Journal of Materials and Environmental Science
ISSN : 2028-2508
e-ISSN : 2737-890X
CODEN : JMESCN

J. Mater. Environ. Sci., 2024, Volume 15, Issue 3, Page 427-440

http://www.jmaterenvironsci.com

Critical analysis of Waste Electrical and Electronic Equipment (WEEE) management in Côte d'Ivoire: Challenges and prospects

LAMAH Labilé [1,3]*, DEGNI Banah Florent [1,2,3], YABLE D. Didier[2], HABA Cissé Théodore [1,2,3]

[1]*Laboratory of Electronic, Electrical Engineering and Embedded Systems (LIEESE) National Polytechnic Institute Félix Houphouet -Boigny, Yamoussoukro BP 1093, Ivory Coast*
[2]*Laboratory of Instrumentation, Image and Spectroscopy (L2IS)* National Polytechnic Institute Félix Houphouet -Boigny, Yamoussoukro BP 1093, Ivory Coast
[3]*Laboratory of Research in Computer Science and Telecommunications (LARIT)* National Polytechnic Institute Félix Houphouet -Boigny, Yamoussoukro BP 1093, Ivory Coast
**Corresponding author, Email address:* zatioula11512@gmail.com

Received *28 Feb 2024,*
Revised *19 Mar 2024,*
Accepted *22 Mar 2024*

Keywords:
- ✓ *E-waste;*
- ✓ *Management;*
- ✓ *Technology;*
- ✓ *Ecology*

Citation*: Lamah L., Degny B. F., Yable D. D. Haba C. T. (2024) Critical analysis of Waste Electrical and Electronic Equipment (WEEE) management in Côte d'Ivoire: Challenges and prospects, J. Mater. Environ. Sci., 15(3), 427-440*

Abstract: In this study, we assess the current management of Waste Electrical and Electronic Equipment (WEEE) in the Republic of Côte d'Ivoire. This assessment is based on a field survey that involved various key players, including importers, distributors, consumers, repairers, collectors and recyclers of WEEE, as well as government departments such as the Ministry of the Environment and the General Directorate of Customs. The study highlights the multiple challenges facing the WEEE sector, encompassing social, economic, environmental, political and technological aspects. It examines the lack of appropriate technologies for the treatment of WEEE, the problems of traceability of Electrical and Electronic Equipment (EEE) linked to imports, and the shortcomings in the application of institutional and legislative decisions. Firstly, we describe the limitations of unconventional methods of managing WEEE, such as open-air incineration, burial in soil, abandonment in the wild, and unprotected manual dismantling. We then identify the main challenges hindering the application of conventional WEEE management methods, highlighting the lack of information and financial support. Finally, we present some preliminary results from a sample of two scrapyard sectors, in Marcory and Adjamé. These results underline the crucial importance of implementing a national plan for the sustainable management of WEEE, as well as developing environmentally- friendly and economically viable technologies capable of handling all fractions of WEEE, particularly plastics and glass.

1. Introduction

The advent of the industrial revolution has led to significant developments in technology and engineering on a global scale. Every year, this technological evolution generates a considerable quantity of Waste Electrical and Electronic Equipment (WEEE). The lifespan of this equipment is increasingly shortened by programmed obsolescence, rapidly condemning it to the status of waste (Dieng *et al.* (2018). According to European regulations, WEEE covers a wide range of devices operating at voltages of up to 1000 volts DC or 1500 volts AC. They include large and small household appliances, IT and telecommunications equipment, consumer equipment, lighting devices, power tools,

leisure and sports equipment, non-implanted medical devices, control and monitoring instruments, and vending machines (Douet. (2018) . The major problem lies in the exponential growth of global WEEE production, estimated at around 300%, three times higher than the total solid waste stream going to landfill (Kong *et al.* (2012). In 2015, more than 93.5 million tonnes of WEEE were produced worldwide (Wang *et al.*, 2016). Some countries in Europe and the USA illegally export it to developing countries, mainly in Africa (Ohajinwa *et al.* (2018). Although these WEEEs represent only 2% of the total solid waste stream, they are an important secondary source of raw materials, including base, rare and precious metals, while making up 70% of the hazardous waste stream destined for landfills (Li & Achal, (2020); Zhao *et al.* (2008). The unconventional management of these wastes has harmful consequences for the soil, leading to the leaching of toxins (Cesaro *et al.* (2019), air pollution through the release of dioxins and furans during incineration (Singh *et al.* (2020), as well as impacts on human health, including anaemia due to cadmium toxicity (Moeckel *et al.* (2020), nervous system disturbances, hormonal disorders, altered cell growth and development, adverse reproductive effects, immune system damage, and even cancer (Gangwar *et al.* (2019) . Faced with these challenges, international institutional and governmental decisions have been taken to regulate the cross-border transport and treatment of WEEE. These include Recommendation N°177 of 1990 on the responsible use of chemicals (Asibey *et al.* (2021), the Basel Convention of March 22, 1989 governing the control of transboundary movements of hazardous wastes and their methods of disposal (Khan. (2020), the Minamata Convention adopted in 2009 (Selin & Selin. (2022) to protect human health and the environment against mercury emissions and to regulate gold mining, the 1998 Rotterdam Convention (revised in 2017) establishing procedures for the application of certain hazardous chemicals and pesticides (Manuilava. (2021), the 2001 Stockholm Convention (revised in 2015) on persistent organic pollutants, the European Union directive on waste electrical and electronic equipment (Selin & Selin. (2022), and the January 30, 1991 Bamako Convention prohibiting the import of hazardous waste into Africa and regulating the transboundary movement and management of hazardous waste generated in Africa (Matemilola & Fadeyi. (2020). Despite the Republic of Côte d'Ivoire's adherence to several of these conventions, it has not yet succeeded in integrating the sustainable management of WEEE into its overall solid and liquid waste management policy. Craftsmen in search of precious metals such as copper adopt practices that are detrimental to their health and the environment (Ike-Eze et al. (2023). Our aim is to carry out a national diagnosis of the current situation of WEEE management, by comprehensively studying the process from import to collection, sorting and recovery (Asante et al. (2019). This article first presents the methodology we used, then the results obtained from this approach.

2. Methodology

2.1. Introduction to Côte d'Ivoire

The Republic of Côte d'Ivoire is a coastal country in West Africa, bordered by Ghana to the east, Guinea and Liberia to the west, Mali and Burkina Faso to the north, and the Atlantic Ocean to the south. It covers an area of 322,462 km2 and has a population of around 26 million, 50% of whom live in urban areas. The country has two seaports, the Autonomous Port of Abidjan, which handles imports of electrical and electronic equipment, and the port of San-Pedro. We chose to study the District of Abidjan, the economic capital, as well as the city of Yamoussoukro, the political capital. Our choice was justified by the widespread access to electricity, which conditions the acquisition and use of electronic equipment.

2.2. Policy framework

To better structure our survey questionnaire and draw up our specifications for field observations, we visited several departments. The main objective of these visits was to take stock of and evaluate the current WEEE management systems in Côte d'Ivoire. Our observations revealed that, in Côte d'Ivoire, waste management is mainly focused on solid waste, while waste from electrical and electronic equipment is often neglected or poorly managed, despite efforts by the authorities to take decisions and participate in international conventions.

The country does not prohibit the import of used electronic equipment, resulting in the importation of over 10,000 tonnes of second-hand electrical and electronic equipment every year. Some of this equipment is destined for re-use, while others are intended as spare parts for other electronic devices. To regulate this sector, the Ivorian government has taken several decisions at national and international level, including:

- Law No. 88-651 of July 7, 1988 on the protection of public health and the environment against the effects of toxic and nuclear industrial waste and noxious substances;
- Decree No. 94-327 of June 9, 1994 on accession to the Basel Convention;
- Decree No. 94-330 of June 9, 1994 on accession to the Bamako Convention;
- Law No. 96-766 of October 7, 1996 formally prohibits the import of hazardous waste into Côte d'Ivoire, and Order No. 00710 of 2008 prohibits the import or export of industrial waste destined for recovery;
- Decree No. 96-894 of November 8, 1996 determining the rules and procedures applicable to studies of the environmental impact of development products;
- Decree No. 98-43 of January 28, 1998 on facilities classified for environmental protection;
- Decree No. 2003-228 of July 10, 2003 ratifying the Stockholm Convention;
- Law N°214-390 of June 20, 2004 on sustainable development;
- Decree No. 2005-03 of January 6, 2005 on environmental auditing;
- Decree No. 2017-217 of April 05, 2017 on the environmentally sound management of waste electrical and electronic equipment;
- Decree N°2017-692 of October 25, 2017 on the creation, attribution, organization and operation of the industrial and commercial public establishment called National Waste Management Agency.

In addition to these decrees and laws, projects have been set up to further regulate the sector, including a project dedicated to the rational management of Non-Intentional Persistent Organic Pollutants and Polybrominated Diphenyl Ethers, aimed at reducing their emissions from the industrial waste sector, with the support of the Global Environment Facility (GEF). These initiatives have led to the proposal of draft laws concerning industrial waste, the application of the Basel Convention, the creation of youth cooperatives for the collection and treatment of end-of-life vehicles and WEEE, and the classification of hazardous waste.

2.3. Data acquisition

To gather crucial data for our study, we undertook an exhaustive survey as well as direct observation in dismantling and recovery facilities for Waste Electrical and Electronic Equipment (WEEE) in two specific cities. This methodological approach involved several key stages.

Firstly, we gathered information from pre-prepared data sheets, which we had completed by a representative sample of 50 importers, 100 public and private institutions, 250 households, 50 repairers, 100 recyclers and 50 reclaimers, carefully selected at random. This diversity of players in the WEEE

chain enabled us to gain a comprehensive perspective on the issue. Then, for users of electrical and electronic equipment (both institutions and households), we made a selection across various neighborhoods, divided into three distinct categories according to standard of living, which often defines the conditions for equipment acquisition. In Abidjan, these categories included high standard (such as Millionaires in Yopougon and Kokui in Abobo), medium standard (such as Soguéla in Abobo, Quartier résidentiel in Cocody, Alocodrome in Cocody) and low standard (such as Vietnam in Cocody, Kenedi in Abobo, Banko in Yopougon). In Yamoussoukro, they included high-standard (with 220 homes), medium-standard (such as Kokrénou) and low-standard (such as Djihakro).

The main objective was to identify and evaluate verifiable information concerning the working conditions of players operating in the WEEE management chain, as well as their level of awareness of the associated risks. In addition, we sought to establish traceability, from the initial import of electronic equipment to its declared waste status.

Finally, we conducted interviews with the relevant administrative authorities to gain an in-depth understanding of the laws in force, the conditions for importing second-hand equipment, and the current WEEE management plan. Institutions such as the Direction Nationale de la Douane, the Ministry of the Environment, the National Waste Management Agency, municipalities, and the Association of modern scrap merchants in Côte d'Ivoire (AFECAM-CI) were essential partners in this quest for crucial knowledge.

3. Results and discussion

3.1. Import and use of electrical and electronic equipment

In this study, we took a close look at two groups of importers of electrical and electronic equipment in Côte d'Ivoire. Firstly, there are the importers of new equipment, such as the Max DATA group in Marcory zone 3, Intel Afrique in Le Plateau, Les Virus in Le Plateau and Treichville, and Samsung, Sony, LG in Le Plateau. In parallel, we also studied second-hand equipment importers, generally based in the Adjamé Mirador electronics market. These importers were identified in Abidjan, the economic capital, and are closely linked to the presence of the port, which serves as the main gateway for electronic equipment into the country.

We paid particular attention to the provenance and working order of second-hand equipment. In this context, we found that 96% of these importers source their goods from Europe, 3% from the USA, and 1% from Asia and some West African countries (figure 1). It is important to note that the import sector for electronic equipment in Côte d'Ivoire remains poorly organized, making it difficult to trace and precisely control the quantity of equipment imported.

Among imported second-hand equipment, we found mainly televisions (30%), cell phones (5%), computers (10%), refrigerators and freezers (40%), and other small appliances (15%) (figure 2). Many of these items are functionally tested on receipt, while others are resold without prior verification. Of all the equipment tested, 76% was found to be functional and ready for use without repair, 20% required minor reconditioning, and 4% was beyond repair, being declared as waste for disposal. It is crucial to note that the import of second-hand equipment must comply with the current provisions of the Basel and Bamako Conventions, having become the main route for WEEE in various forms to enter Ivorian territory **(**Matemilola & Fadeyi. (2020**)**.

After import, equipment distribution begins, serving as a link between importers and end-users. In this phase, we have identified three groups of distributors: those who distribute new equipment, those who specialize in second-hand equipment, and those who offer a mixed range of products. It should be noted

that 80% of second-hand equipment distributors are foreign nationals, mainly from Nigeria, Niger and Mali.

Two groups of electronic equipment users were also identified. Small users, such as households, include refrigerators, freezers, air conditioners, laptops, cell phones, radios, televisions, video players, irons, light bulbs and various small household electronic appliances. Larger users, such as companies and public and private institutions, mainly use desktop and laptop computers, air conditioners, printers, photocopiers and light bulbs.

The user survey revealed that 35% of the equipment acquired was new, particularly among heavy consumers, while 60% was second-hand equipment in perfect working order. Around 4% were also second-hand, with some minor malfunctions, while a small percentage (1%) showed major problems.

We also looked at how long equipment lasts with users. This varies according to the user's standard of living, the type of equipment and its condition at the time of purchase (new or second-hand). On average, it ranges from six (06) months for light bulbs, two (02) years for cell phones, five (05) years for televisions, two (02) years for small household appliances, four (04) years for computers, three (03) years for printers and photocopiers, five (05) years for air conditioners, three (03) years for fans, and ten (10) years for refrigerators.

When this electronic equipment reaches the end of its useful life, it either undergoes a reconditioning process or is declared as waste. In this context, 90% are entrusted to repairers for reconditioning or remain stored at home, 2% are treated as other household solid waste and thrown into the garbage can, while 8% are sold to metal collectors at prices ranging from 200 to 800 FCFA per kilogram.

When we asked participants about the risks associated with the unconventional management of WEEE, particularly with regard to handling and storage, as well as the existence of legislation governing this sector, we found that only 8% of respondents (mainly among large consumers) had limited knowledge of these issues, while 92% stressed that this category of waste had no consequences and that they were unaware of any legislation regulating this sector. The electronics market is awash with second-hand equipment. Indeed, 98% of refrigerators and over 70% of computers.

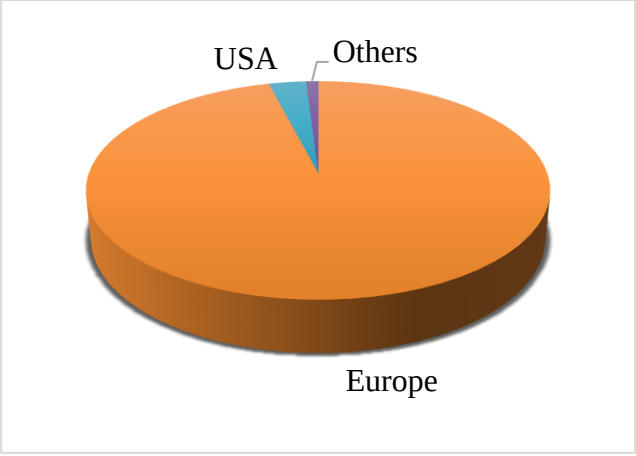

Figure 1: Provenance of hand-held electronic equipment

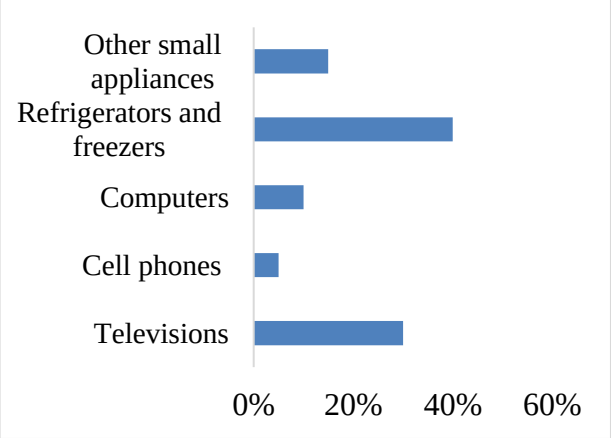

Figure 2: Secoud-hand electronic equipment imported into Cote d'Ivoire

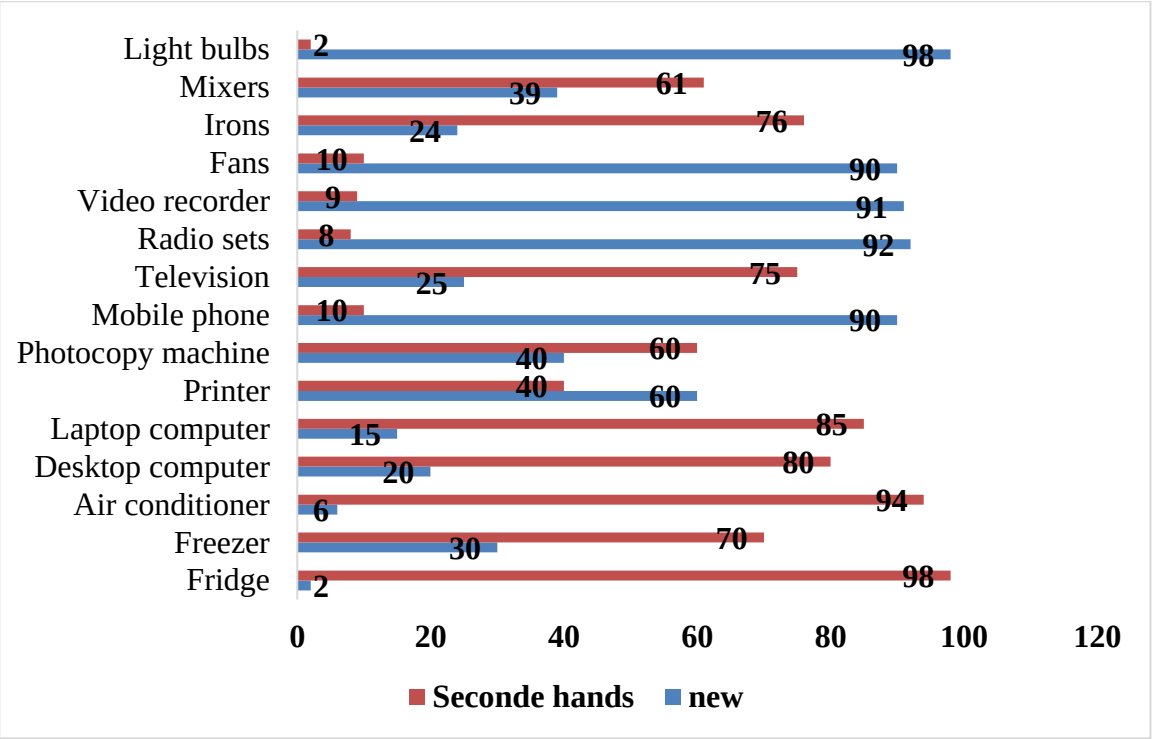

Figure 3 : Acquisition rates by operating status

Here is a summary of the equipment identified and their annual operating times, as shown in the following table 1:

Table 1: Equipment surveyed and duration of use

N°	Equipment	Quantity counted (units)	Useful life (years)
1	Fridges / Freezer	522	10
2	Air conditioners	1503	8
3	Desktop computers /Laptop computers	1700	4
4	Photocopy machines / Printers	330	3
5	Mobile phones	6200	2
6	Televisions	300	5
7	Radio sets	40	3
8	Video recorder	20	3
9	Fans	600	3
10	Irons	280	2
11	Mixers	150	2
12	Light bulbs	1300	0,46

3.2. Current WEEE management in Côte d'Ivoire

The management of Waste Electrical and Electronic Equipment (WEEE) in Côte d'Ivoire poses a significant problem, particularly when such equipment is declared as waste or becomes no functional in the eyes of users. Reconditioning is emerging as the first approach to recovery, offering a chance to extend the life of such equipment. This activity, although mainly informal, contributes to job creation. Surprisingly, among the craftsmen who engage in this sector, 78% have no training in electronics, or even a basic education in this field. They enter the trade out of necessity, often due to a lack of other

employment opportunities. The remaining 22% have received training in reconditioning workshops. In these workshops, we identified various types of appliances, including fans, air conditioners, refrigerators, telephones and computers, according to their respective specialties. However, this business faces a number of challenges, such as customers not picking up equipment when repair costs are high, lack of materials, and difficulties in sourcing specific spare parts. As a result, much equipment is declared as waste, when it could have been reconditioned for further use, but this does not happen due to a lack of professionalism. It is important to note that, in our observations, reconditioning activities are carried out without any protection.

When the equipment is finally considered to be waste, collection comes into play. Collection is generally carried out by young people aged between 8 and 30. They regularly scour the city with bags, weighing scales and sometimes screwdrivers, looking for metal waste other than WEEE. There is no specialized collection channel for WEEE, which is treated like other scrap metal. Potential sources of supply for these collectors include households (27%), public and private services (7%), stores that import and distribute second-hand electronic equipment (30%), reconditioning workshops (23%) and garbage cans (13%). Some of these collectors sort their waste at source, thus avoiding long-distance transport of fractions with no market value. The waste collected is then transported and sold to dismantling sites for possible recovery.

WEEE processing sites were at the heart of our observation, as we were primarily seeking to assess the methods and techniques used to recover WEEE (figure 4). These sites are organized and managed by the Association of modern scrap merchants in Côte d'Ivoire (AFECAM-CI), represented by branches in various communes of Abidjan (Adjamé, Abobo, Yopougon, Koumassi, Marcory-Anoumabo, Port-Bouët) as well as in the towns of Bingerville, Dabou, Bouaké, Korhogo and Bouna. Craftsmen working in these junkyards are involved in dismantling, crushing, dismantling, reconditioning and even incineration, with the aim of recovering spare parts, copper, scrap metal, aluminum, or giving new life to equipment. These activities are mainly carried out by men aged between 20 and 45. However, women and children have been spotted on these sites, mainly involved in commercial activities. Surprisingly, 70% of these recyclers have no formal training in this field, while 30% hold diplomas, albeit in completely different areas of e-waste management.

Figure 1 *:* WEEE dismantling workshop

Dismantling and recovery sites represent the final destination of collected WEEE. Here, the equipment is dismantled, shredded and regrouped into various fractions of interest (as illustrated in figure 2). The methods employed are often unconventional, unprotected and involve the use of rudimentary tools. It

is important to note that many fractions are not taken into account in this value chain. Plastic carcasses and wire sheaths are often incinerated in the open air, buried in the ground, or thrown into the garbage can. Similarly, glass, generally from electric lamps and screens, is sent to landfill. Only base metals such as copper, iron and aluminum are recycled locally as raw materials for kitchen utensils and other small tools, by local smelters and blacksmiths. Precious metals such as gold and silver are not recovered due to a lack of knowledge and dedicated technologies. These metals remain in electronic components and printed circuit boards, untreated figure 4. The map of Côte d'Ivoire, the autonomous district of Abidjan, and the specific locations where we conducted our study are illustrated in figure 5 below.

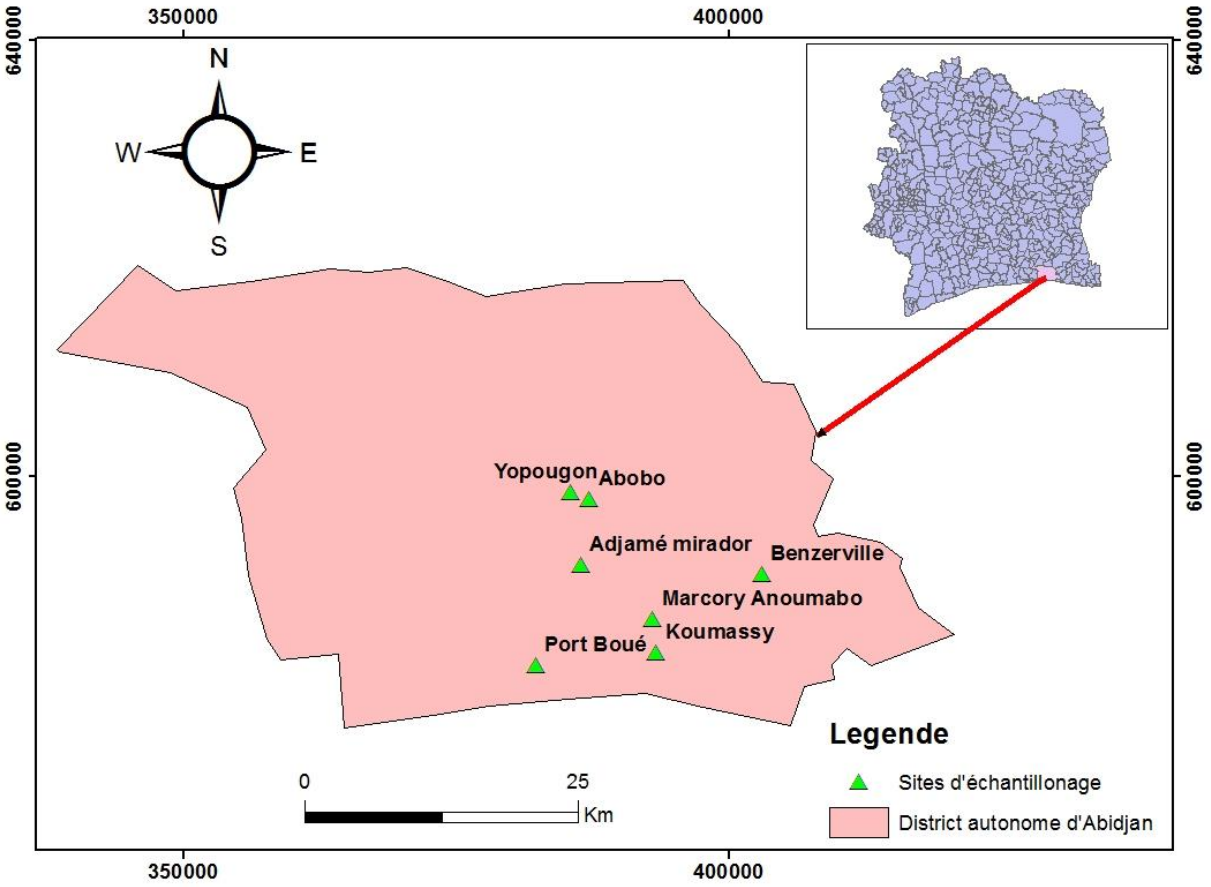

Figure 2 : WEEE dismantling site

3.3. Constraints to the sustainable management of WEEE in Côte d'Ivoire

In addition to the failure to comply with, and insufficient monitoring of, the laws and regulations in force, our study has highlighted a series of major problems in the management of waste electrical and electronic equipment (WEEE) in Côte d'Ivoire, from the import of such equipment to the process of dismantling the resulting waste.

We have noted that customs authorities do not have full control over the flow of electrical and electronic equipment entering the country. In particular, when second-hand equipment is imported, waste is not properly declared, and customs do not have the necessary means to distinguish between equipment in good condition and that which is no longer in working order. What's more, importers and distributors are not organized within a structure, which makes it difficult to gather precise information on their numbers, the brands of equipment they import, and above all distribution rates. As a result, it is extremely complex to know the total quantity of imported equipment, and to establish effective

traceability for this electrical and electronic equipment. Inexplicably, a significant proportion of electrical and electronic equipment declared as waste remains stored in households, without being properly managed.

Workers involved in WEEE management operate in the informal sector, using rudimentary tools such as hammers, fire, screwdrivers and pliers. We observed significant exposure of workers, vendors and even children to serious health risks. Some have reported developing skin diseases, cancers, heart problems and respiratory disorders. These illnesses are probably linked to unprotected handling of the toxic components present in WEEE. Dismantling residues, made up of plastic, glass and fragments of electronic cards, are often dumped in the lagoon, where artisanal fishing is carried out by children. Following our surveys, we found that many workers, instead of burning electrical cables, strip them with knives, this change in behavior being the result of an awareness-raising campaign on the dangers of cable burning conducted by the UPOP project.

All these craftsmen say they are ready to adopt other techniques and technologies if the conditions of acquisition are affordable. Although the majority of them do not yet fully understand the consequences of WEEE management, they are seeking support from the government and other institutions for funding and technical regulation of their sector.

As a result of our investigation, we have identified a number of feasible avenues to explore and propose for the overall management of WEEE. For future research, it would be imperative and beneficial to:

- Study the environmental and health impacts of non-conventional WEEE management in Côte d'Ivoire;
- Carry out a statistical study on the exact total quantity of waste electrical and electronic equipment produced and available in Côte d'Ivoire;
- Set up systems or programs to enable customs to sort second-hand equipment and declare waste;
- Find environmentally-friendly ways of recovering the non-metallic fraction (glass and plastic) and the precious metals contained in this waste.

3.4. Proposal to set up a WEEE management program

The rational and sustainable management of WEEE must be based on a decentralized global plan, with priority given to health and environmental protection and the economic recovery of the resulting products and by-products. It must take into account the socio-economic, geographical and political realities of the area of application, from awareness-raising and collection to recovery and disposal.

The plan is to be managed by a decentralized committee made up of traditional chiefs, administrative and communal authorities, health workers, environmental engineers, Ministry of Transport staff and education officials. The committee's tasks include information and awareness-raising, pre-collection, collection, transport, recycling, processing and disposal.

Awareness-raising: Our survey revealed that people do not have enough information about the risks and benefits of WEEE. Awareness and information campaigns will therefore be carried out mainly in the media and in higher education and pre-university establishments. These messages will focus on the health and environmental consequences and economic losses arising from the current unconventional management of WEEE.

Placed under the responsibility of the Ministry of the Environment, the WEEE management program aims to encourage the principle of extended producer responsibility for WEEE, to ensure environmentally sound management, to promote reconditioning and recycling with the aim of collecting a significant number of WEEE produced in the country, and to actively involve the players

concerned in WEEE management. It also aims to avoid the disposal of WEEE by open burning, in water, in landfill or by abandonment.

First level of collection: One of the most important phases in the management of WEEE in developing countries is undoubtedly the recovery of appliances once they have been declared waste. In most cases, this waste is stored at the user's premises. In such cases, an incentive-based recovery policy should be considered in collaboration with distributors. Garbage cans dedicated solely to the pre-collection of WEEE of all kinds will be installed in each village or district (8,000) and will be managed by a community agent under the responsibility of the village or district chief. Beyond this corporation, local AFECAMCI representatives will be given the technical tools they need to carry out this activity.
Second collection level: WEEE collected from households (neighborhoods and villages) will be transported to collection centers located in 143 communes across the country. Under the direction of the commune authorities or the AFECAMCI manager, the teams at these centers will be equipped with personal protective equipment, packaging materials and vehicles. Waste will be packaged according to the type of WEEE. The following information will be noted on the packaging: type of WEEE, recovery date, batch weight, number of WEEEs in the batch, origin.
Third collection level: Storage centers will be set up in each department (19 in all). These stores will serve as transition points for WEEE. The managers of these stores will group WEEE of the same category in containers, then label them with the same information and work tools.
Fourth level: 10 sorting centers will be set up in the regional capitals. These centers will be staffed mainly by computer and electronics technicians and engineers. Their main task will be to test equipment to determine whether it should be declared as waste, or whether it can be reconditioned for a new use. The reconditioning departments of these centers will take charge of bringing the equipment back into working order and putting it on the market for a new life. Equipment declared as waste will be carefully conveyed to the national WEEE management center table 2.

National WEEE processing center:
The final destination of waste electrical and electronic equipment declared at the sorting centers is the national WEEE processing center. This center must be located in an isolated area, far from human and animal zone. It must have two departments, one for recovery and the other for decontamination and disposal. It will have to comply with the regulations of decree No. 2017-217 of April 5, 2017 on the environmentally sound management of waste electrical and electronic equipment. To this end, it will be required to have operating permits, an emergency plan, comprehensive pollution liability insurance, scales and a system for recording waste admitted to the center, an impermeable floor, liquid recovery channels, decanters, cleaner-degreasers, a fire-fighting system, lightning rods.
Special mention will be given to depollution, as recommended by the provisions in force under European WEEE regulations. The components concerned will be extracted and treated individually: those containing mercury, batteries, printed circuit boards, ink cartridges, plastics containing polybrominated biphenyls and polybrominated diphenyl ethers, elements containing asbestos, cathode ray tubes, chlorofluorocarbon compounds, hydrochlorofluorocarbons, LCDs, radioactive compounds and condensers.
The equipment concerned includes battery cells, printed circuits, cathode ray tubes, printer cartridges, plastics containing brominated flame retardants, discharge lamps and liquid crystal displays figure 6.

Table 1 : Planned areas for collection points (green), sorting and reconditioning points (yellow) and storage and transition points (red)

Chief town	Departments	Communes
Abidjan		Abobo, Adjamé, Attecoubé, Cocody, Koumassi, Marcory, Plateau, Port-Bouet, Treichville, Yopougon, Anyama, Bingerville, Songon,
	Dabou	Alépé, Oghwyapo, Sikensi, Grand-Lahou, Jacqueville, Tiassalé, Taabo
Korhogo	Boundiali	Dikoudougou, Guiembé, Karakoro, Gorhogo, Komborodougou, M'bengue, Napieledougou, Niofoin, Tioroniaradougou, Sinematiali, Sirasso, Gbon.
	Ferkessedougou	Diawala, Kong, Koumbala, Nielle, Ouangolodougou, Kanakono, Tengrela
Aboisso		Ayame, Bianouan, Mafere, Tiapoum, Assinie-Mafia, Grand-Bassam, Bonoua
Daloa		Bédiala, Gadouan, Gboguhe, Zaibo, Zoukougbeu, Boguedia, Iboguhe, Issia, Saioua, Dania, Seitifla, Vavoua
Agboville		Azaguie, Grand morie, Rubino, Adzopé, Affery, Becedi-Brignan, Akoupé
Abengourou		Bettie, Niable, Agnibilekrou
Bouaké		Diabo, Botro, Bouké, Languibonou, Beoumi, Bodokro, Kondrobo, Bassawa, Dabakala, Samata-Sokouro, Katiola, Niakaramandougou, Tafire, Sakassou
Man		Facobly, Kouibly, Logouale, Sangouiné, Semien, Niadrou, Totrodrou,
	Danané	Bangolo, Biakouma, Sipilou, Bin-houye, Zouan- hounien, Mahapleu
Divo		Fresco, Guitry, Hiré, Yocoboué, Lakota, Niambézaria, Zikosso
Gagnoa		Bayota, Gnagbodougnoa, Guiberoua, Ouragahio, Oumé, Diégonéfla, Oumé
Yamoussoukro		Didievi, Attiégouakro,
	Tiebissou	Tié-n'diékro
	Toumodi	Djekanou, Angoda, Kpouebo, Kokoumbo
Guiglo	Duekoué	Bagohouo, Gbapleu, Guihiebly, Guézon
		Tai, Toulepleu, Bakoubly, Péhé, Tiobly,
Bondougou		Gouméré, Tabagne, Sorobango, Sapli, Sandégué, Bouna, Nassian, Tehini, Tanda, Assuefry, Transua, Tankessé
Touba		Booko,Borotou, Guintéguéla, Koonan, Koro, Ouaninou, Foungbesso
San-Pédro		Grand-Béréby, San-Pédro
	Soubré	Gueyo, Sassandra, Buyo, Grand-Zattry, Méagui, Okrouyo Grabo, Tabou,
Dimbokro		Anoumaba, Arrah, Bongouanou, M'batto,Tiemelékro, Bocanda
	Daoukro	Ettrokro, Kouassi-Kouassikro, Ouellé, M'bahiakro, Banguera, Prikro
Bouaflé		Bonon, Sinfra, Kouetinfla, Bazré, Gohitafla, Zuenoula
Séguéla	Mankoko	Dianra, Kongasso, Kouahiri, Marandallah, Sarhala, Tieningboue
		Djibrosso, Dualla, Kani, Massala, Morondo, Séguéla,
Odienné		Bako, Dioulatiedougou, Gbeleban, Goulia, Kaniasso, Madinani, Minignan, Samatiquila, Séguélon, Seydougou, Tiémé, Tienko

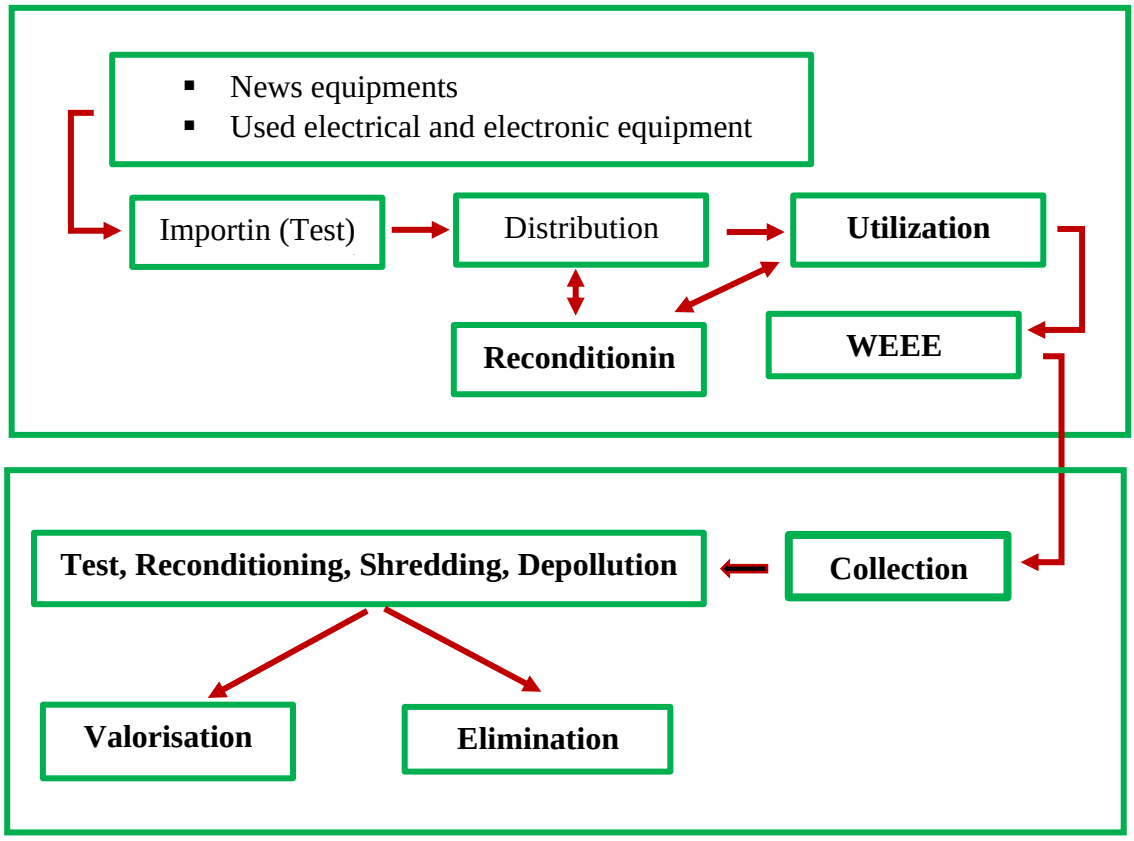

Figure 3 : Diagram describing the management of WEEE from import to recovery or disposal

4. Conclusion

This study has successfully confirmed the non-recovery of waste electrical and electronic equipment in the Republic of Côte d'Ivoire. We have validated the hypothesis of the existence of significant quantities of unrecycled electronic waste. This finding was supported by the actions taken by the authorities through legislative and institutional decisions aimed at regulating this issue.

We have demonstrated that the economic losses as well as the environmental and health risks resulting from the exposure of individuals and their environment to this category of waste call for urgent action in a number of areas. Despite the efforts made by the authorities through these legislative and institutional measures, it is clear that technical and technological solutions must be envisaged for ecological management, guaranteeing protection of the environment and human health, and promoting the circular economy.

We assessed the processes and methods used to collect, transport and recycle e-waste as less efficient and unconventional. The implementation of sustainable technologies is seen as a solution to remedy this deficient management, notably by offering financial support to the workers involved. However, it was also noted that the use of these sustainable technologies is hampered by a lack of capacity building and reluctance to use protective equipment at work due to their perceived discomfort.

The results of this study clearly underline that the integration of new and economically accessible technologies is the way forward for rational management that limits the waste of raw materials and reduces health and environmental risks. This requires a holistic approach, involving changes to current practices, investment in training and capacity building, and strict compliance with existing laws and regulations for more sustainable management of waste electrical and electronic equipment in Côte d'Ivoire.

Acknowledgement: We would like to thank the African Centre of Excellence for the Valuation of Waste (CEA-VALOPRO).

Disclosure statement: *Conflict of Interest:* The authors declare that there are no conflicts of interest.

References

Asante, K. A., Amoyaw-Osei, Y., & Agusa, T. (2019). E-waste recycling in Africa : Risks and opportunities. *Current Opinion in Green and Sustainable Chemistry*, *18*, 109-117. https://doi.org/10.1016/j.cogsc.2019.04.001

Asibey, M. O., King, R. S., Lykke, A. M., & Inkoom, D. K. B. (2021). Urban planning trends on e-waste management in Ghanaian cities. *Cities*, *108*, 102943. https://doi.org/10.1016/j.cities.2020.102943

Cesaro, A., Belgiorno, V., Gorrasi, G., Viscusi, G., Vaccari, M., Vinti, G., Jandric, A., Dias, M. I., Hursthouse, A., & Salhofer, S. (2019). A relative risk assessment of the open burning of WEEE. *Environmental Science and Pollution Research*, *26*(11), 11042-11052. https://doi.org/10.1007/s11356-019-04282-3

Dieng, D., Diop, C., Sonko, E. H., Gning, J., Djitte, M., & Gassama, C. (2018). Gestion des déchets d'équipements électriques et électroniques (DEEE) au Sénégal : Acteurs et stratégie d'organisation de la filière. *International Journal of Biological and Chemical Sciences*, *11*, 2393. https://doi.org/10.4314/ijbcs.v11i5.35

Douet, M. (2018). La circulation inverse des déchets d'équipements électriques et électroniques (DEEE) : Entre consolidation et développement. *Logistique & Management*, *26*(1), 3-14. https://doi.org/10.1080/12507970.2017.1384702

Gangwar, C., Choudhari, R., Chauhan, A., Kumar, A., Singh, A., & Tripathi, A. (2019). Assessment of air pollution caused by illegal e-waste burning to evaluate the human health risk. *Environment International*, *125*, 191-199. https://doi.org/10.1016/j.envint.2018.11.051

Ike-Eze, I. C. E., Ucheji, O. N., Ubi, P. A., Oji, E. O., Aigbodion, V. S., Omah, A. D., & Ogbuefi, U. C. (2023). *An Overview of Flame Retardants in Printed Circuit Boards for LEDs and other Electronic Devices*.

Khan, S. A. (2020). Clearly hazardous, obscurely regulated : Lessons from the Basel convention on waste trade. *American Journal of International Law*, *114*, 200-205. https://doi.org/10.1017/aju.2020.38

Kong, S., Liu, H., Zeng, H., & Liu, Y. (2012). The Status and Progress of Resource Utilization Technology of e-waste Pollution in China. *The Seventh International Conference on Waste Management and Technology (ICWMT 7)*, *16*, 515-521. https://doi.org/10.1016/j.proenv.2012.10.071

Li, W., & Achal, V. (2020). Environmental and health impacts due to e-waste disposal in China – A review. *Science of The Total Environment*, *737*, 139745. https://doi.org/10.1016/j.scitotenv.2020.139745

Manuilava, H. (2021). *The Rotterdam Convention and the Republic of Belarus : Adherence matters*.

Matemilola, S., & Fadeyi, O. (2020). Bamako Convention. *Encyclopedia of Sustainable Management*, 1-5. https://doi.org/10.1007/978-3-030-02006-4_522-1

Moeckel, C., Breivik, K., Nøst, T. H., Sankoh, A., Jones, K. C., & Sweetman, A. (2020). Soil pollution at a major West African E-waste recycling site : Contamination pathways and implications for potential mitigation strategies. *Environment International*, *137*, 105563. https://doi.org/10.1016/j.envint.2020.105563

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

Selin, H., & Selin, N. E. (2022). From Stockholm to Minamata and beyond : Governing mercury pollution for a more sustainable future. *One Earth*, *5*(10), 1109-1125. https://doi.org/10.1016/j.oneear.2022.09.001

Singh, N., Duan, H., & Tang, Y. (2020). Toxicity evaluation of E-waste plastics and potential repercussions for human health. *Environment International*, *137*, 105559. https://doi.org/10.1016/j.envint.2020.105559

Wang, J., Guo, J., & Xu, Z. (2016). An environmentally friendly technology of disassembling electronic components from waste printed circuit boards. *Waste Management*, *53*, 218-224. https://doi.org/10.1016/j.wasman.2016.03.036

Zhao, G., Wang, Z., Dong, M. H., Rao, K., Luo, J., Wang, D., Zha, J., Huang, S., Xu, Y., & Ma, M. (2008). PBBs, PBDEs, and PCBs levels in hair of residents around e-waste disassembly sites in Zhejiang Province, China, and their potential sources. *The Science of the Total Environment*, *397*(1-3), 46-57. https://doi.org/10.1016/j.scitotenv.2008.03.010

(2024) ; http://www.jmaterenvironsci.com