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Challenges And Perspectives Of Electrical And Electronic Equipment Waste Management In The Republic Of Guinea.

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Abstract
Most developing countries face enormous challenges in implementing sustainable waste electrical and electronic equipment (WEEE) management systems. Informal WEEE management practices in the Republic of Guinea have become a major challenge for the government and various stakeholders due to their impacts on the environment and health. The review article presents a close link between the WEEE and household solid waste (HSW) management system in Guinea, based on legislative and policy documents, research studies and reports published by national and international organizations, Directives and Conventions, and Ministry decrees. The article discusses topics such as the legal and regulatory framework, the current situation of HSW management and WEEE, the flow of the Guinean market for electrical and electronic equipment (EEE), and a strategic year of sustainable WEEE management in Guinea. The study results indicate that the country lacks effective strategies covering all stages of the product life cycle, particularly at the end of life. Economic and financial limitations are the important obstacles to WEEE formalization. Establishing resourced environmental government agencies for effective monitoring and auditing and appropriate sustainable WEEE management practices is the most important way forward.

Keywords: *Waste Electrical and Electronic Equipment (WEEE), recovery, metals, plastic, recycling, Guinea.*

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I. Introduction

Over the past decades, waste electrical and electronic equipment (WEEE) has become the largest waste stream, after municipal solid waste, in terms of growth rate [1]. Although their management is beginning to be adequately regulated almost worldwide, there are still clear gaps that need to be resolved in many aspects, particularly in sub-Saharan Africa**.** WEEE is obtained from electrical and electronic equipment (EEE) that is no longer fit for use and that the last owner has discarded [2]. The EEE designation therefore covers a multitude of devices with very different dimensions and weights (Table 1) [3,4]. Unlike conventional solid waste such as household solid waste (HSW), WEEE has the dual characteristics of being both hazardous and ingenious [5,6].

WEEE is a complex mixture of hazardous materials (e.g., lead, polychlorinated biphenyls [PCBs], polybrominated biphenyls [PBBs], mercury, polybrominated diphenyl ethers [PBDEs], and brominated flame retardants [BFRs]), and other coolants with high potential for environmental impact (Table 2) [7,8]. They also contain valuable substances (e.g. non-precious metals: iron, steel, copper, aluminum, etc.; precious metals: gold, silver, platinum, palladium, plastics, etc.) [9,10]; which require specialized collection, transportation, separation, treatment and disposal processes [11].

On the other hand, it has been suggested that approximately 50 million metric tons (Mt) of WEEE are produced worldwide each year, with a projection of doubling by 2050 [12]**.** With an annual increase of 3.58%, Africa's urban population is the fastest in the world and is expected to reach 1.26 billion by 2050 [13]. Waste

production in sub-Saharan Africa is estimated to triple, from 174 million tonnes annually in 2016 to 516 million tonnes annually in 2050. In Guinea this production is estimated based on the urban population according to three waste production rates, namely 0.5; 0.75; and 1.0 kg/person/day (Figure 1) [14]. The collection rate is low in most African countries, below 55%, and there is a tendency to illegally dump uncollected waste. Inadequate collection/sorting, intermediate treatment, recycling, and final disposal jeopardize sanitation and public health [15].

However, in West Africa, particularly in Guinea, the problem is all the more critical because the recycling of these products is not regulated or organized, it belongs to the so-called "informal" domain. The recovery of metals is the main WEEE recycling activity in the country, and it is most often carried out by dismantling and open-air incineration. There are no specific regulations that limit the recycling of electronic waste and that also address the dangers caused by such activities [16,17]. In light of the data presented, the main objective of the approach proposed in this work is to facilitate a better understanding of the WEEE management system in the Republic of Guinea. Then, to provide key information and ideas that will contribute to the achievement of the objective of developing a WEEE management policy, define priorities, and propose approaches for better collection, sorting, and efficient treatment of WEEE. It seeks possible effective alternative strategies and the best technologies, pre-treatment, and final treatment for WEEE management in Guinea.

II. Methodological Research

To draw up a realistic picture of the WEEE sector in the Republic of Guinea, we examined and analyzed information from several sources.

- Research studies: A comprehensive search was conducted on PubMed, Science Direct, and Google Scholar in June 2024. The keywords for searching the literature were: waste electrical and electronic equipment (WEEE), Republic of Guinea, West Africa, electrical and electronic waste management in Africa, regulations and WEEE, directives and WEEE in Africa, environment, human health, and WEEE.
- Legislative and policy documents: Basel, Stockholm, and Bamako Conventions; the European Directives on WEEE and RoHS (Restriction of the use of certain hazardous substances in EEE).
- In the documentary research and field observation, it was possible to identify the structures operating in the field of waste management (importers, professional users, repairers/recyclers, waste managers, and NGOs)
- Reports and other public and internal documents published by national organizations in the field of domestic solid waste management, and orders of the Ministry of the Environment and Sustainable Development of the Republic of Guinea (MEDD).

Table 1. Current classification of waste electrical and electronic equipment [3]

No.	Type	Products
1	Temperature control equipment	Refrigerators, freezers, equipment that automatically transfers cold, air conditioners, dehumidifiers, heat pumps, oil-filled radiators, and other temperature exchange equipment using non-aqueous liquids.
2	Screens, monitors, and any display device measuring more than 100 cm^2	Monitors, televisions, LCD photo frames, monitors, laptops.
3	The lamps	Straight tube fluorescent lamps, compact fluorescent lamps, fluorescent lamps, high-density discharge lamps including high-pressure sodium and metal halide lamps, low-pressure sodium lamps, light emitting diodes
4	Large equipment	Washing machines, tumble dryers, dishwashers, cooking equipment, electric cookers, electric hotplates, lamps, sound and image reproducing equipment, musical instruments (excluding wind instruments in churches), sewers, mainframe computers, large-scale printers, photocopiers, large-scale slotting machines, large medical equipment, large monitoring instruments, large electrical appliances that automatically deliver products and parts, photovoltaic solar panels
5	Small equipment	Vacuum cleaners, carpet cleaners, electrical sewing appliances, lamps, microwave ovens, fans, electric irons, ovens electric, electric sewing machines, electric kettles, clocks and watches, electric shavers, electric scales, electric hair and body care appliances, calculators. , radios, digital cameras, image recorders, high-fidelity equipment, musical instruments, sound and image reproducing equipment, electric toys, sports equipment, computers for cycling, diving, running, throwing, etc., smoke detectors, heating regulators, thermometers, small electric tools, small medical equipment, small monitoring instruments, small household appliances that automatically deliver products and small appliances with photovoltaic solar panels.
6	Small computer and communication equipment (length external not exceeding 50 cm)	Mobile phones, global positioning systems, portable calculators, routers, personal computers, printers, telephones.

Table 2: Hazardous elements and substances frequently present in equipment electricaland electronic equipment [8].

Components	Found in	Substances of concern
Cathode ray tubes	Old TVs, PC monitors, oscilloscopes	Pb in a conical glass Ba in the electron gun getter Cd in phosphors
Printed circuit boards	Ubiquitous, from Beeps to PCs	Pb, Sb in the solder Cd, Be in the contacts Hg in switches BFRs in plastics
Batteries	Portable devices	Cd to Ni-CD in batteries Pb in lead batteries Hg in Hg batteries.
Gas discharge lamps	Backlighting of LCDs	Hg in phosphorus
Plastics	Wire insulation, plastic enclosure printed circuit boards	PVC BFRs

Estimated amount of waste

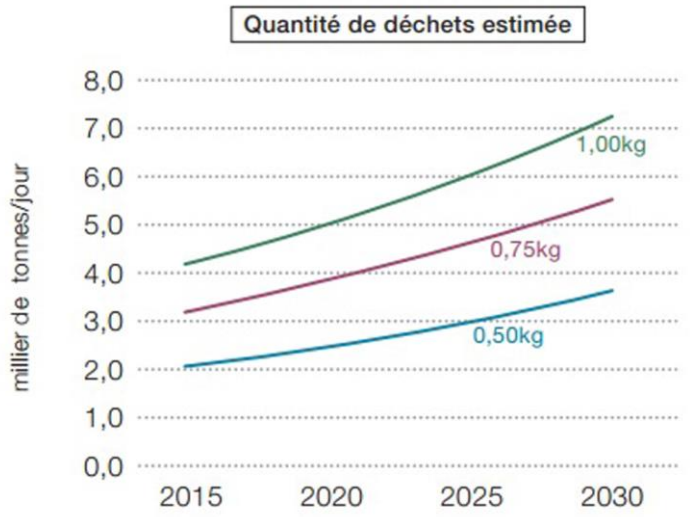

Figure 1. Estimated amount of waste based on urban population at three waste generation rates, namely 0.5, 0.75, and 1.0 kg/person/day. Waste quantity = (Generation rate) x (Urban population) [14].

III. Legal Framework And Regulations Relating To Hazardous Waste

To date, there is no law or policy in the Republic of Guinea to regulate WEEE. Guinea does not have a formal WEEE collection system. However, it is subject to certain laws relating to the importation, possession, sale, and use of chemicals, of which some of these equipments are constituents. Due to the lack of reliable statistics, or even implementing texts, it is sometimes difficult to implement these laws. However, the country has ratified and concluded several international and national agreements on the management of hazardous waste. In particular, the Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal established a framework for controlling the movement of waste from developed countries to developing countries, was promulgated by Law L/2016/040/AN/SGG of August 9, 2016, of the National Assembly [18]. In addition, the one in Stockholmon the risks of persistent organic pollutants (POPs) was also signed in 2001 and ratified in October 2005. LAW L020/2005/AN of the National Assembly of the Republic of Guinea adopted it in 2005 [19]. In addition, the one from Bamako envisages the criminal sanction of offenses under the principle of the prohibition of the introduction of hazardous waste into Africa, in addition, to the Basel Convention [20].

On the other hand, Legal and regulatory measures have been taken by Guinea at the national level to preserve its policy of preserving the environment and the health of its inhabitants. The texts drafted deal with health, water, soil, and air pollution, environmental preservation, management of toxic substances, MSW, and WEEE. This includes, among other things, the health code drawn up in 1997, in Articles 29, 32, and 33, respectively on chemical, organic, or nuclear pollution, which affects the quality of water by modifying the organic and biological rate. Then, they also prohibit any discharge or burial of toxic products, organic, chemical, or nuclear waste in the bed of a watercourse (river, lake, pond, stream) and the sea, under penalty of sanctions provided for by law [21].

Based on Order No. A/2019/5159/MEEF/CAB, The Guinean government has implemented the SGS Renovo program, a revolutionary approach to waste management, combining environmental protection and social responsibility. Therefore, SGS Renovo collects the anticipated Ecotax on all new or used EEE and tires, which will allow mandatory physical inspections in the country of origin for goods declared as used, finally improving the social and environmental situation in Guinea [22].

IV. Current Situation Of Management Of HSW And WEEE In Conakry

The Republic of Guinea is experiencing rapid urbanization, with the projected proportion of the total population living in urban areas increasing from 2.8% in 2005 to 2022, compared to the previous year, increasing the population to 13.5 million with a density of 53.4 inhabitants/km^2 [23]. According to a finding of the Fifth Edition of the World Bank's Economic Review focusing particularly on the three West African capitals, namely Bamako, Niamey, and Conakry. These three cities contribute significantly to the national economy, Bamako has 34% of Mali's GDP; Conakry and Niamey have 27% of the GDP of Guinea and Niger [24].

Rapid urbanization is driving increasing demand for information and communication technology (ICT). This is driven by the integration of information technologies into public administration reforms to digitalize and optimize service delivery and the governance process. Also, in education; health; medicine, the food sector; environmental monitoring; and others [25]. According to environmental researchers, basic EEE devices that have become an integral part of human life, such as (refrigerators, televisions, mobile phones, laptops, personal computers (PCs), irons, washing machines, children's toys, and photocopiers and printers), have become indispensable in daily life [26,27]. This urban development, where around 70% of the population is concentrated in the main cities, including 30% in the capital Conakry [28]. The population's consumption patterns have changed, leading to a diversification of waste and an increase in the rate of MSW production [29]. These HSW combined with WEEE have led to unsanitary conditions in the capital Conakry. It is important to remember that there are no manufacturers of EEE in the Republic of Guinea. However, Guinea does not provide any estimate of the quantity of EEE present in the country, where they are located, and where they migrate to.

However, Conakry, the capital, has only one landfill, that of the mining company, which is completely clogged, because the garbage dump far exceeds the developed site, and which is today a real ecological and social disaster, because it is located in the middle of homes [30]. Various studies have been conducted to move the landfill to other sites such as Kagbelen, Fria, and Kouria, and to create Technical Landfill Centers (TLC) within them. These identified sites are already filled with homes [31]. With this in mind, several structures, organizations, and NGOs in waste management have been created.in the Republic of Guinea, in particular:

- National Agency for Public Health (ANASP);
- Industrial Waste Management Center (CEGEDI);
- Federation of Waste Managers of Guinea (FEGEDEG);
- Conakry Urban Environment and Sanitation Improvement Program (PADEULAC);
- Transitional Waste Management Program (PTGD);
- Public Waste Transfer Service (SPTD);
- Belgian Development Agency (Enabel);
- SGS Renovo Guinea program.

To reduce the number of illegal dumps that pollute water and soil, and endanger the fishing potential of waterways, which are a source of protein, Enabel and other development partners have decided to create collection points in the five communes of Conakry. (ANASP, 2017; Almadius et al., 2019). Figure 2 shows the arranged grouping points of the areas examined.

Furthermore, ANASP was set up to improve waste management in the city of Conakry, by Decree D/2016/369/PRG/SGG of November 30, 2016 [18]. This agency, in its strategy to professionalize the management of solid waste (SW) in the city of Conakry, which extends over a period of ten years (2019-2029), is planned to implement a legislative and regulatory framework on the management of HSW, as well as on the neutralization and recycling of WEEE [32].

According to the FEGEDEG report, only CEGEDI is specialized in the collection of WEEE. This center is little known to informal workers because it only works with a few multinational companies. This highlights the fact that WEEE is combined with HSW which ends up in landfills. Despite the development of collection points, waste accumulates in gutters and fields, on the banks of waterways, and in other uninhabited places. After a thorough analysis, data demonstrate that in Guinea, the flow of WEEE is a complex issue. As a result, it is difficult to know the flow of secondary equipment and waste, as well as the contribution of WEEE generated by individual households, business sectors, public institutions, government services, and others. As in many developed countries, increasing attention is being paid to quantifying WEEE production as well as identifying

WEEE flows [25]. However, in Guinea due to the lack of specific controls on WEEE management, there is virtually no data on the specific types of WEEE generated or disposed of by individual households, business sectors, and public and private institutions. This indicates that data on the amount of WEEE generated and produced per capita from various sources could not be determined, almost non-existent, which highlights the need for screening and/or inventory of WEEE as well as their sorting/collection, and treatment for sustainable management.

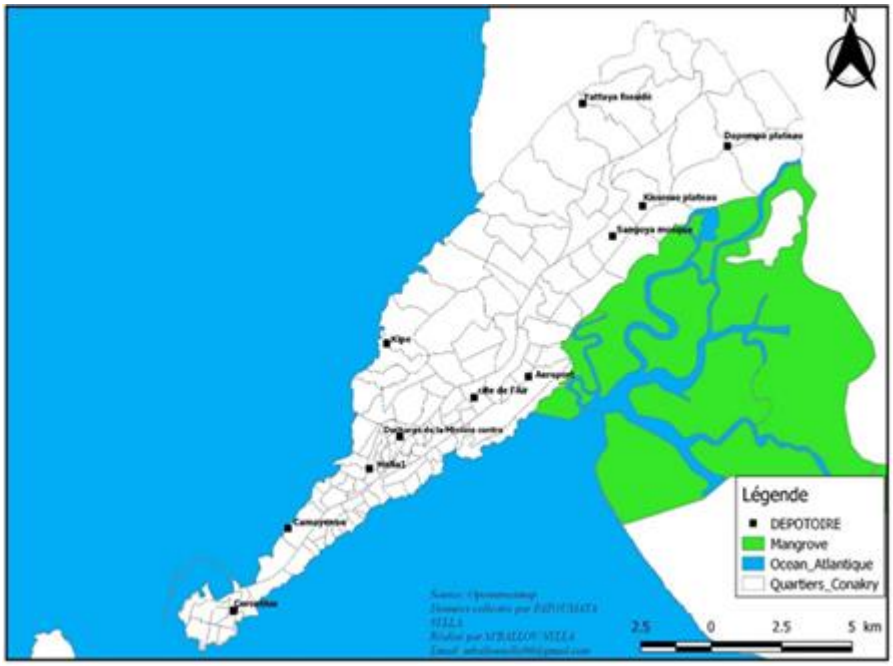

Figure 2. Garbage dump in the communes of Conakry

Strategic plan for sustainable management of WEEE in Guinea - a prospective look

In the Republic of Guinea, EEE management should be separated from HSW management. However, a policy should be put in place for the management of WEEE separately from HSW. As well as specific laws on WEEE could be developed. Notwithstanding, The WEEE management option is recovery through:

Recover WEEE through:

- Reuse of entire equipment;
- Reuse of parts;
- Recycling and recovery of materials;
- Energy recovery.

Bridging the knowledge gap through sector studies.

Sectoral studies could shed light on some important aspects of the WEEE management sector and should be encouraged. These include:

- An assessment of environmental degradation caused by poor WEEE management. The cost of environmental degradation due to current WEEE management practices will provide a monetized indication of the burden that these current WEEE sector practices place on the country's environment.
- Prioritization of WEEE management interventions following a risk-based approach.
- Support the development of primary infrastructure. The development of landfills, the construction of dismantling, sorting/collection, and landfill centers. This support could be provided in the form of technical assistance to help in the design and development or creation of WEEE treatment sites.

Strengthening the capacities of DSM management structures in the country (**ANASP, CEGEDI, FEGEDEG, PADEULAC, PTGD, Enabel, and SPTD**), including for the management of public-private partnership contracts.

Advocacy for a complete professionalization of the WEEE sector through small businesses, cooperatives, or unions is necessary. Such a structure implies increased responsibilities of the above-mentioned structures at the top, particularly in terms of contract management, environmental and technical monitoring, performance management, and communication.

Creation of job opportunities and professionalization in the WEEE sector.

Training sessions for young entrepreneurs in the waste sector in general to promote professionalization towards WEEE. These sessions will be designed to help young people look beyond pre-collection when considering the waste sector. In addition, they will aim to provide beneficiaries with a broader vision of WEEE, examining possibilities such as environmental communication, and management of facilities (deposits, transit, landfill, sorting, collection, dismantling, and landfill).

Implementation instruments

They will need to provide WEEE management structures with the relevant information they will need to ensure good management. For this propose, the databases must be created and made public by appropriate means. They will cover in particular the following subjects:

- List of WEEE with indication of the most appropriate operations for their recovery or disposal;
- List of WEEE which must be subject to mandatory selective collection for recovery or disposal;

Application of the activity theory approach

Furthermore, in the Republic of Guinea, WEEE management is not dissociated from HSW management. Therefore, it can be managed through resource management, collaborative efforts, and viable knowledge that progressively advocate the need to establish participatory learning platforms, where individuals can meet, interact, learn collaboratively, and make collective decisions. In this perspective, Activity Theory (AT) can be used to methodically design a theoretical framework for analyzing systems development and can be applied to solve problems that arise in the social domain such as WEEE management [34,35]. The study suggests strategic policy directions in applying the TA system, arguing that to win sustainability in WEEE management; an integrated and collaborative policy is needed by national and international communities to address this complex problem. Sustainable WEEE management in Guinea focuses on raising awareness of recycling and waste disposal, product reuse, and elimination of toxic substances [36,37]. Engaging and involving consumers is also crucial [38]. The TA assumes that activity is not tied to the action of a single person. In addition, it relates to societal parameters that are located in culture, and history and functions as a community-based learning process. It also emphasizes the sharing of community knowledge; it also provides a basis not only for individual behavior change but also for the transformation of community behavior [39]. Moreover, the framework designed with the application of real data adds value to the analysis; and can be applied quickly and understood by the public without difficulty. The essential elements of the proposed WEEE activity modeling are summarized in Figure 3. In other words, TA arises from intentional activity in a cultural and historical context and constitutes the fundamental unit for the study of human behavior [40].

Figure 3. System activity diagram for WEEE management
Source: Compiled and adapted according to [41, 42].

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Moreover, In TA, clear concepts and ideas are essential to try to find viable solutions to the problems that arise in the context of an interdisciplinary problem leading to sustainability. Thus, the problem-modeling framework identifies the cause of the problems and describes the empirical path to solve the interdisciplinary problems. In addition, it also helps to design policy-oriented social research appropriate to the Guinean context. The modeling of the WEEE activity problem is illustrated in Figure 4: It describes the root causes of WEEE management in Guinea.

Modeling TA solutions for WEEE management involves knowledge acquisition models, perspectives, and artifacts to guide the design of collaborative learning activities in WEEE management in Guinea [43]**.**

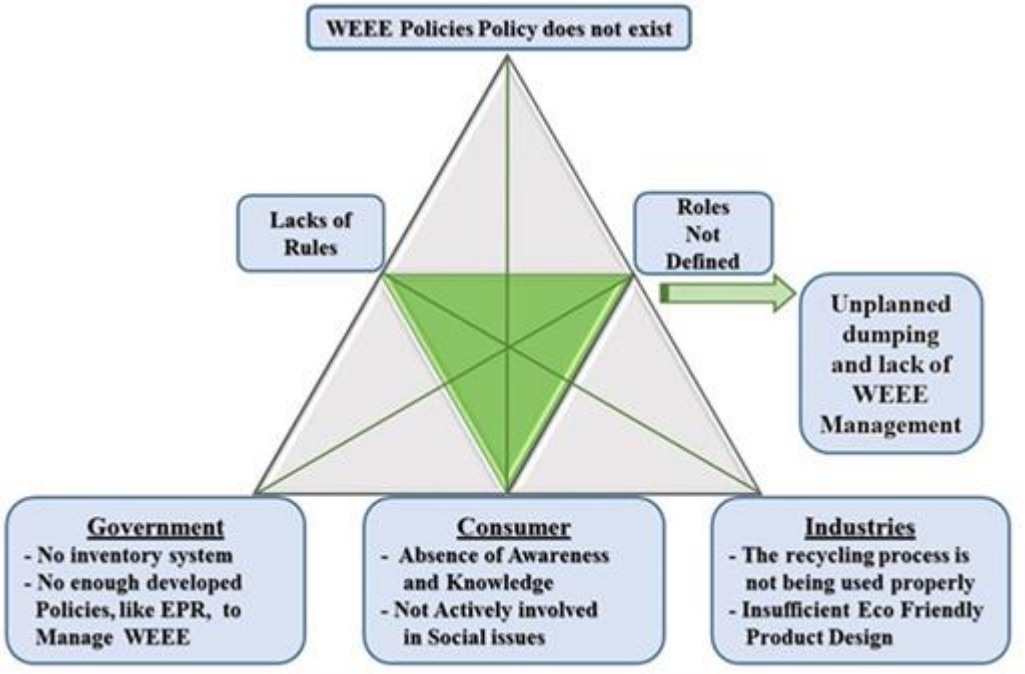

Figure 4. Modeling of system activity problems for WEEE management
Source: Compiled and adapted according to [41,42].

The desired outcome of WEEE management in Guinea can be achieved through education and a participatory approach. More importantly, the essential parameters of modeling the solution for WEEE management are the education system, governance, role of civil society, role of the actor, and inventory system.

The government needs to establish several organizational structures and strategies for the proper management of WEEE to achieve the desired results. These include establishing a WEEE management plan, promoting WEEE collection and handling campaigns, and involving the private sector and NGOs.

Adaptive management arrangement

What does it consist of? It consists of establishing an environmental management instrument through which the producer (individual system) or a group of producers (collective system) presents to the competent authority the actions to be developed for the proper management of WEEE. This plan must be prepared by the stakeholders involved, including importers, repairers (assemblers), traders, and informal workers in the WEEE recycling sector.

WEEE collection and handling campaigns

The campaigns aim to disseminate and raise awareness among the population about the importance of good WEEE management so that this waste is not rejected by HSW collection services to avoid mixing them. But rather through collection points of collective or individual systems set up by the country's administration services, municipal services, company, and others. Its objective will be:

- Raise awareness among the population about the proper management of WEEE.
- Establish among the population the habit of collecting WEEE separately from MSW.

Involving the private sector and NGOs

An increase in waste collection through private sector participation is one avenue to consider. Over the last decade, these organizations have become increasingly important in the overall management of HSW in Guinea. Among HSW management organizations, the most important are limited liability companies and NGOs. Today, many private organizations are involved in waste transportation. Even if the private sector is limited to HSW collection only, its participation remains very encouraging. On a smaller scale, waste collection campaigns are conducted by communities and NGOs, and youth clubs are also involved in waste collection.

Regulate the import of second-hand EEE.

- Developing countries like Guinea have the opportunity to follow the trend of Thailand which, fearing that the Thai market would be overwhelmed by WEEE, imposed restrictions on the importation of used EEE in October 2003, and recently Ghana has also followed this path.

- Ensure efficient shipment tracking, proper marking, and validation of the functionality of used devices.
- Propose the establishment of a WEEE recovery process (renovation and reassembly), the enhancement of raw materials (formal recycling technology), and the energy recovery of the incineration of plastic waste.
- Implementing economic measures such as the advance recycling tax on new and used electrical equipment (preferably based on weight) will generate revenue to finance the proper management of EEE at the end of its life.
- Establishing official recycling structures and adopting legislation on the export of non-functioning equipment.

V. Recommendations

A need for information regarding concentrations in WEEE dismantling sites as well as exposures of informal workers through different routes of exposure to these contaminants.

Although no study on the treatment of environmental contamination by WEEE has been found for Guinea.

It appears beneficial to better understand emissions from WEEE treatment sites, particularly those that use open-air dismantling and incineration of WEEE. It would be possible to monitor dust, particularly trace elements such as Br, Cd, Cu, Pb, Y, and Ba, as well as flame-retardants.

To obtain data (statistics) on the level of environmental pollution, there are two possible options:

- Fund research, screening, and metrology studies to fill data gaps.
- Adopting product reuse methods such as refurbishment and formal recycling will be essential to tame current low-end management practices that are causing negative environmental impacts. As WEEE has become global, finding a global solution is also essential.

It can also support policymakers, environmental management practitioners, and waste sector workers in developing policies related to the circular economy and sustainable WEEE management to achieve the 2030 Sustainable Development Goals.

VI. Conclusion

WEEE is constantly growing. The hazardous substances it contains include heavy metals and halogenated compounds.

In developing countries, it is possible to consider the health consequences for workers and residents of WEEE treatment sites, as shown in the bibliography.

In developing countries like Guinea, the conditions for processing WEEE are more harmful to the environment, employees of repair and recycling workshops, or their inhabitants than in Western countries.

Under the Basel Convention, it is illegal to export significant quantities of EEE to developing countries such as Guinea. However, it appears that the Guinean authorities are mistaken, and are dramatically failing to put into practice and properly implement the Convention for post-consumer WEEE. By not requiring proper testing and labeling to ensure the functionality and quality of the equipment. In addition, to ensure that it does not constitute an exchange of hazardous waste. It is therefore essential to put in place a specific law on WEEE in Guinea.

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