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GEOGRAPHIES OF URBAN MINING IN THE GLOBAL SOUTH

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Abstract

The collection, recycling and sale of waste electrical and electronic equipment (WEEE) – or e-waste – are part of the so-called "urban mining" and have been occurring according to different technical-normative conditions, which impact the environment, society and the economy in different ways, especially in the urban spaces of the Global South. This article establishes a comparative analysis of urban mining in the Sao Paulo Macrometropolis (Brazil) and the Greater Accra Region (Ghana) through exploratory qualitative research. The results reveal a broad spectrum of actor-network arrangements established in the universe of e-waste, also confirming the relevance of political economy for understanding the technical and regulatory aspects of recycling in different geographical contexts.

Keywords: WEEE; Recycling; Collect; Commercialization; Comparative Urban Study.

Resumo / Résumé

GEOGRAFIAS DA MINERAÇÃO URBANA NO SUL GLOBAL

A coleta, reciclagem e comercialização de resíduos de equipamentos elétricos e eletrônicos (REEE) – ou e-waste – fazem parte da chamada "mineração urbana" e vêm ocorrendo de acordo com diferentes condições técnico-normativas, que impactam o meio ambiente, a sociedade e a economia de diferentes formas, especialmente nos espaços urbanos do Sul Global. Este artigo estabelece uma análise comparativa da mineração urbana na Macrometrópole Paulista (Brasil) e na Grande Região de Acra (Gana) por meio de uma pesquisa qualitativa exploratória. Os resultados revelam um amplo espectro de arranjos ator-rede estabelecidos no universo do e-waste, confirmando também a relevância da economia política para o entendimento dos aspectos técnicos e regulatórios da reciclagem em diferentes contextos geográficos.

Palavras-chave: REEE; Reciclagem; Coleta; Comercialização; Estudo Urbano Comparado.

GÉOGRAPHIES DES MINES URBAINES DANS LE SUD MONDIAL

La collecte, le recyclage et la vente des déchets d'équipements électriques et électroniques (DEEE) – ou e-déchets – font partie de ce que l'on appelle «l'exploitation minière urbaine» et se sont déroulés selon différentes conditions technico-normatives, qui ont un impact sur l'environnement, la société et l'économie de différentes manières, en particulier dans les espaces urbains du Sud. Cet article établit une analyse comparative de l'exploitation minière urbaine dans la Macrometropole Paulista (Brésil) et la Région du Grand Accra (Ghana) à travers une recherche qualitative exploratoire. Les résultats révèlent un large éventail d'arrangements acteurs-réseaux établis dans l'univers des déchets électroniques, confirmant également la pertinence de l'économie politique pour comprendre les aspects techniques et réglementaires du recyclage dans différents contextes géographiques.

Mots-clés: Mots clés: DEEE; Recyclage; Collecter; Commercialisation; Etude Urbaine Comparative.

INTRODUCTION

On a busy corner of Nima, a neighborhood in the central area of Accra, a young man carefully pushes a yellow handcart containing an organized selection of various electrical and electronic devices, such as television sets, computers, printers, wires, and cell phone charger cables. At one point, he observes a discarded fan on the street, next to a blue metal tin filled with a variety of waste, probably produced by the residents of the immediate vicinity. The young man then picks it up from the floor, blows on it, carefully places it in his cart, and continues on his way through the streets of the Ghanaian capital. Approximately 6,000 kilometers away, a white dumpster occupies part of a street in Jardim Paulista, one of São Paulo's most prestigious residential areas, home to the most affluent social classes. In this container, there are different types of waste: large concrete blocks, cracked bricks, two green upholstered chairs with broken feet, a chipped mirror, two lamps that appear to be in perfect condition, and, finally, three huge wire rolls of white plastic-covered copper.

Defined by Josh Lepawsky (2012: 1194) as the "material debris of the Information Age," waste electrical and electronic equipment (WEEE), also known as e-waste, includes a broad spectrum of objects that "depend on an electrical current or electromagnetic field to function" (XAVIER and CARVALHO, 2014: 2) and that have been discarded by their consumers. Baldé et al. (2015) categorize WEEE into the following groups: a) temperature changing equipment, such as refrigerators, freezers, air conditioning, and heaters; b) screens and monitors, like televisions, monitors, computers, and tablets; c) lamps of all types; d) large appliances, such as washing machines, dryers, electric stoves, large printers and copiers, and photovoltaic panels; e) small appliances, for example, vacuum cleaners, microwave ovens, fans, toasters, electric shavers, calculators, radio equipment, video cameras, electronic toys, electronic instruments, and medical equipment and; f) small IT and telecommunications equipment, including mobile phones, GPS devices, pocket calculators, routers, and printers. (SANTOS, 2020: 1-2).

The dramatic increase in e-waste makes it the category that has grown the most at the beginning of the twenty-first century (SCHWARZNER et al., 2005). Data collected by The Global E-waste Monitor 2020 reveals that 53.6 million metric tons (Mt) of WEEE were generated in 2019, a volume 1.4 times higher than that recorded in 2014 (FORTI et al. 2020: 24). If the current consumption and disposal patterns continue in the coming years, it is estimated that this volume may reach 74.7 Mt in 2030.

The increase in e-waste generation has been on the agenda consistently since the 1989 Basel Convention when it was placed in the category of hazardous waste, and its cross-border commercial flow was banned by the signatory countries of the Treaty.

However, while their chemical composition can negatively impact the environment and human health (ROBINSON 2009; HUANG et al., 2014; KUMAR et al., 2017), WEEE can also be collected, recycled, and marketed. These practices are part of the phenomena known as "urban mining," a set of activities with the potential to enable the development of the circular economy (BACCINI and BRUNNER, 2012; LEDERER et al., 2014; GRANT, 2016; BOULDING, 1966; PEARCE and TURNER, 1990).

Given that urban mining occurs under differing technical and regulatory conditions, which are closely related to the socioeconomic and political contexts of each territory, this article investigates the organization of e-waste processing activities in two urban spaces in the complex and multifaceted Global South: the São Paulo Macrometropolis (Brazil) and the Greater Accra Region (Ghana).

In recent years, several articles and sectoral reports, many of them linked to the United Nations Environmental Program (UNEP), have called attention to the environmental and health risks arising from the production, importation, and recycling of WEEE, particularly in the territories of Latin America, Africa, and Asia, where the regulatory framework relating to the management of such waste is often recent or non-existent (UNEP, 2007; BANDYOPADHYAY, 2008; PICKERN, 2014, BALDÉ et al. 2015; RUCEVSKA et al. 2015, BALDÉ et al. 2017; FORTI et al., 2020).

To the extent that increases in e-waste result from the consolidation of the consumer society (BAUDRILLARD, 1995), especially in cities, we believe that this article can contribute to debates in urban geography, especially in its interface with economics, sociology, and environmental studies. Furthermore, as this study's methodology is based on a controlled comparative analysis, it is possible to identify similarities and differences in how urban mining is organized in territories that differ significantly despite belonging to the Global South. We concur with Michael Storper and Allen Scott's premises (STORPER and SCOTT, 2016) regarding the comparative method's importance when considering the central role of political economy in urban and regional dynamics.

Thus, section 2 briefly discusses the geographic literature related to waste management and, more specifically, e-waste management. Next, section 3 presents the methodology used and characterizes the two case study areas while justifying their selection. The investigation's results are outlined in section 4, presenting and analyzing the regulation, generation, collection, and recycling of WEEE in SPMM and GAR from a comparative and exploratory perspective. Following this is a discussion and the final remarks addressing the broad spectrum of urban mining geographies in the Global South.

LITERATURE REVIEW

Geographic studies on the theme of waste are markedly interdisciplinary. In the article Garbage matters: concepts in new Geography of waste, Sarah Moore explains that geographers generally have three distinct and possibly complementary approaches to the topic (MOORE, 2012). The first perspective views "waste as a pollutant," giving rise to numerous studies on the negative impacts of different types of waste on the environment and human health. Overall, this approach's arguments are in favor of the notion of "socio-environmental justice" (KURTZ, 2003; TOWERS, 2000; WILLIAM, 1999).

The second approach understands "waste as a resource." In this scenario, scholars focus their analysis on the recycling process (especially of urban solid waste), and on the forms of social, political, and economic organization of the actors involved in the process, and on the articulation between formal and informal recycling systems (MOORE, 2012; GUTBERLET, 2008; NGO, 2001; SICULAR, 1992). Moreover, there appears to be a consensus on changing the ontological status of waste in the scientific community. In their article Metamorphosing waste as a resource, Les Levidow and Sujatha Raman explain how this change creates social relationships, social institutions, and particular material cultures. The authors also state that this polyvalent aspect should be understood from the multiple contingencies influencing how waste impacts a given geographical reality, nature, and society (LEVIDOW and RAMAN, 2018, p.3).

Moore (2012) offers a third approach that understands waste as a commodity. As well as viewing these residues as possible pollutants and potential resources, this perspective addresses standards and processes that go beyond waste recycling and involve its circulation and, more specifically, its commercialization (MOORE, 2012; SHINKUMA and HUONG, 2009; SHINKUMA and MANAGI, 2010). Based on this approach, geographers' analyses of e-waste management have been structured and debated with a greater degree of complexity (LEPAWSKY, 2011; GUTBERLET, 2015; GRANT, 2016; LOPES DOS SANTOS, 2020).

"Urban mining" can be understood as the set of activities responsible for recycling a variety of objects in cities, from a small cell phone discarded by a resident to abandoned urban buildings and infrastructure (BACCINI and BRUNNER, 2012; LEDERER et al., 2014; GUTBERLET 2015; GRANT, 2016). WEEE is the waste with the highest concentrations of expensive and rare metals (COSSU and WILLIAMS, 2015: 2), justifying the development of numerous activities dedicated to collecting, recycling, and trading it worldwide. WEEE frequently contain minerals with a high reuse rate (over 50%), such as aluminum, titanium, chromium, manganese, iron, cobalt, nickel, copper, zinc, niobium, palladium, silver, tin, rhenium, platinum, gold, and lead (PACE, 2019).

Jutta Gutberlet (2015) points to the diversity of workers involved in e-waste urban mining activities in the Global South, like collectors, intermediaries, and recyclers, who may be self-employed or work formally or informally in cooperatives or recycling companies. Given this universe, one can ask: how do the various workers and institutions (State, cooperatives, and recycling companies) relate to each other in specific geographic spaces to guarantee WEEE recycling?

Josh Lepawsky and Charles Mather (2011) suggest that an interpretation based on Latour's (2005) "actor-network" theory is the most suitable for a geographic understanding of urban mining. The authors argue that this interpretation avoids the linear, calcified perspectives derived from the notion of "value chains." By inserting the actor-network theory in the analysis of e-waste management, Lepawsky and

Mather make a crucial contribution to scientific research by drawing attention to the "flexibility" of the arrangements established between multiple actors (workers and institutions) to develop the activities of WEEE collection, recycling, and commercialization, and the varied geographic scales in which these arrangements are set up.

The aspect of flexibility raised by Lepawsky and Mather is fundamental to understanding the complexity in which the urban mining actors in the Global South operate among themselves and form networks constituted in different geographical scales. The diverse ways in which these actors guarantee the recycling of e-waste in the Global South depend on their levels of capitalization and organization, the functional relationships they establish with other actors, and the normative context of the space in which they operate, which may eventually limit specific actions. In other words, a recycling company operating under formal conditions does not recycle WEEE in the same way as an autonomous waste picker working informally. Hence, the "actor-network" theory is the basis for this study's methodology.

METHODOLOGY AND CHARACTERIZATION OF THE STUDY AREAS

The research structure presented in this article uses the controlled comparison methodology based on two case studies (SKOCPOL and SOMERS, 1980; SLATER and ZIBLATT, 2013). Given the objective of analyzing the organization of e-waste collection, recycling, and marketing activities in the São Paulo Macrometropolis (SPMM) and the Greater Region of Accra (GAR), this method enabled the revelation of the numerous similarities and differences in the arrangements of the activities shaping the geographies of urban mining in the Global South.

Based on this methodology, we adopted a qualitative and exploratory approach operationalized through semi-structured interviews. These interviews were composed of questions that aimed to gather information about the organization of the different urban mining actors and the action networks they had established in different geographical scales. These interviews were carried out between 2019 and 2020. Representatives of ten recycling companies (operating in a formal situation) were interviewed in the SPMM; six interviews, including visits to recycling plants, took place in person, and four were conducted by telephone due to the Covid-19 pandemic. The number of respondents corresponds to the companies willing to collaborate with the research, from 22 enterprises consulted in the study area.

In GAR, twenty self-employed workers (operating in an informal situation) were interviewed. All the meetings took place in person, as they occurred before the pandemic. For five of these interviews, a translator for "Twi" (a native language of southern Ghana) was hired since the workers did not speak English (the country's official language). The twenty Ghanaians who were willing to collaborate with the research, from a total of fifty approached, were interviewed in different parts of GAR, but mainly the Agbogbloshie neighborhood, where the e-waste processing activities are concentrated.

The landscapes in SPMM and GAR were recorded through a dense description (GEERTZ, 1993), highlighting other critical organizational attributes and the material conditions of urban mining in the two study areas. In addition, other information, especially about laws on WEEE management and the volume of this waste produced in recent years, was obtained in national legislation and statistical yearbooks.

In our quest to understand the complexity of the geographies of urban mining in the Global South, we selected two urban spaces that are functionally integrated and dynamic in their respective national territories. Both primarily concentrate their country's industrial and service activities and have their biggest and most diversified labor and consumer markets. Lencioni (2003) also emphasizes the intensity of flows and networks of people and capital (material or immaterial) in these urban-regional extensions, verified by the concentration of circulation and distribution infrastructures.

Nevertheless, despite these similarities, these two urban spaces belong to countries with different positions in the world system (WALLERSTEIN, 2006). Since despite its marked social inequality Brazil has an industrialized and relatively diversified economy, it can be considered part of the semiperiphery of the global system. On the other hand, Ghana can be considered part of the periphery; its economy depends heavily on the export of agricultural products and minerals, and the country has more than a few social problems. The figure below identifies some of these differences.

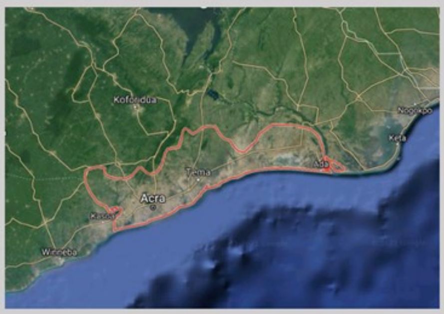
	SPMM	GAR
EXTENSION	53.3 thousand square km (0.6% of national territory)	3.4 thousand square km (1.4% of National territory)
MUNICÍPALITIES	174	16
POPULATION	33.6 millions inhabitants (16% of national population)	4 millions inhabitants (13% of national population)
GDP	USD 290 billions (72% of national GDP)	USD 20 billions (31,4% of national GDP)
HDI	0,76 (Brazil)	0,66 (Ghana)
LOCATION	 	 

Figure 1 - General aspects of the study areas. Source: IBGE, 2020; GSS, 2020.

Therefore, we believe that the case study of semiperiphery and periphery urban spaces of the world-system offers the best understanding of the geographies of urban mining in the Global South in its broadest spectrum.

RESULTS

THE GENERATION OF E-WASTE

E-waste has been generated in practically all countries in the Global South. However, there is a pattern in which the most significant volume of this type of waste has been produced in the wealthiest countries of the world-system's semiperiphery (LOPES DOS SANTOS, 2020). As well as their relatively consolidated and diversified industrial parks, these territories have significant consumer markets. In addition to China, other major e-waste generators in 2019 were India (3.2 thousand tons), Brazil (2.1 thousand tons), and Mexico (1.2 thousand tons) (FORTI et al., 2020).

In Brazil, the per capita generation of WEEE was 10.2 kilos in 2019. This average tends to be higher in the SPMM due to the large population and the consumer society's consolidation in urban spaces (FORTI et al. 2020). Although this urban space is the most dynamic in the country, enormous socioeconomic inequalities persist, expressed spatially in the relationship between the central and peripheral neighborhoods of the municipalities that compose the Macrometropolis. In practice, the purchasing power and disposal of the low-income population living in areas far from the center are limited. However, access to formal credit has increased significantly among these social strata in the first decades of the twenty-first century, which has enabled the increased acquisition of electrical and electronic equipment in urban peripheries (SANTOS, 2017) and boosted the generation of e-waste (LOPES DOS SANTOS, 2020).

In Ghana and the GAR, e-waste generation is significantly different. Although socioeconomic inequalities are also expressive in this peripheral territory of the world system, low-income segments predominate in society; 23% live below the national poverty line (WORLD BANK, 2021). Additionally, there are low levels of banking (35% in 2014) (WORLD BANK, 2021), which hinders the population's access to formal credit, a mechanism that could induce an increase in the consumption of electrical and electronic equipment, as in the Brazilian case.

In an attempt to subvert this situation, in 2004, the national government reduced the import taxes on used or "second-hand" electrical and electronic equipment (EEE) to zero, mainly from Western European countries, the United States, Japan, and Australia. The policy aimed to bring the Ghanaian people into the age of information technology. Instead, a large part of this flow of supposed second-hand EEE was, in reality, WEEE, and thus an illegal movement originating from Global North countries (RUCEVSKA et al., 2015). Richard Grant points out that between 300 and 600 containers full of EEE and WEEE arrive at the Port of Tema (in GAR) each month thanks to the activities of small import companies, usually backed by Ghanaian, Togolese or Nigerian capital. Of this amount, 70% are objects that cannot be reused for their original purpose and are therefore considered waste (GRANT, 2016). Thus, unlike Brazil, urban mining in Ghana involves WEEE imported illegally under the guise of used EEE. It is estimated that 53 thousand tons of e-waste were generated in the country in 2019, a per capita production of 1.8 kg (FORTI et al. 2020).

Thus, significant differences are evident in the initial configuration of urban mining in the two case studies during the e-waste generation stage. In SPMM, WEEE results from product disposal by Brazil's largest consumer market, which is diverse. EEE is accessed differently depending on consumers' income and access to credit and installment payments. Thus, it involves waste generation within the SPMM's regional scale. In GAR, most of the waste is imported from Global North countries, given that the population's low income makes it challenging to purchase EEE. Furthermore, these imports mobilize different actors, such as importing companies, who, in turn, form a network of international operations. They articulate with suppliers, distribution (ports), and circulation (transport companies) activities spread through other countries.

THE REGULATION OF URBAN MINING ACTIVITIES

Both Brazil and Ghana have legislation on WEEE management. However, the Sectorial Agreement approved in 2019 and implemented in 2020 (BRASIL, 2020) in Brazil has not impacted the interviewees. In Ghana, the Hazardous and Electronic Waste Control and Management Act was passed in 2016 (GHANA, 2016), and, although enforced, it has not altered the collection, recycling, and commercialization practices of the actors interviewed.

THE COLLECTION OF E-WASTE

The collection of e-waste is a crucial activity for urban mining since the quality and quantity of the input of waste for recycling activities are extremely irregular because they depend on disposal by individuals and legal entities with distinctly specific dynamics.

In the SPMM, in 100% of the interviews, the recyclers collect the waste in private trucks themselves. Thus, any home or business with waste to dispose of can schedule a collection during the week. In 90% of the cases, the service is free of charge, except for one company, which charges for collection in other municipalities. Concerning the scope of the activity, the companies operate on different geographical scales, but always within the Macrometropolis: three only operate in the municipality of São Paulo, while the other seven work in several municipalities, all within the study area.

All the companies interviewed in SPMM accept WEEE deliveries to their recycling plants, offering donors a receipt and guaranteeing that the discarded EEE will be processed under the appropriate environmental conditions provided for in the legislation in force. However, there are not many e-waste collection points throughout the national territory. Until 2020, initiatives to implement recycling points were uncoordinated and individual and mainly located in areas of intense consumption, such as supermarkets and shopping malls. With the new Sectorial Agreement, the expectation is that collection points will be installed in 72 municipalities of the São Paulo Macrometropolis, in cities with populations above 80 thousand inhabitants (BRASIL, 2020).

Comparing the situation of SPMM with the Greater Accra Region reiterates the complexity of the Global South. In Ghana's most dynamic urban space, the collection is mainly done by waste pickers who work in an informal situation, a condition that befalls 90% of the country's urban workers (HAUG, 2014; GSS, 2020).

Mainly circulating through Accra and Tema (an important port and industrial city in the country), these subjects are known locally as Kaya Bola and act individually or in pairs. All the respondents are self-employed and sell the collected WEEE to recyclers in Agbogbloshie, a neighborhood located two kilometers from the center of Accra, where most of the recycling takes place. Aged between 18 and 26, Ghanaians from different regions of the country, especially the North (where poverty and inequality are most severe), work approximately 10 hours a day, seven days a week.

Six interviewees owned their handcarts, while four rented them from intermediaries in the Agbogbloshie neighborhood. As well as pulling the handcart, they carry hammers and screwdrivers to dismantle the larger objects they find on the streets. Although the literature refers to collectors who use rented trucks, none were interviewed here (AMANKWAA, 2013).

The most significant challenge for urban mining companies operating in SPMM is guaranteeing a regular flow of waste input. Consequently, all the recyclers interviewed establish partnerships with enterprises of all types, such as companies in the secondary and tertiary sectors, universities, schools, hospitals, and city halls. In the case of GAR, the interviewees venture into densely populated neighborhoods, in the commercial centers of Accra and near the Port of Tema.

A fundamental link between disposal and recycling, in both case studies, e-waste collectors are highly relevant urban mining players with significant territorial fluidity within the regional scale in which they operate with their networks. However, the collection takes place in these two spaces under different technical conditions. While in the SPMM, recycling companies carry out on-demand collection using their trucks in a formal situation, in the GAR, the collectors scavenge strategic points operating in an informal condition, using their own or rented handcarts. This technical distinction highlights the differing speeds at which WEEE collection can occur in urban spaces in the Global South.

THE RECYCLING OF E-WASTE

Waste electrical and electronic equipment recycling can occur at three levels, depending on the type of waste to be processed and the raw material extracted from it. Table 1 summarizes these levels, according to the United Nations Environmental Program "Electronic Waste Manual" (UNEP, 2007).

In SPMM, six companies operate in Level 1 and 2, while the remaining four only operate in Level 1, selling their products to other recyclers located in the same or neighboring municipalities. In GAR, the self-employed, informal recyclers interviewed operate Levels 1 and 2, although under significantly different technical conditions from those seen in the Brazilian urban space. Neither of the two case studies carries out Level 3 urban mining operations, which depending on the type of machinery used, is the costliest, as explained in more detail below.

LEVEL 1 LABOUR INTENSIVE	Input I: WEEE
	Process I: data destruction, classification and disassembly
	Output I: large fractions of metals and plastics, CRT, printed circuit boards and cables
	Discarded I: capacitors, batteries, Hg switches, CFCs, oils, others (they are discarded and recycled in other segments)
LEVEL 2 CAPITAL INTENSIVE	Input II: Output I
	Process II: crushing (of metals and plastics) and special treatment (of glass and printed circuit boards)
	Output II: small fractions of metals (ferrous, non-ferrous and precious), different fractions of plastic and glass and printed circuit boards
	Discarded: remaining CFCs
LEVEL 3 CAPITAL INTENSIVE	Input III: Output II
	Process III: recycling and melting of metals (ferrous and non-ferrous), separation of precious metals, energy recovery (and / or plastic incineration), recycling of printed circuits and glass industry
	Output III: recycled metals, plastic and glass

Table 1 - Levels of electronic waste recycling (actors operating under formal conditions). Sources: UNEP, 2007.

All the respondents perform Level 1 activities. It is a fundamentally laborious and low-cost step, requiring some tools, such as hammers and screwdrivers. Three SPMM companies use screwdrivers, and electric drills, purchased in the national market. Activities at this level consist of data destruction and the classification and dismantling of WEEE. Waste is also classified according to the possible presence of hazardous substances, which will require specific safety procedures and potential components for reuse. Once disassembled, plastics, cables, printed circuit boards, cube televisions, and other WEEE are transported to Level 2. At this point, oils, CFCs, mercury switches, batteries, and capacitors disposed of are discarded. The Brazilian actors operating under formal conditions follow the normative framework regarding the disposal of dangerous substances. In Ghana, these substances are disposed of in the open air, on the ground, and in watercourses like the Korle Lagoon.

In São Paulo, Level 1 work takes place in warehouses. According to the interviewees, the number of workers varies according to the organization and the capital invested by the company. Employee numbers range from 12 to 55, all of whom are covered by national labor standards. Most are men, and ages vary from 21 to 57. While this stage occurs in recycling plants spatially dispersed in different SPMM municipalities, in GAR, it is concentrated in the capital Accra, especially in the Agbogbloshie neighborhood. The recyclers interviewed in the latter are self-employed young men aged between 18 and 27 who use their own tools to dismantle WEEE. The neighborhood's landscape evidences how these recyclers organize their tasks spatially since each phase occurs in a designated area. However, aside from the visible impact on the neighborhood, the precarious nature of the respondents' work is apparent as none of the recyclers use PPE, such as glasses, gloves, and shoes. Once separated and disassembled, WEEE goes to Level 2 of the recycling process.

The use of technology increases at Level 2, especially in the formal sector, so that WEEE taken apart at the previous level goes through machines that continue the physical fragmentation through crushing. These machines vary according to the material processed (plastic, ferrous metals, non-ferrous metals, and precious metals).

The machinery used in Level 2 includes hammer mills, crushers, and machines for unique treatment processes, such as electromagnetic separation, centrifugal separation, and density separation (UNEP, 2007). It is noteworthy that the hammer mill and the crushing reduce the size of the WEEE pieces so that the crushed material can be separated according to its density, size, and magnetic properties. The efficiency of the operations determines the recovery rate of the metal at the next technological level (MAZON, 2014). In SPMM, the machinery used for the second level is imported from Germany, the USA, and Japan. Given the high level of recycling mechanization, fewer workers are needed at this stage.

Once more, there is a stark contrast between the technical conditions of recycling companies in São Paulo and the actors who recycle informally in GAR. In Agbogbloshie, only three of the recyclers interviewed used crushing machinery, similar to those used in SPMM, but they were of Chinese origin and purchased second-hand. The rest of the interviewees use cheaper, hazardous, and harmful techniques, such as burning plastic threads and diluting WEEE in acidic substances. Again, it is worth mentioning that both procedures are carried out without any protection or isolation. Burning e-waste in Agbogbloshie releases heavy metals that contaminate the air, soil, and water bodies. This process also harms the workers' respiratory health and contaminates locally sold food, mainly fruits and vegetables. Some research has shown a high concentration of lead in the neighborhood's soil (18,000 parts per million, while the standard suggested by the United States Environmental Protection Agency is 400 ppm). In addition, blood and urine samples from recyclers demonstrate high concentrations of barium, cobalt, copper, iron, and zinc (HUANG et al., 2014).

THE PRODUCTS

Level 2 produces fractions of plastics, ferrous metals (such as iron and steel), non-ferrous metals (such as copper and aluminum), precious metals (such as gold, silver, and palladium), and printed circuits that will be passed on to Level 3. None of the actors interviewed has the technology needed for the third level. Thus, these fractions have different destinations. They can be:

•Sold to companies specialized in metal recycling (ferrous and non-ferrous). They have appropriate techniques for the completion of recycling, such as pyrometallurgy (use of high temperatures in smelting furnaces), hydrometallurgy (use of acids and aqueous solutions of caustic soda), and electrometallurgy (which uses electric current).

•Sold to companies specialized in recycling plastics.

•Sold to commercial companies specialized in recycling printed circuit boards.

•Sold to steel companies.

•Incinerated or disposed of in landfills (regulated or unregulated).

In SPMM, all recyclers operating at Level 2 sell their products to specialized formal recyclers that process metals, plastics, and steel companies that use some metallic elements as scrap in their production process. Printed circuit boards are exported to recyclers in Global North countries, such as the United States, Canada, Belgium, and Japan.

In GAR, all the interviewees sell the metal fractions to intermediaries, who also operate informally. These intermediaries sell these materials to domestic and foreign metallurgical companies located in Tema. The plastic fractions are either burned or discarded in the Agbogbloshie landfills along the Odaw River and the Korle Lagoon, intensifying pollution in the region.

Therefore, the interviewees revealed essential aspects related to their organization and the dynamics of electronic waste management. Although none of these actors has the technology required to carry out the whole recycling process, which can only be fully completed by WEEE recycling companies in the Global North, the flexibility of the network created between urban mining actors operating on multiple geographic scales is well known. Table 2 provides a qualitative summary of the process of collection and recycling in the case studies:

	SPMM	GAR
INPUT	**Input:** 100% of the recyclers interviewed collect on demand using their trucks and all of them receive e-waste from companies and homes at their facilities. Although there are some collection points scattered around the SPMM, they were not mentioned as a source of WEEE input by respondents. **Coverage:** 100% regional (in SPMM municipalities).	**Input:** 100% of the of the self-employed collectors interviewed collect on the streets using wheelbarrows. However, existing literature points to the existence of collectors at GAR that use their own or rented trucks (AMANKWAA, 2013). **Coverage:** 100% regional (in GAR municipalities).
RECYCLING	**Level 1:** 100% of the recyclers interviewed. **Technology:** Labour intensive, with the use of hammers, screwdrivers and (eventually) drills and electric screwdrivers. **Level 2:** 60% of interviewed recyclers. **Technology:** Capital intensive, with the use of new fragmentation machinery imported from the United States, Germany, Japan and Italy.	**Level 1:** 100% of the of the self-employed recyclers interviewed. **Technology:** intensive work with the use of hammers and screwdrivers. **Level 2:** 100% of the self-employed recyclers interviewed. **Technology:** Labour intensive, using incineration and dissolution techniques in acidic substances; Capital intensive, using used fragmentation machinery imported from China.
OUTPUT	**Output:** Metals (ferrous and non-ferrous and precious), plastics and printed circuits. **Destination:** In Brazil: metal recyclers; metallurgical and plastic recyclers. Abroad: printed circuit recyclers (Canada, Belgium and South Korea).	**Output:** Metals (ferrous and non-ferrous and precious), plastics and printed circuits. **Destination:** In Ghana: metal recyclers. Abroad: metal recyclers, metallurgists and circuit recyclers.

Table 2 - WEEE collection and recycling activities in SPMM and GAR. Source: Author's fieldwork, 2019-2020

In the semiperiphery of the world system, a dynamic urban space such as SPMM has recyclers operating in a formal situation who, in some cases, collect and recycle e-waste at Levels 1 and 2. However, the irregular input of WEEE prevents these actors from investing in the purchase of Level 3 recycling machinery. Consequently, their products are sold as raw materials to other national industries or exported to Global North countries, where better-capitalized recyclers perform Level 3 recycling.

In the periphery, the autonomous recycling actors in GAR operate in an informal situation, revealing how WEEE processing can negatively impact the worker's environment and quality of life through dangerous techniques.

Although SPMM and GAR are vastly different countries within the complex Global South, there is no evidence of Level 3 recycling in either case study, which uses machinery only found in recyclers in Global North countries. Thus, due to their capital and technology limitations, urban mining actors need to internationalize their relationship networks, articulating with intermediaries and the transport and distribution companies that take partially processed waste to recyclers in North America, Europe, or Japan.

CONCLUSION

The geographies of urban mining in the Global South are as complex and unequal as the Global South itself, encompassing both countries with diversified economies ranked among the largest globally, albeit marked by unequal wealth distribution, such as Brazil, and countries with less diversified economies. The latter, such as Ghana, are strongly associated with commodities exports and have significant challenges related to providing essential goods, services, and infrastructure to their population. We consider that in this study, the flexible aspect of the actor-network permitted an understanding of the complexity of urban mining activities in the most dynamic spaces of the Brazilian and Ghanaian territories: the São Paulo Macrometropolis and the Greater Region of Accra.

The articulation between actors, with varying levels of consolidation, is not linear or calcified, even in recycling companies operating under formal conditions in the SPMM. The flexibility of the urban mining actors and networks is even more significant in GAR, where autonomous collectors and recyclers work informally, employing hazardous techniques detrimental to human health and the environment.

Although, as revealed by the comparison between the case studies, the geography of urban mining in the Global South is diverse and multifaceted, the condition of periphery and semiperiphery are confirmed in opposition to the center due to some actors' access to modern WEEE recycling technology and facilities. Neither the formal recyclers in São Paulo nor the informal ones in Accra have viable conditions for full recycling, prompting the two macroregions' technological dependence on central countries.

Urban mining actors in the Global South end up establishing networks with multiple geographic scales, depending on their activity, including collection, recycling, commercialization, and intermediation. Furthermore, they use different technologies to transform waste into resources for other industrial processes, further expanding the relevance of the networks they develop in urban spaces. However, limited access to specific technologies is a partially common factor in the Brazilian and Ghanaian case and to the entire urban Global South in general, given that the technologies of the final level of recycling (Level 3) are located in countries like Canada, the United States, Belgium, and Japan.

Thus, at present, the ability to guarantee the complete recycling of the waste of electrical and electronic equipment that they produce (and import, in the Ghanaian case) is beyond the territories of the Global South. In this case, the internationalization of networks created by urban mining actors is not beneficial and reflects the technological inequalities that persist in the current International Division of Labour. The lack of access to certain technologies is the central aspect that countries as distinct as Brazil and Ghana have in common, even though the geography of urban mining in the Global South occurs through the specific articulation of multiple actors in networks in each territorial reality.

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