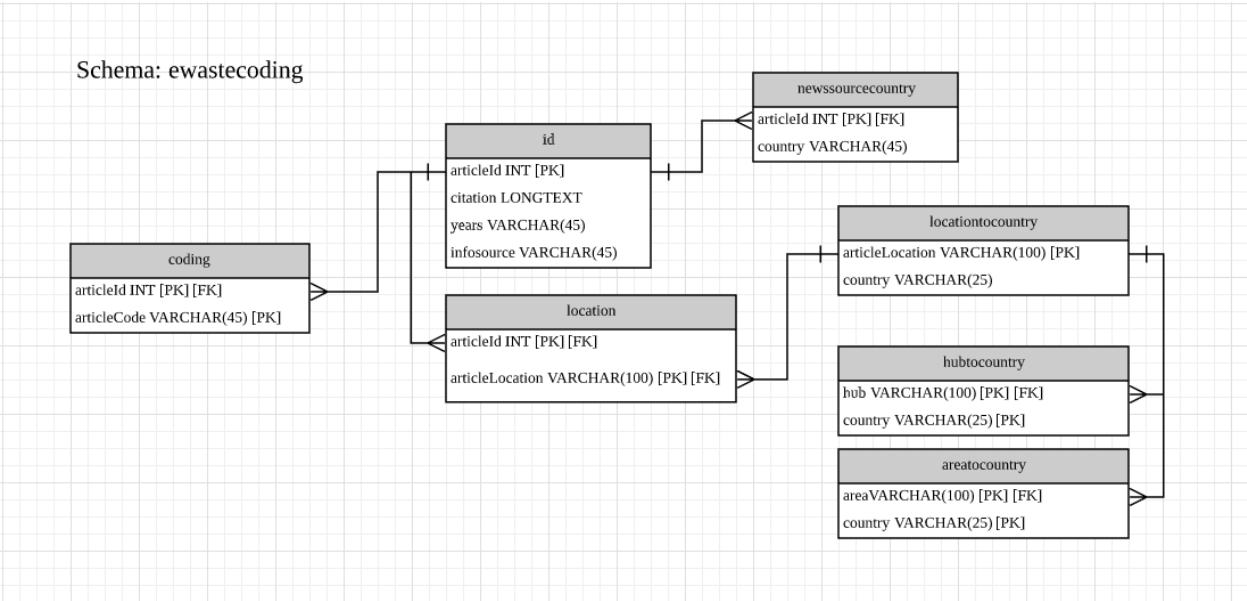
- E-waste Producer Responsibility Organization Nigeria

Vietnam

- Vietnam Recycling Platform
- Central Vietnam Association of Environmental Economics

Appendix J: SQL Database Relational Model

Our database is made of seven tables. The ID table gives every citation a citation reference number, holds the year of publication, and identifies the source of the document. The coding and location tables link each article to its codes and locations respectively. The “locationtocountry” table acts as the verification for the unique locations listed throughout the system and associates each location to its country. “Hubtocountry” and “areatocountry” hold the lists of locations we delineated as hubs and as areas. The “newssourcecountry” table holds the country of origin for the news articles. The figure is the database relational model for our SQL database. To access the database visit: https://github.com/gormes/WPI-Ewaste



Appendix K: Academic Citations

The following are all the relevant citations from our content analysis of academic literature. Each of the following articles mentioned the location of an informal E-waste location. The number on the left of each is a reference number linking each to the locations that we found in it and the list is organized alphabetically. A list of locations found, and their respective citation reference numbers are in Appendix D. A similar list for hubs and their respective citation reference numbers is in Appendix C. The reference numbers listed here are the same as the ones in our database, which link locations and codes to each article. We recommend starting at Appendix C or D, and selecting a hub or location and then looking up the related number in this Appendix.

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Appendix L: News Citations

The following are all the relevant citations from our content analysis of news articles. Each of the following articles mentioned the location of an informal E-waste location. The number on the left of each is a reference number linking each to the locations that we found in it and the list is organized alphabetically. A list of locations found, and their respective citation reference numbers are in Appendix D. A similar list for hubs and their respective citation reference numbers is in Appendix C. The reference numbers listed here are the same as the ones in our database, which link locations and codes to each article. We recommend starting at Appendix C or D and selecting a hub or location and then looking up the related number in this Appendix.

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Appendix M: NGO Report Citations

The following are all the relevant citations from our content analysis of NGOs reports. Each of the following articles mentioned the location of an informal E-waste location. The number on the left of each is a reference number linking each to the locations that we found in it and the list is organized alphabetically. A list of locations found, and their respective citation reference numbers are in Appendix D. A similar list for hubs and their respective citation reference numbers is in Appendix C. The reference numbers listed here are the same as the ones in our database, which link locations and codes to each article. We recommend starting at Appendix C or D, and selecting a hub or location and then looking up the related number in this Appendix.

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