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Research Paper

Social Hotspot analysis of the e-waste sector in Ghana and Nigeria

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ABSTRACT

The transition towards a circular economy, which has emerged as a promising approach to achieving sustainable development and which involves the reuse of e-waste, may cause significant social impacts on vulnerable groups if it is not addressed in a proper manner. The European Union has established a clear circular economy plan with particular attention on e-waste treatment. However, a considerable amount of e-waste still ends up outside Europe, mainly in African Countries. Social Life Cycle Assessment (S-LCA) has been recognized as a valid methodology to assess the social impacts caused by products or services to stakeholders involved along the life cycle perspective. Most S-LCA studies are conducted in the formal sector; however, informal sectors constitute a crucial element of the economy in emerging and developing countries. In particular, formal waste management practices are complemented by the informal sector in Indonesia, African and Latin American countries. The informal sector represents an important support element. Few studies have been conducted on the social impacts of the e-waste sector and even fewer have been implemented following the guidelines of Social Life Cycle Assessment for Products and Organizations. However, we are still far from a complete overview of the social impacts in the e-waste sector, in particular for developing countries. Knowing that most e-waste through illegal exportation ends up in African countries, a social hotspot analysis has been conducted on the electronic sector in African countries, focusing on Nigeria and Ghana, which are the most affected. The study also identifies a set of indicators needed to assess the social performance of e-waste in Nigeria and Ghana.

1. Introduction

1.1. European legal framework

Today, society depends on electrical and electronic tools and appliances to implement activities. Electronic or electrical appliances, such as fridges, vacuum cleaners, and dishwashers, are examples of necessary tools that support our daily lives. However, these tools and devices, although highly practical, have a relatively short lifespan and are still far from being recyclable or even recycled. Indeed, the European Union generated 4.7 million tons of electronic waste in 2020, including old washing machines, fridges, cathode-ray tube TVs, mobile phones, and computers. Eurostat 2020 data revealed that highest e-waste generation countries are, in ascending order, Germany, Belgium, Sweden and Austria, with per capita generation ranging from above 12 kg to almost 16 kg (Statistisches Bundesamt (Destatis), 2023).

The EU has introduced a set of Producer Responsibility directives and norms to reduce the waste generated by those products at their End-of-Life (EoL) and improve their environmental performance in the operational stage and along their product life cycle (Directive 2008/98/EC; Directive 2012/19/EU; Regulation (EU) 2023/1542). These aim to support a more sustainable approach to resource consumption and reduce the amount of waste going to landfill. With the European Circular Economy Plan (2015), further efforts have been made to promote and increase reuse, recycling, and other forms of recovery, while banning and strongly limiting the use of certain hazardous materials as well as reducing energy consumption and environmental impacts along their life cycle. Key examples of norms supporting the strategy in the electrical and electronics industries include the WEEE, RoHS, and Energy-using Products Directives and Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation (Regulation (EC) No 1907/2006). In addition, a new package proposal on Ecodesign for Sustainable Products Regulation (ESPR) was published on March 30, 2022 (European Commission, 2024).

In the ESPR proposal, a clear preference is given to reduced environmental impacts of products "… *across their life cycle and to improve the*

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functioning of the EÚs internal market "Among others, the proposal will define eco-design requirements, including reusability, upgradability, reparability, remanufacturing and recycling, and information requirements comprising a Digital Product Passport".

According to the Basel Convention, an international treaty on the Transboundary Movements of Hazardous Wastes and their Disposal, the shipment of hazardous waste, including e-waste, from developed to developing countries was banned (UNEP, 2019). It excludes the United States, which has not ratified this treaty yet. The Bamako Convention is a treaty of African Nations prohibiting the import into Africa of any hazardous (including radioactive) waste. The Bamako Convention specifies more specifically, with active guidelines for both sides of the trade than the Basel Convention. More in details, the Bamako Convention (1998) states that "*all Parties shall take appropriate legal, administrative and other measures within the area under their jurisdiction to prohibit the import of all hazardous wastes, for any reason, into Africa from Non-Contracting Parties. Such import shall be deemed illegal and a criminal act*" (Bamako Convention, 1998).

According to a manuscript published in the Environmental Science and Technology journal (Breivik et al., 2014), developed countries still send around 23 % of their electronic waste to developing countries every year. These are mainly shipped to China, Ghana, Nigeria, Pakistan, India, and Vietnam, resulting in significant environmental and health impacts on the population and workers involved (Abalansa, et al., 2021; Maes, 2022).

E-waste in the EU is one of the fastest-growing waste flows (Constantinescu et al., 2022) and is far from being covered by the circular economy concept (European Parliament, 2020). Indeed, less than 40 % of e-waste is recycled today. It is essential to understand where it mainly ends up and what social hotspots these critical materials and products generate. Even if the transport of e-waste outside Europe is forbidden today, according to several reports, illegal European e-waste is found in African and Asian countries (Maes & Preston-Whyte, 2022).

Hence, this study focuses its attention on understanding the social hotspots of the e-waste sector in Nigeria and Ghana, which are the main receivers of e-waste from Europe. Only a few studies have been conducted on this topic so far (Ghisellini et al., 2023) Arnab Kumar Pahari, 2019). The assessment of the social impact of products has been generally neglected in the European Directives, except for a few products, such as batteries for electric vehicles or those containing critical raw materials. Indeed, the definition of critical raw materials, according to the European Commission, combines raw materials with high importance to the European economy and high environmental and social risk associated with their supply chain (European Commission, 2017). This definition highlights the importance of social risks and gives the same importance compared to environmental aspects.

1.2. The conditions of African countries

Africa is considered one of the world's main destinations for large-scale shipments of electronic waste from the United States and Europe. In particular, West Africa, Ghana and Nigeria are considered the main countries where e-waste are landed. However, consistent volumes also go to Cote D'Ivoire and the Republic of the Congo. Nigeria is particularly burdened by Waste from Electrical and Electronic Equipment (WEEE), with over 1.1 million tonnes of e-waste every year deriving from both local and imported Electrical and Electronic Equipment (EEE).

The classification of Electrical and Electronic Equipment (EEE) products presents challenges for effective e-waste management and measurement. While various systems exist for categorizing Waste Electrical and Electronic Equipment (WEEE), harmonization is crucial to ensure meaningful indicators (Forti et al., 2018). EEE classification serves commercial and consumer understanding, typically based on criteria like function, size, and performance, whereas WEEE classification focuses on waste management and environmental concerns, often considering factors such as recyclability, hazardous materials content, and disposal methods. Effective criteria for aligning EEE and WEEE classification include grouping by function, material composition, and end-of-life attributes, with consistent weight and lifespan distributions within categories (Forti et al., 2020). Directive 2012/19/EU of the European Parliament and Council mandates that Waste Electrical and Electronic Equipment be classified into six product categories since 2019. However, inconsistencies like differing categorizations of CRT monitors or microwaves among countries reduce data quality, hindering international benchmarking and policymaking (Forti et al., 2018). The UNU-KEYS classification system, aligned with EU directives, offers a solution by organizing EEE into 54 categories across six waste management groups. This systematic approach ensures comparable weights, compositions, and end-of-life characteristics, encompassing around 660 EEE product types (Baldé et al., 2015). Implementing such a framework facilitates comprehensive e-waste statistics compilation, thereby enhancing policymaking effectiveness in this critical domain.

Long-term solutions to e-waste management can be achieved only if a fair and economically viable approach to Extended Producer Responsibility (EPR) is implemented. EPR calls for producers – such as manufacturers, importers, or distributors – to take responsibility for the end-of-life management of electronics sold on the market. It includes several aspects, such as taking items back, recycling them, and properly disposing of them when no more reuse/recycling is possible.

To achieve this target, the legislation must first contain clear and easy-to-understand definitions of the different e-waste stakeholders to avoid confusion.

E-waste, as defined by the European Parliament, consists of electronic and electrical waste, or e-waste, covering various products discarded after use. These products include large household appliances, such as: washing machines and electric stoves, consumer equipment and photovoltaic panels (video cameras, fluorescent lamps), IT and telecommunications equipment (laptops, printers), and small household appliances (vacuum cleaners, toasters). Additionally, it includes all other categories, such as electrical tools and medical devices.

While the definition is clear and general in Europe, many African countries have provided definitions in their regulations covering e-waste management and Extended Producer Responsibility (EPR). For example, in several African countries such as Côte d'Ivoire, Cameroon, Ghana, Madagascar, Nigeria, Rwanda, and South Africa, the focus is on a person or persons rather than on entities regarding introducing, importing, and manufacturing electronics. It makes identifying who must be registered to a EPR scheme easier.

Currently, most of the e-waste in Africa is mainly disposed of in local landfill sites (Lebbie et al., 2021; Maes & Preston-Whyte, 2022). Those items are often further disassembled and scanned in a rudimental way to extract valuable materials by informal workers. It is mainly done by heating, burning, incubating in acids, and other similar methods. Those activities result in high health risks to workers and residents in communities near the recycling sites. Children and people in the local communities are exposed to toxic substances even if they are not involved in the e-waste treatments (Lebbie et al., 2021).

The health and safety of workers, children and local communities are undoubtedly important social issues stemming from the informal e-waste sector. It is crucial to emphasize that the informal sector carries out primary e-waste treatment in African countries. On the one hand, it represents a critical economic source for poor people and, on the other hand, the primary cause of health impacts on workers and the local community. Although some studies have already been conducted to assess local environmental damage and the impact on human health, the majority have not followed the life cycle thinking approach. More details on the state of the art is reported in the next paragraphs.

1.3. Novelties of the study

A possible methodology to assess the social performance associated to a product is the Social Life Cycle Assessment (S-LCA) described in the Guidelines of S-LCA for products and organizations (UNEP, 2020). The S-LCA has been developed as a complementary approach to environmental Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) (Swarr et al., 2011) mainly to assess the positive and negative impacts generated by a product or an organization for all relevant stakeholders involved in the product life cycle or value chain (Hauschild et al., 2008; Tokede & Traverso, 2020; UNEP, 2009, 2020). An ISO norm to standardize S-LCA is currently under development: the ISO 14075 – Principle and Framework for the Social Life Cycle Assessment, and it is planned to be published in 2024.

As a matter of fact, this methodology is also mentioned in the new European battery regulation, Regulation (EU) 2023/1542, particularly in Annex X, where UNEP (2020) is cited as a primary source for measuring battery-related social risks.

Because batteries remain an exception, we are far from having a complete overview of the social risks and impact generated by electronic and electrical appliances, and even less on the EoL phase and in those products that often end up in the informal waste management sector in developing and emerging countries. Hence, the main objective of this manuscript is to provide an overview of the main risks and social impacts generated by the e-waste sector, with particular attention to Nigeria and Ghana, and to define a possible set of indicators that can support practitioners in assessing the social impact of the formal and informal e-waste sector in African countries.

2. Methodology

2.1. Social life cycle assessment of a product

The Social Life Cycle Assessment methodology has been recognized as one of the methodologies for assessing social impacts, whether focusing on products (S-LCA) or on organizations (Social Organizational Life cycle assessment) (Hauschild et al., 2008; Tokede & Traverso, 2020; UNEP, 2009, 2020). The framework used is based on the ISO 14040 framework, which has been developed to standardize the environmental life cycle assessment (LCA), and the S-LCA includes four phases: goal and scope definition, social life cycle inventory, social life cycle impact assessment, and interpretation.

An essential difference compared to LCA is related to the stakeholder's role. In LCA, stakeholders are only considered for defining the audience of the report while in S-LCA they are part of the evaluation process. Indeed, S-LCA involves measuring the positive and negative social impacts generated on all stakeholder categories involved in the product life cycle.

Another important difference compared to LCA is the importance of the local conditions. Indeed, the social impacts are related to the company's behavior and the specific local conditions, which could significantly differ from the International Labor Organization Convention due to national law and local customs. A S-LCA according to the UNEP guidelines 2020 suggests 6 stakeholder categories: workers local communities, consumers, society, value chain actors, and children (UNEP, 2020).

In this study, due to the first of its kind nature, we started with a Hotspot Analysis based on the Social Hotspot Database (SHDB) identifying the main stakeholder categories to be addressed by the SHDB as workers, local communities, and the subcategory corruption considered in society stakeholder. This implies focusing on the 20 main subcategories related to workers and local community as depicted in Fig. 1.

Each of the subcategories can be measured with one or more indicators. This implies that collecting life cycle inventory primary data can be challenging in terms of time and costs.

When the study is implemented by collecting primary and site-specific data, it is important to further validate those data through a triangulation process. According to the UNEP Guidelines 2020 triangulation can be defined as a mix of different approaches and consideration of different perspectives to collect data for the same indicator. The definition highlights the importance of involving those stakeholders that are affected negatively and positively by the product life cycle (UNEP, 2020). It is particularly important for measuring social issues, which can vary depending on whether they come from companies or NGOs or even from managers and normal employees involved in the product lifecycle. A triangulation check is always strongly recommended for the collection of primary data. This study is mainly based on the secondary data that it the reason why a triangulation has not been applied.

The social life cycle impact assessment (S-LCIA) can be obtained by two different approaches: type 1 called reference scale, and type II – impact pathway. The first one assessed the impact by evaluating the performance of single inventory indicators against a reference value and assigning a score according to a scale (Russo Garrido et al., 2018). The second approach, type II, is mainly obtained by characterizing the value of social inventory throughout characterization factors (Neugebauer et al., 2014; Sureau et al., 2020).

A first step, which can also be considered a possible result of the S-LCA study are the so-called Social Hotspot Analysis (Benoît-Norris et al., 2014). It is conducted when primary data are not available or when the

Stakeholder categories	Worker	Local community
Subcategories	1. Freedom of Association and Collective Bargaining 2. Child Labor 3. Fair Salary 4. Working Hours 5. Forced Labor 6. Equal opportunities/ Discrimination 7. Health and Safety 8. Social Benefits/Social Security 9. Employment relationship 10. Sexual Harassment 11. Small Holders Incl. famers	1. Access to material resources 2. Access to immaterial resources 3. Delocalization and Migration 4. Cultural Heritage 5. Safe & healthy living conditions 6. Respect of indigenous rights 7. Community engagement 8. Local employment 9. Secure living conditions

Fig. 1. The subcategories considered according to the UNEP, 2020 Guidelines.

priority is to identify the main social risks associated with the product life cycle considered. In this case, the social hotspot analysis mainly refers to the social risks associated with the countries and the sectors involved. It helps identify the main social issues in that specific local and sector context, and it can lead to the second assessment, which focuses on the collection of primary data only for the relevant aspects resulting from the social hotspots analysis. The Social Hotspot Analysis can be carried out with the support of software and databases such as Social Hotspot Database and PSILCA (PSILCA; SHDB). The SHDB provides comprehensive data coverage, with information on 244 countries and 57 economic sectors. This allows for detailed analysis of social risks and impacts across a wide range of geographies and industries. The data in the SHDB is organized into 30 social themes, which group over 132 risk indicators related to human rights, working conditions, community impacts, and governance issues. This thematic structure enables in-depth assessment of social hotspots across multiple dimensions. The SHDB utilizes a combination of quantitative data from reliable sources as well as qualitative information to assess social risks. This mixed-methods approach provides a more holistic understanding of social impacts. The SHDB utilizes a "life cycle attribute assessment (LCAA) methodology developed by Norris (2006)". This methodology assigns a risk (or opportunity) level to the data for each "unit process" (defined as a country-specific sector when using global input–output models). The risk levels are then combined with labor hour intensity factors (developed by converting wage payment data into estimates of worker hours) to express the social risks and opportunities in terms of work hours, by sector and country. the "level of risk" in the SHDB refers to a relative scale that quantifies the social risks and opportunities for different countries and sectors, based on a comprehensive assessment of various social impact indicators. This allows the database to identify "social hotspots" where the risks are highest compared to other locations. The approach use in the SHDB is the reference scale or type I and the values are discrete number between 0 (low risk) and 4 (very high risk).

2.2. Social life cycle assessment in the e-waste sector

The first study on the social assessment of e-waste according to the UNEP Guidelines was conducted in 2010 by Prakash and Manhart. It was applied following the Guidelines for Social Life Cycle Assessment of Products (UNEP, 2009) and formed part of the report of an e-waste Africa Project under the umbrella of the Secretariat of the Basel Convention of the UNEP and jointly managed by the national governments in African countries. The project aims to improve environmental governance related to e-waste and the social and socio-economic conditions obtained for partnerships and small businesses in the recycling sector in Africa. The focus was to understand better and regulate the transboundary movements of used and obsolete electronic equipment from Europe to Africa. Additionally, it aimed at enhancing local e-waste management capacities in several African countries, including Côte d'Ivoire, Benin, Nigeria and Ghana.

Another assessment of the social impacts of e-waste was carried out for the informal recycling of Information and Communication (ICT) waste in Pakistan (Umair et al., 2015). This study used the first version of the Guidelines for S-LCA of products from UNEP (2009). Primary data were collected during a field trip to eight selected urban centers in Pakistan. The primary data were collected for 4 out of 6 stakeholder categories (Workers, Local community, society, and Value chain) and about 12 subcategories out of 40.

One of the pilot projects based on the UNEP (2020) Guidelines focused on the goal and scope of the informal waste sector in Cuenca, Chile (Traverso et al., 2022). The case study centers explicitly on two stakeholder categories considered the most relevant: workers and local communities. The pilot aimed to assess the potential social impact of recyclers' activities, such as collection, transportation, pre-processing, and commercialization of a ton of recyclable waste disposed of in the streets of Cuenca in 2019. A "cradle to gate" approach was used, and the assessment encompassed social performance, social risk and social hotspots. About 19 subcategories (12 for workers and 7 for local communities) for 52 indicators were used to implement the case study. The results for workers demonstrated poor performance in subcategories related to fair wages, equal opportunities, social benefits, and even cases of child labour. Non-compliance was also observed in aspects related to health and safety, and forced labour.

3. Results

3.1. Social hotspot analysis of Nigeria and Ghana

Nigeria is the world's second-largest receiver of e-waste and the highest importer in Africa, with up to 100,000 informal workers operating in the sector. E-waste is disposed of through open burning, releasing toxic elements and organic substances that endanger the environment and human health. E-waste recyclers work without Personal Protective Equipment (PPE) and as a result, they experience various health complications.

In 2015, Nigeria received 56,000 tons of imported e-waste. In 2017, this amount reported in the reports increased to 288,000 tons, showing an increasing trend four times higher than two years earlier. Moreover, half of the EEE imported into the country in 2012, was second-hand.

Regarding Ghana, a study has been conducted to understand the environmental exposure and working conditions of the informal workers in the e-waste sector (Akormedi et al., 2013). According to the study, e-waste in Accra from various residential areas is dismantled and burned in open air. This process allows the recovery of important materials such as copper, aluminum, steel, and other products for sale to customers on-site or at the nearby Agbogbloshie market (Canavati, 2022). The workers labor under unhealthy conditions, often surrounded by waste and human excrement, without any form of protective equipment, exposed thus to frequent burns, cuts, and inhalation of highly contaminated fumes (Adanu et al., 2020). No social security system for the workers has been developed until now. The study's conclusions indicate, on the one hand, that e-waste recycling conditions for informal workers are very challenging, particularly concerning health and safety. On the other hand, creating a formal system requires financial support to establish a system with cleaner technologies for recycling to guarantee the health of the workers and the general public.

Because, collecting primary data on social conditions of the formal and informal collectors as well as on the impact generated on the local communities is today for this sector very challenging, the authors proposed to proceed at least on a social hotspot analysis using generic data to identify according to the sector and countries involved the main social hotspots. The Social Risk Mapping tool of the Social Hotspot Database (SHDB) considering the waste and electronic sectors and the specific countries has been done, to identify which are the main risks.

According to a social hotspot Analysis conducted by the SHDB, a comprehensive overview of the risks associated with these countries can be identified. This analysis helps in defining the primary focus for assessing social impacts (Benoit-Norris et al., 2012).

The results reported in Fig. 2 indicate that Nigeria and Ghana have very high social risk in most of the subcategories considered within the Social Hotspot Database (SHDB). Specifically, for Nigeria, 7 out of 13 indicator values fall between 4 and 3, representing very high risk and high risk, respectively. More in detail, the main topics with very high risk include child labour, occupational toxics and hazards, occupational injuries and fatalities, Gender Equality Index, forced labor and the risk of high conflicts.

In Ghana, only the risks associated with occupational toxics and hazards, as well as the risk of occupational injuries and fatalities, are very high. The remaining risks fall within high risk and medium risk. Additionally, it is noteworthy that the risk that average wage is below the country minimum wage is low risk for Ghana.

The differences between the results are due to a different political

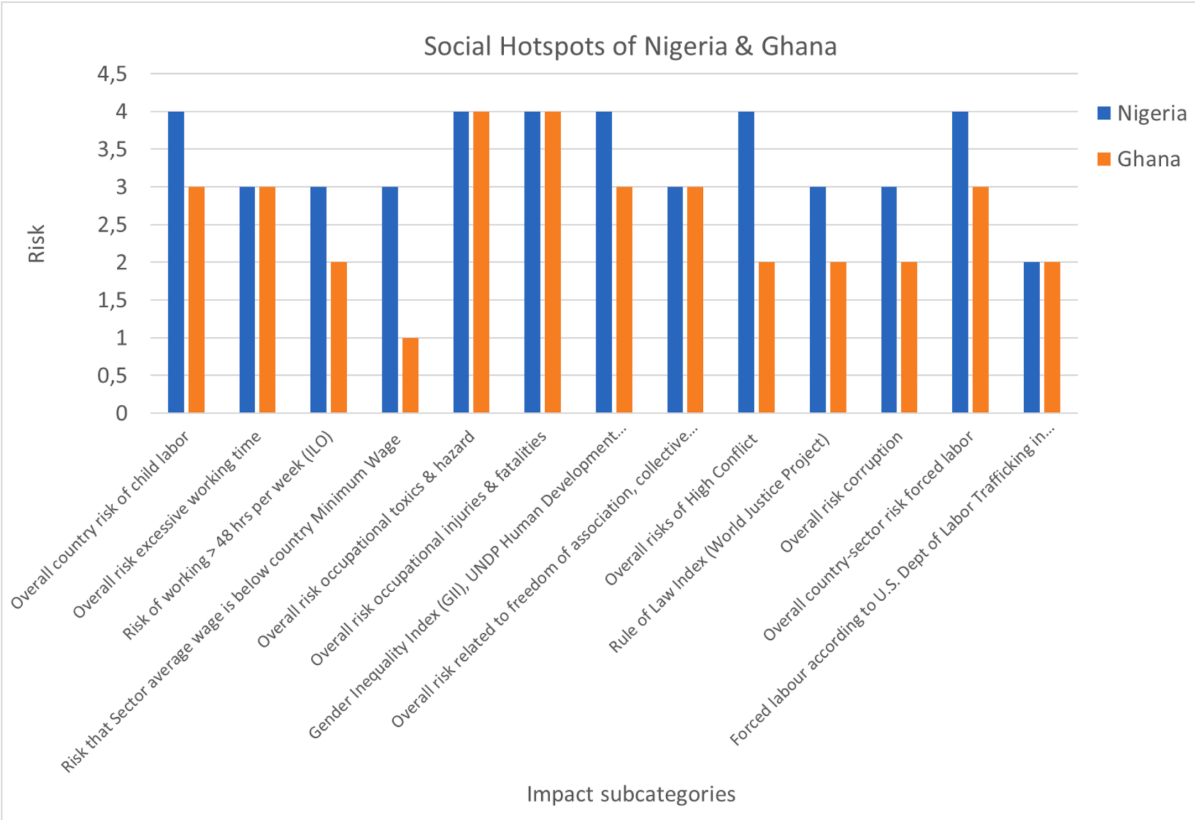

Fig. 2. Social Hotspot Analysis of Nigeria and Ghana.

conditions of the two countries. Ghana has developed in the last years a strategy plan for waste treatment and it is one of the Waste African Countries most developed and innovative.

According to the Social Hotspot Analysis, data collection campaigns should be conducted in both countries of study, focusing on all aspects with high and very high risk. For collecting primary or site-specific data in formal e-waste management, specific indicators have been identified and proposed in Table 1, 2 and 3. This list of indicators should aim to collect both quantitative and qualitative data, including yes/no questions. Moreover, a different approach and questionnaire are required when dealing with informal e-waste collectors. The indicators proposed here is obtained by filtering and adjusting the list elaborated during the implementation of the 9 Project pilots carried out to assess the UNEP Guidelines 2020 (UNEP, 2022), The elaboration has been carried by considering the Methodological Sheets for Small Holder and Farmer (UNEP, 2021) and considering the SHDB results.

As shown in Fig. 2, for both countries, we have a very high risk for Health and Safety. Consequently, primary data should be collected for workers and local community stakeholders. In Table 1 and 2 an example of possible indicators elaborated by the authors for the UNEP pilots and readjusted for this case study is presented.

An example of different indicators used to measure the social impact

Table 1
Possible indicators for collecting data on Health and Safety for workers in formal e-waste sector.

Health and safety training for employees	Hours per employees per year
Average rate of injuries occurring at the job	Number/year *Please indicate the type of injury*
Regular health checks for employees	Number/year & employee group *Please indicate employee group*
Provision of free meals for employees	Number/month & employee group *Please indicate the kind of meal per employee group*
Provision of sanitation facilities for employees	yes/no
Existence of a health & safety committee with participation of employees	yes/no
Provided tool and protection to workers	yes/no *Please indicate type of protection and employee group*
Number of cases of desease among workers due to the chemicals/hazardous substances contained in the e-waste	Number/years please indicate the type of disease

Table 2
Possible indicators in Health and Safety for local community.

Health impact identified to local community due to pollution and noise created by the e-waste treatment	Number of cases/year *Please indicate type of impact*
Negative health impacts due to harmful substances released to the environment	Number of cases/year *Please indicate type of impact*
Negative health impacts due to water pollution	Number of cases/year *Please indicate type of impact*
Improvement of local infrastructure due to recycling collection	yes/no *Please indicate type of improvement*
Improvements in the populatioń́s education/skills due to recycling collection	yes/no *Please indicate type of improvement*
Programs to enhance community health & safety	Number of programmes *Please indicate type of programme*
Dependency on mine for sustaining local economy	yes/no
Water use competition between local community and mine? (e.g. reduced water supply, water contamination, increased water scarcity)	yes/no *Please indicate type of competition*

Table 3
Example of indicators for informal recycling presented in.

Indicators in informal sector	Number of workers included in the informal sector created Number of family included in informal sector increase of wellbeing of the family involved in the informal sectors increment of diseases and/or injuries in the families involved in the informal sector average of the income in the informal waste sector minimum and maximum income obtained by workers involved share of women included in the informal sector and their occupation

of the informal waste sector in the pilot is "Fair Salary," where income is preferred over salary for measurement. Table 3 provides an example of possible indicators.

In any case, site-specific data collection should be conducted through interviews with workers (formal and informal), NGOs, and local communities to validate the results.

4. Conclusions and discussions

The generation of e-waste in the EU and other developed-country realities has been increasing along the years and this trend is expected to continue even at a faster rate. Despite the ban on the transboundary movement of e-waste and their disposal, most fast-growing developing countries, such as Nigeria and Ghana, are the destination of European e-waste. The increase in the generation of e-waste in these countries is also influenced by the importation of second-hand electrical and electronic appliances, at the very end of their service life. However, irrespective of where they come from, e-waste is an important resource for these countries, and the informal sector plays the principal role in extracting precious minerals, reusing and recycling e-waste. Consequently, e-waste-related activities provide important economic support to many families connected in some way to the formal and informal sector. In the African context, the informal sector represents a large portion of the population also contributing to the economic development of these countries. On the other hand, the actors along the value chain of e-waste treatment are exposed to health and safety hazards and other social issues. Applying the UNEP Guidelines on S-LCA and aiming to carry out a social hotspot analysis, it was possible to identify the social hotspots in the e-waste sector in Nigeria and Ghana. The Social Risk Mapping Tool has been used to identify the hotspots. the main focus has been given to workers and local community stakeholder categories and their subcategories. Indeed, those are considered the main stakeholders affected. The obtained results are very high and high risks in Nigeria, while in Ghana, only the risks associated with occupational toxics and hazards, as well as the risk of occupational injuries and fatalities, are very high. It highlights the different levels of development and political contests as the consideration of the waste treatment sector of the two countries. The outcome of the hotspot analysis of those two African countries highlights the importance of collecting and assessing site-specific data to better capture the relevant positive and negative social aspects that need to be addressed. To collect primary data, a set of possible indicators has been proposed in the study in particular for Health and Safety which is considered an high risk impact categories for both workers and local community. It can support further research based on primary data and push toward a standardization of the evalauton to allow better comparions. Finally, the study derives and proposes suitable indicators to assess the social performance of e-waste treatment in developing countries This will enable a comparison of the social performance of specific e-waste treatment facilities against the country-level social risk assessment from the hotspot analysis conducted in this study.

In the study, we have introduced a few indicators for the informal recyclers, which often represent an important component used in developing countries for the success and efficacy of recycling collection. However, the informal sector can not be assessed with the same indicators used for workers in the formal one; the informal sector is more similar to smallholders as it was also represented in the pilots of UNEP, 2020. As stated in the UNEP Guidelines, S-LCA aims to assess and improve the positive and negative impacts generated by a product or an organization for all relevant stakeholders involved in the product life cycle or value chain. The study done is a first analysis and it doesńt aim to be exhaustive. The main goal was, indeed to identify potential risks and develop a possible tool to assess in detailed and efficiently those aspects. Hence, it is recommended for future studies, to include the assessment of indicators relevant to the economic relevance of the informal sector in e-waste treatment, considering the studied African countries but also expanding to other developing country realities.

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CRediT authorship contribution statement

Marzia Traverso: Writing – original draft, Methodology, Conceptualization. **Rose Mankaa:** Writing – review & editing. **Maria Concetta Pedalá:** Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Marzia Traverso reports financial support and administrative support were provided by RWTH Aachen University.].

Data availability

No data was used for the research described in the article.

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