E-WASTE MANAGEMENT IN ALEPPO

A Technical Research Paper

Introduction and Background[1]

Electronic waste (e-waste), such as mobile phones, computers, televisions, batteries, and household electrical appliances that have reached the end of their useful life or are no longer in use, represents a growing environmental and public health threat worldwide. This risk stems from the presence of toxic heavy metals—such as lead, mercury, and cadmium—and harmful chemical compounds, which require special management to prevent negative impacts on human health and the environment.

Syria is among the countries increasingly affected by this challenge. Population growth, rapid technological change, the widespread availability of low-cost electronic devices, low levels of environmental awareness, and the absence of binding legislation and institutional frameworks have all contributed to the escalation of the problem. At the national level, Syria lacks specific laws or enforceable regulations governing e-waste management. Instead, the country is party to several international agreements addressing hazardous waste in general, including the Basel Convention, the Rotterdam Convention, the Stockholm Convention, and the Minamata Convention.

In parallel, there is no organized infrastructure for the collection or treatment of electronic waste. The impacts of prolonged conflict and economic hardship have further compounded the issue, making safe and systematic management increasingly difficult.

This report sheds light on the issue of electronic waste in the city of Aleppo, Syria, with a focus on the current situation and its environmental and social impacts. It attempts to estimate e-waste quantities and examine existing collection and treatment practices. It should be noted that detailed, city-level data—particularly for Aleppo—are scarce or unavailable, although indicative estimates exist, such as an average of approximately 4.6 kg of electronic devices available per capita in the market.

The objective of this paper is to provide a technical and research-based analysis of the e-waste situation in Aleppo, identify practical intervention points, and develop implementable recommendations for collection, reuse, and recycling mechanisms suitable for a resource-constrained environment.

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Executive Summary

4. Overview

This paper presents a comprehensive analysis of the electronic waste (e-waste) challenge in the city of Aleppo, Syria, within a context characterized by infrastructure collapse, weak legislation, and the absence of formal systems for the safe management of hazardous waste streams.

Electronic waste generated from mobile phones, computers, televisions, batteries, household appliances, and damaged solar energy systems poses an escalating environmental and public health threat. These materials contain toxic heavy metals such as lead, mercury, and cadmium, as well as hazardous chemical compounds that contaminate soil, groundwater, and air when disposed of through informal practices such as open burning or dumping in municipal landfills. [2]

The Situation in Aleppo

E-waste generation: Total e-waste generated in Greater Aleppo, with a population estimated between 3.5 and 4 million, is estimated to range between 8,000 and 12,000 tons per year, corresponding to 2.5–3 kg per capita annually.

Sources:

- The dominant waste streams include:
- Communication devices and computers (35–40%(
- Low-quality small household appliances (25–30%(
- Alternative energy equipment such as substandard solar panels (10–15%(
- LED lamps and electronic lighting components (10–12%(

Current management practices: There is no formal infrastructure for e-waste management. Collection and dismantling activities are dominated by informal actors—such as scavengers and repair shops—using unsafe practices including burning and manual breaking, with no occupational safety measures. These practices pose serious risks to workers and the environment.

Key challenges:

- Absence of a legal and institutional framework
- Weak infrastructure
- Dominance of the informal sector
- Lack of reliable data and technical expertise
- Low public awareness
- Economic crisis and conflict-related impacts

This paper was developed using a participatory methodology drawing on inputs from the E-Waste Challenge Mapping Convening Event (September 2025), design thinking workshops, an innovation hackathon that produced seven prototype projects, a review of regional and international literature, and interviews with local stakeholders.

5. Key Recommendations

The paper proposes a phased, practical pathway for managing electronic waste in Aleppo based on decentralization and the use of local resources.

Short-term (Pilot Phase: 6–12 months)

1. **Establish a community-based collection network:** Set up 10–15 collection points across major neighborhoods in Aleppo, in cooperation with municipalities and local organizations. These points should be equipped with color-coded containers for different waste types (batteries, small devices, screens, etc.).
2. **Create a local safe dismantling center:** Establish a basic sorting and dismantling workshop (100–200 m^2) equipped with simple tools and ventilation systems to recover materials suitable for reuse or local recycling, such as copper wires, metals, and plastics.
3. **Launch a refurbishment and reuse program:** Create a central repair workshop—hosted by a university or technical institute—to refurbish functional second-hand devices (computers, communication equipment) and redistribute them to educational and community institutions.

4. **Integrate and train the informal sector:** Implement short training programs (20–30 hours) for scrap collectors and informal workers on safe dismantling and sorting practices, transforming them into active partners within the system.
5. **Community awareness campaign:** Launch intensive public awareness campaigns highlighting the risks of e-waste and the importance of delivering it to designated collection points.

Medium-term (1–3 years)

1. **Develop a local regulatory framework:** Issue municipal bylaws regulating e-waste collection and storage, and introduce conditional licensing for dismantling centers that comply with safety standards.
2. **Enhance economic viability:** Develop partial self-financing mechanisms through the sale of recovered raw materials (copper, aluminum), and explore partnerships with local private-sector actors.
3. **Establish final treatment mechanisms:** Partner with regional facilities (Jordan, Lebanon, Turkey) or UN programs, in line with the Basel Convention, to export hazardous or high-value components (e.g., printed circuit boards) for specialized treatment.

Long-term (3–5 years)

1. **Develop a national policy:** Advocate for a national e-waste management framework based on Extended Producer Responsibility (EPR), obligating importers and manufacturers to participate in managing end-of-life products.
2. **Establish monitoring and data systems:** Create a national database to track e-waste generation and treatment.
3. **Transition toward a circular economy:** Promote small-scale local industries based on recycled e-waste materials, generating green jobs and reducing dependence on imported raw materials.

Methodology for Developing This Research Paper

This paper was developed using a combined research and applied methodology that integrates technical analysis, community participation, and hands-on experience within the Syrian context. The development process relied on four main sources of data and knowledge:

1. E-Waste Challenge Mapping Convening Event

A large participatory event was held in Aleppo on 16 September 2025, organized by Field Ready Syria in cooperation with World Vision Syria and the Response Innovation Lab. More than 20 local institutions, private-sector actors, universities, and international organizations participated. Outputs included a situational analysis, stakeholder mapping, and intervention priorities, which formed the initial foundation of the paper.

2. Design Thinking Workshop with Innovation Teams

A design thinking workshop was conducted with innovators to analyze e-waste challenges and develop technically feasible solutions. Discussions and exercises helped deepen understanding of technical and behavioral barriers and shaped realistic management pathways.

3. Innovation Hackathon

A specialized hackathon supported the development of seven innovative projects selected based on professional criteria.

Project Title	Targeted Waste Type	Main Objective	Waste Handling Mechanism	Key Innovation	Expected Results & Impact
The Sustainable Smart E-Waste Bin	Household electronic waste	Prevent e-waste from landfills and ensure full sustainability	Smart recyclable bin with automatic classification and user interaction	100% recyclable smart bin convertible into new materials	Closed-loop recycling, 60% carbon reduction, sustainability model
Bio-mining	Printed circuit boards	Extracting heavy metals in an environmentally safe manner	Using fungi to absorb minerals from mildly acidic solutions	Application of bio-absorption technology for metals from waste	Reducing ,pollution recovering minerals using biomass as fertilizer
Recycling solar panels to achieve a circular economy	Damaged solar panels	Reducing the accumulation of e-waste and promoting sustainability	Mechanical and chemical separation of materials	Developing a mechanism for recycling panels to extract reusable materials	Reducing environmental ,impacts recovering materials, and promoting circular economy
From Waste to Technology	Printed Circuit Boards (PCBs)	Reduce environmental harm from PCB waste	Mechanical, electronic, and eco-chemical processing	New PCB production method	Marketable scientific product
ReMed	Decommissioned medical devices	Reuse idle medical equipment	Multi-stage component separation and reuse	Optimized reuse of functional components	Repaired medical devices

E-Cycle Hub	Screens, lamps, small appliances, ICT equipment	Transform e-waste into economic resources	Digital tracking platform with incentives	Waste-to-resource digital ecosystem	Circular economy, youth jobs, scalable model
E-Parts Library – Aleppo	Computers, phones, batteries, boards	Educational and technical reuse of e-waste	Mobile collection and open parts library	First community e-parts library in Syria	Youth training, innovation support, pollution reduction

The projects E-Cycle Hub and E-Parts Library – Aleppo were chosen among the seven projects to be sponsored.

The preliminary outputs, treatment methods, and expected impacts of these prototypes enriched the paper with locally appropriate technical solutions.

4. Literature Review and Regional and International Case Studies

The research team conducted a systematic review of recent reports and publications on e-waste management, including the Global E-Waste Monitor 2024 and experiences from Lebanon, Jordan, Egypt, Ghana, Nigeria, and South Asia. Lessons learned from previous Field Ready projects in northwest Syria related to medical and electronic waste recycling were also incorporated.

5. Technical Interviews and Consultations

Interviews and consultations were conducted with representatives from municipalities, environmental directorates, private-sector repair and scrap workshops, university faculty members, and humanitarian organizations working in environment and energy. These inputs helped refine realistic and implementable recommendations.

Methodological Summary

The paper adopts a participatory, multi-source methodology that integrates:

- Technical analysis
- Local field experience
- Global evidence
- Youth-led innovation

As such, it presents a practical and context-adapted framework rather than a purely theoretical model.

Chapter One: Current Situation and Challenges

The Current Situation in Aleppo and Its Impact on E-Waste Generation

Over the past years, the city of Aleppo has experienced severe deterioration in infrastructure and public services as a result of the prolonged conflict in Syria. This has directly affected consumption patterns and living standards. A sharp decline in individual income levels and purchasing power has driven widespread reliance on low-quality electronic and electrical devices with short operational lifespans, often imported through informal or poorly regulated markets and originating from unreliable sources.

Among the most prominent examples are low-cost LED lighting products, which are produced and imported in large quantities without adherence to technical standards or electrical safety specifications. As a result, many of these products fail within a very short period—sometimes in less than one year of operation. Other widely used devices include low-quality induction heaters, commercial inverters, and substandard photovoltaic panels, all of which contribute significantly to rising volumes of electronic waste due to their short lifespans and limited repairability.

In addition, there has been a noticeable increase in the importation of second-hand electronic devices, particularly laptops, communication equipment, and smartphones. In most cases, these devices enter the local market near the end of their operational life. In the absence of effective maintenance systems or refurbishment networks, such devices rapidly become waste that is difficult to manage safely.

Electricity supply instability further exacerbates the problem. Aleppo residents experience prolonged and frequent power outages, pushing households and businesses to rely on alternative energy sources such as private generators and small-scale solar energy systems. However, poor power quality and voltage fluctuations associated with these sources accelerate the degradation of electronic devices and damage internal components—especially in the absence of protective equipment such as voltage stabilizers.

The interaction between low-quality devices and unstable power supply creates a self-reinforcing cycle that accelerates the generation of electronic waste across the city and its surrounding areas.

Findings from Interviews with Electronic Repair and Retail Shops

Black Phone – Mobile Equipment Sales and Repair Shop

Defective components identified during sorting of newly imported goods:

- Wired earphones: defect rates range from 1% to 40%, depending on quality
- Bluetooth earphones: defect rates depend largely on battery manufacturing date (often not disclosed), relying on importer integrity
  - High-quality: (0–5)%
  - Low-quality: up to 40%
- Mobile phone chargers: defect rates of (0–3)%, depending on quality

Reusable components extracted from damaged mobile phones:

1. Microphones
2. Speakers
3. Charging ICs (if compatible with other models)
4. Fingerprint sensors

Remaining circuit boards are sold by weight for metal recovery, as they contain small quantities of precious metals such as gold and silver.

The highest failure rates in mobile phones are associated with screens and charging ports. Although charging ports are physically small components, screens represent the largest share by volume and weight within mobile e-waste streams.

Orange Store Mobile Phone Shops

Approximate daily electronic waste output per branch (four branches operating in Aleppo):

- 5 broken or defective screens
- 3 defective or swollen batteries
- 2 internal or external phone frames
- 5 charging flex cables, connector flexes, or fingerprint flexes

E-Waste Generation, Collection, and Treatment in Syria (National Level) [1]

Generation: Electronic waste is generated by both household and commercial/industrial sectors. There are no accurate national statistics on generation volumes.

Collection: Most collection activities are informal and conducted by:

- Scavengers ("pickers") who retrieve devices from public waste containers or purchase them cheaply from households
- Electronic sales and repair shops, which buy old or defective devices for reusable components or resale

Treatment: There are no binding national laws or regulations governing electronic waste management, nor is there an organized infrastructure for collection and treatment. Informal recycling practices dominate, including:

- Manual dismantling in small workshops or open spaces to extract valuable metals (such as copper, aluminum, and small amounts of gold)
- Hazardous practices, including cable burning to recover copper and breaking cathode-ray tube (CRT) displays, releasing toxic gases and dust

Residual materials such as plastics and glass are disposed of alongside municipal waste or dumped in informal landfills, leading to soil and groundwater contamination.

Quantitative and Qualitative Estimates of E-Waste in Aleppo-[2]

Global statistics and projections indicate a steady increase in electronic waste generation worldwide as showed in Figure1

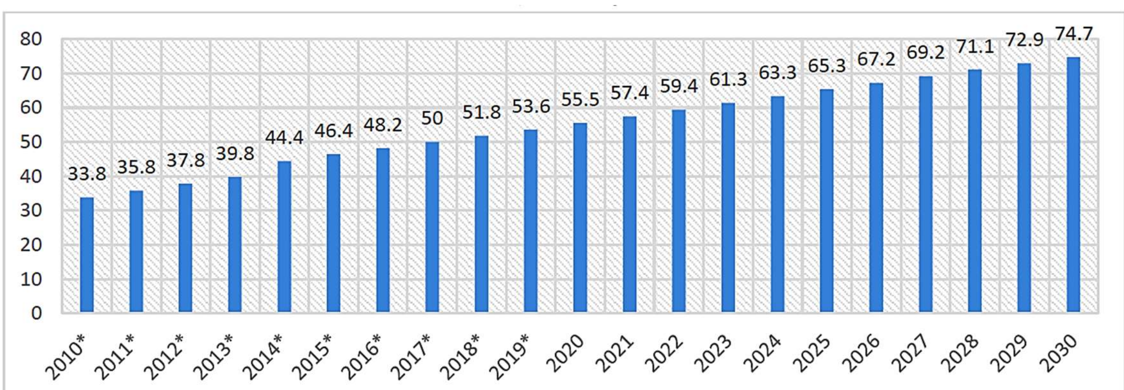

Figure1 Statistics and projections of electronic waste generated globally from 2010 to (million tons) 2030 -**[3]**

However, the absence of a national monitoring system in Syria makes it difficult to obtain precise data on quantities and geographic distribution.

Approximate estimates can be developed based on population consumption indicators, device circulation rates, and per-capita e-waste generation in low- and middle-income countries, as reported in the Global E-Waste Monitor 2024 published by the International Telecommunication Union (ITU) and the United Nations University (UNU).

According to these sources, average per-capita e-waste generation in low-income countries ranges between 2.5 and 3 kg per year. Assuming a population of 3.5–4 million in Greater Aleppo (including surrounding rural areas), total annual e-waste generation is estimated at:

8,000–12,000 tons per year

Estimated Composition of E-Waste in Aleppo

- Communication devices and computers: 35–40%
- Small household appliances: 25–30%
- Alternative energy equipment: 10–15%
- LED lamps and electronic lighting components: 10–12%
- Industrial and office equipment: 8–10%

These estimates indicate that alternative energy equipment has become a growing source of electronic waste, driven by increased reliance on low-quality solar systems. Similarly, poor-quality LED lamps generate increasing volumes of waste that are difficult to dismantle due to their mixed electronic, metallic, and plastic components.

It should be noted that these figures are conservative estimates, as they do not fully account for:

1. Stored e-waste in households
2. Unregistered informal disposal
3. Unreported trade in second-hand electronics [2]

Institutional and Environmental Challenges in Managing E-Waste in Aleppo

E-waste management in Aleppo faces interconnected technical, institutional, and environmental challenges that reflect conditions across many Syrian cities, though they are more severe in Aleppo due to war-related impacts and economic decline.

1. Absence of an Integrated Regulatory and Institutional Framework
   - As of 2025, Syria lacks dedicated legislation for electronic waste management within environmental or industrial laws. No local authority holds a clear mandate to coordinate e-waste management at the municipal level.
   - This regulatory gap results in overlapping roles among municipalities, humanitarian organizations, and informal actors, and the absence of licensing or oversight systems for collection and dismantling activities—allowing unsafe and unregulated practices to proliferate.

2. Weak Infrastructure and Municipal Services
   - Aleppo currently has no dedicated e-waste collection or treatment facilities. Most electronic waste ends up in general landfills, open dumping sites, or is partially burned to recover metals.
   - Manual burning releases toxic emissions—including lead, dioxins, and mercury—contaminating air, soil, and groundwater, particularly in peripheral residential areas where such activities are concentrated.

3. Reliance on the Informal Sector
   - The lack of formal facilities has led to widespread informal collection and dismantling activities carried out by untrained workers, sometimes including children, under unsafe conditions.

- While this sector contributes to limited material recovery, it also causes major losses of reusable materials and severe environmental contamination due to primitive extraction methods such as open heating or acid leaching.

4. Lack of Data and Technical Knowledge

- Local authorities and environmental organizations suffer from a severe shortage of reliable data on annual e-waste quantities and composition, as well as limited technical capacity in classification, dismantling, and reuse.
- This deficit hinders the development of sustainable management plans, cost estimation, and access to international funding or technical assistance.

5. Direct Environmental and Health Risks

- Unsafe practices expose workers and nearby residents to risks such as lead and cadmium poisoning, respiratory irritation from toxic fumes, and cumulative contamination of soil and water resources.
- These risks remain largely undocumented due to weak environmental and public health monitoring systems, suggesting that actual impacts may be more severe than currently recognized.

6. Low Public Awareness

- Preliminary behavioral assessments indicate that most residents are unaware of the hazards associated with electronic waste or its recycling potential. Damaged devices are commonly discarded with household waste or stored indefinitely in homes, reducing opportunities for separate collection and recycling.

Chapter Two: Practical Solutions and Tested Technical Models

Global and regional experience demonstrates that effective electronic waste management does not necessarily require large-scale investments or advanced infrastructure. Meaningful results can be achieved through simple, low-cost technical models based on a phased management approach, with the active participation of local institutions and the informal sector within organized frameworks.

This chapter presents a selection of models that have proven successful in contexts with comparable economic constraints and institutional capacity, followed by an assessment of their applicability to the Aleppo context.

The Jordanian Experience [1]

Key Statistics (2019)

- Total e-waste generated: 55,000 tons (4.2 kg per capita)
- E-waste collected: 1,300 tons (0.1 kg per capita)
- Collection rate: 2.6%, the highest in the Arab region

Figure 2 Shows e-waste collection and transmission in Jordan.

Figure 2 e-waste collection and transmission in Jordan.-**[4]**

Legal and Regulatory Framework

- No dedicated e-waste law; e-waste is regulated under hazardous waste legislation.
- Specific e-waste management instructions issued by the Ministry of Environment (entered into force on 17 May 2021).
- Extended Producer Responsibility (EPR) system under development as part of an internationally supported project.
- Jordan is a party to four multilateral environmental agreements: Basel, Rotterdam, Stockholm, and Minamata Conventions.

Collection and Management System

- Formal collection is conducted through seven licensed companies (as of 2019–2020).
- Collection points are concentrated in major cities and do not cover all municipalities.
- No domestic treatment facilities; collected e-waste is exported in accordance with the Basel Convention.
- Ongoing efforts to license informal-sector workers and integrate them into the formal system.

Challenges

- Limited local treatment infrastructure
- Continued dominance of the informal sector in collection activities
- Low public awareness of e-waste risks
- Absence of national collection targets

Achievements

- Highest e-waste collection rate in the Arab region
- Adoption of modern regulatory instructions (2021)
- Initial licensing of companies involved in collection and recycling

The Aleppine Experience

Innovative Healthcare Sustainability and E-Waste Reuse in Northwest Syria

Field Ready MENA, in partnership with several international organizations, implemented multiple projects focused on repairing and refurbishing medical equipment in northwest Syria. These initiatives resulted in the repair of more than 400 medical devices, while training technicians in safe maintenance, digital fabrication, and applied manufacturing.

More recently, these projects expanded to address electronic waste management by recycling and repurposing discarded equipment in ways that reduce environmental harm and support circular economy principles.

From Medical E-Waste to Road Safety Solutions

- More than 200 road reflectors were manufactured from metal and plastic recovered from end-of-life medical equipment.
- These reflectors were installed on high-risk roads in northwest Syria, improving nighttime visibility and road safety.

From Medical E-Waste to Educational Tools

- Anatomical teaching models were produced using recycled electronic and medical waste materials.
- Products included skulls, teeth, organ models, and instructional tools that support anatomy education.

E-Cycle Hub project and E-Parts Library

As a result of the Innovation Hackathon the projects E-Cycle Hub and E-Parts Library were chosen among the seven projects to be sponsored.

These initiatives demonstrate the feasibility of value recovery and product re-manufacturing in low-resource environments.

The Lebanese Experience: Community-Based Collection and Organized Manual Dismantling [5]

Figure 3 Lebanese e-waste shredding line-**[5]**

Figure 3 shows Lebanon e-waste shredding line. Organizations such as Arcenciel operate across Lebanon, with a focus on urban and rural areas. Their work concentrates primarily on batteries (portable, automotive, and industrial) as well as selected electronic devices, in cooperation with institutions such as the Lebanese Red Cross.

While treated quantities remain insufficient to meet national demand, the model provides valuable insights.

Challenges

- Limited processing capacity
- Difficulty collecting batteries from dispersed sources
- Managing diverse battery chemistries (lithium, lead-acid, etc.)

Achievements

- Establishment of a preliminary battery collection system
- Partnerships with major institutions
- Access to international funding and technical support

Live Love Recycle and Similar Community Organizations

Most operate in Beirut and Mount Lebanon, with some presence in other regions. They collect a wide range of electronic waste types, targeting households and small institutions.

- Total quantities collected by all active organizations remain modest
- Ecoserv collected approximately 179 tons in 2022, representing the largest share
- Funding sources:
  - 50% NGOs relying on donations
  - 50% private entities funded through material sales

Collection Infrastructure

- Over 120 decentralized collection points in universities, hospitals, and retail outlets
- No centralized treatment facilities; materials are transported to Ecoserv or Verdefech

Key Challenges

1. High logistics costs due to fuel prices
2. Low environmental awareness
3. Absence of a national waste management system
4. Lack of regulatory enforcement
5. Limited awareness of take-back systems (67% unfamiliar)

Positive Outcomes

- Establishment of a nationwide community collection network
- Partial awareness-raising in educational and healthcare institutions
- Provision of a safer alternative to informal dumping
- Willingness among organizations to engage in training programs
- Prevention of uncontrolled burning and disposal

The Egyptian Experience

Figure 4 Egypt's first Legitimate E-Waste Recycling Factory **[6]**

Public–Private Partnerships

In Egypt, a cooperative model has emerged between small companies and large factories for e-waste collection and sorting. Local companies manage collection and preliminary dismantling, while high-value components—such as printed circuit boards and precious metals—are exported to specialized recycling facilities.

This system operates under a partially self-financed economic model, sustained by the sale of recoverable materials. Egypt's first officially licensed e-waste recycling facility was established in 2014, providing a regulatory anchor for the sector.

United Nations Initiatives [7]

A total of 154 past, ongoing, and proposed initiatives have been identified across various stages of the electrical and electronic equipment (EEE) life cycle, including:

- E-waste collection and recycling
- Policy and legislative development
- Capacity building and training
- Eco-design and sustainable product development
- Infrastructure support

Participating UN Entities

- UNDP
- ILO
- UNIDO
- FAO
- UNICEF
- ITU
- United Nations University (UNU)
- Basel, Rotterdam, and Stockholm Conventions Secretariat (BRS)

Geographic Distribution

- Strong concentration in Africa and Asia
- Limited activity in Europe, North America, and Australia
- Growing engagement in Latin America and the Caribbean

Partnerships

- 10 documented inter-agency collaborations
- 49% of initiatives involved public-sector partnerships
- Only 36% involved private-sector partnerships, highlighting a gap

Key Challenges

- Weak coordination among UN entities
- Limited focus on design and production stages
- Insufficient national data on e-waste flows
- Weak infrastructure in developing countries
- Difficulty tracking rare metals in devices

Recommendations to Strengthen UN Initiatives

1. Gap analysis to clarify roles and identify cooperation opportunities
2. Joint action plans to align funding with clear objectives
3. Inter-agency coordination mechanisms to avoid duplication
4. Internal UN e-waste management systems as model practices

South Asian Experiences: [8]

Low-Cost Small-Scale Processing Units

In India and Bangladesh, small-scale semi-mechanized e-waste dismantling units have been developed using mechanical separation basins, filtered exhaust systems, and locally modified plastic compactors.

These models are:

- Mobile
- Scalable
- Low-investment
- Suitable for gradual expansion

Ghanaian and Nigerian Experiences: -[8]

Formalizing the Informal Sector

In West Africa, informal e-waste collection has historically been a major pollution source. Programs such as E-Waste Africa (Ghana) and the Nigeria EPR Initiative have addressed this by:

- Training workers in safe dismantling without burning
- Establishing community-managed drop-off centers
- Integrating former informal workers into formal systems through modest financial incentives

Applicability to Aleppo: Learning from Regional Experiences

Lessons from these models can be adapted to Aleppo as follows:

- **Jordanian model:** Introduce simplified local licensing and regulatory instructions at municipal level, gradually integrating informal workers.
- **Lebanese model:** Establish decentralized community collection points in cooperation with NGOs and universities, and train local staff in safe manual dismantling.
- **Egyptian model:** Engage local metalworking and craft workshops in licensed material recovery operations.
- **UN initiatives:** Leverage technical assistance for training, pilot equipment design, and Basel-compliant export procedures.
- **South Asian models:** Develop a pilot low-cost processing unit (1–2 tons/month) within a business incubator or vocational facility.
- **Local Field Ready experience:** Replicate successful reuse and remanufacturing models such as E-Cycle Hub project and E-Parts Library and product manufacturing from recovered materials.

Preliminary Conclusion of Chapter Two

These experiences demonstrate that successful e-waste management in resource-constrained environments relies on three core principles:

1. **Decentralized management:** Distributed collection and small-scale processing instead of centralized infrastructure
2. **Local training and empowerment:** Transforming informal workers into organized productive actors
3. **Integration with the local economy:** Linking dismantling and reuse to existing workshops and industries

These principles form the foundation for Chapter Three, which proposes practical pathways for designing a localized e-waste collection and recycling system in Aleppo.

Chapter Three: Proposed Pathways for Collection and Recycling

Developing a local system for managing electronic waste (e-waste) in the city of Aleppo represents a fundamental step toward reducing environmental impacts and protecting public health. At the same time, it can constitute an emerging sector capable of generating employment opportunities in maintenance, dismantling, and reuse activities.

Given the absence of formal infrastructure, a gradual approach based on community-level collection and decentralized, low-cost processing is required. This approach allows for future scaling once institutional support becomes available.

Main Models of Waste Management and Recycling-[9]

A) Municipal Recycling Model

- **Context:** High-income countries (e.g., Rotterdam, San Francisco).
- **Mechanism:** Waste disposal is priced (e.g., landfill fees), creating financial incentives for municipalities to divert waste away from landfills.
- **Outcome:** A virtuous cycle in which cities invest in knowledge and recycling infrastructure, improving efficiency and reducing costs.
- **Impact on the informal sector:** Informal waste pickers are often excluded or replaced by organized municipal programs.

B) Inclusive Recycling Model

- **Context:** Low- and middle-income countries (e.g., Quezon City, Belo Horizonte, Bamako).

- **Mechanism:** The informal private sector (waste pickers, small shops, itinerant buyers) retains a central role in material recovery, with recognition and support from municipalities.

Examples cited:

- **Quezon City, Philippines:** Recognition of small "junk shops" as official Material Recovery Facilities (MRFs).
- **Belo Horizonte, Brazil:** Support for cooperatives and provision of contracts to waste pickers.
- **Bamako, Mali:** Leveraging traditional practices such as organic waste reuse without replacing them with costly programs.

Conceptual Framework of the Proposed System

The proposed system is built around three interconnected stages:

1. **Stage One – Collection and Initial Separation**
   Establishment of small, distributed collection points in neighborhoods, in cooperation with municipalities and local organizations. These points receive small devices and defective components (computers, lamps, circuit boards, batteries) and store them temporarily in a safe manner.
2. **Stage Two – Safe Dismantling and Reuse**
   Transfer of dismantlable materials to small technical workshops for component disassembly and recovery of metals, plastics, and repairable circuits. Usable devices (computers, inverters, partially functional solar panels) are refurbished and redistributed through educational or community programs.
3. **Stage Three – Treatment or Export**
   Export of hazardous or high-value components (such as printed circuit boards containing precious metals) to specialized processing facilities outside the region, in coordination with international organizations or UN programs.

Design of a Community Collection Network

It is proposed to establish an initial network of 10–15 collection points distributed across major areas of Aleppo (e.g., Sulaymaniyah, Al-Shaar,
Al-Sakhour, Al-Hamdaniyah, Al-Ansari, western rural areas).

These points may be operated on:

- Community centers and local NGOs,
- Technical or vocational schools,
- Sub-municipalities with secure enclosed yards.

Each point should be equipped with simple infrastructure, including metal containers separated by waste type (batteries, small devices, screens, LED lamps, small photovoltaic panels), along with intake and output logs to document quantities.

Proposed safety measures include:

- Mandatory use of gloves and protective eyewear for workers,
- Storage of batteries and screens in sealed, moisture-resistant containers,
- Prohibition of dismantling or crushing devices at collection sites.

Transport and Decentralized Processing Mechanism

E-waste is transferred from local points to secondary sorting centers on a weekly or monthly basis, using municipal vehicles or transport contracted through NGOs.

At these centers, materials are classified into four main categories:

1. Reusable items (computers, inverters, chargers, control boards),
2. Items suitable for manual dismantling (wires, fans, lamps, small panels),
3. Hazardous items requiring special treatment (batteries, CRT screens, lithium panels),

4. Non-hazardous plastics and metals sent to local workshops as raw materials.

These centers can operate within existing vocational workshops or light industrial facilities using minimal equipment (electric screwdrivers, air filters, metal worktables).

Refurbishment and Reuse Program

To reduce waste volumes, a central refurbishment workshop is proposed within a university or technical institute. This workshop would assess used devices—particularly computers and small solar inverters—and repair those suitable for reuse.

Refurbished equipment would be redistributed to schools, associations, and educational centers under development-oriented programs.

Funding can be derived from:

- Sale of recyclable metal and plastic components,
- Support from international organizations for reuse initiatives.

Integration of the Informal Sector and Municipalities

Workers involved in informal scrap and e-waste collection represent a valuable human resource that can be transformed into an effective partner rather than a source of pollution.

The project proposes a short-term training program (one month) to qualify these workers in safe dismantling and manual sorting using simple tools.

Municipalities would be provided with a unified procedural manual covering:

- Acceptance of e-waste,
- Safety and storage standards,
- Monthly documentation and reporting mechanisms.

This integration creates a hybrid, flexible model capable of future expansion within a formal regulatory framework.

Preliminary Economic and Social Feasibility

Pilot implementation on a limited scale (10 collection points and one dismantling center) could generate:

- 20–30 direct jobs in collection, sorting, and maintenance,
- Approximately 100 tons of e-waste collected annually and diverted from municipal waste streams,
- Reduced toxic emissions from open burning,
- Improved public awareness of environmentally sound practices.

Estimated annual operating costs range between USD 40,000 and 60,000, potentially covered through revenues from recovered metals (copper, aluminum) and support from UN programs and environmental NGOs.

Future Integration with Public Policies

Over the medium term (3–5 years), this system could serve as a foundation for a local regulatory framework through:

- Municipal bylaws regulating e-waste collection,
- Adoption of Extended Producer Responsibility (EPR) schemes in cooperation with importers and traders,
- Mandatory e-waste separation within municipal waste management plans.

Chapter Three Summary

These proposed pathways demonstrate that low-cost, high-impact solutions can be gradually implemented in resource-constrained environments such as Aleppo, provided coordination exists between local authorities, technical organizations, and civil society.

The proposed model is not merely a recycling plan, but a foundational structure for a local circular economy that creates jobs and reduces environmental risks.

Chapter Four: Operational Guidelines for Safe and Scalable Implementation

This chapter sets out practical guidelines for implementing an e-waste management system in Aleppo, drawing on international best practices adapted to local conditions, including unreliable electricity supply, absence of formal facilities, and economic constraints.

These guidelines are intended as an operational reference for municipalities, NGOs, and local initiatives working in environmental or development fields.

1. Occupational Health and Safety Framework

1.1 Core principles

- Prohibition of open burning or manual smelting of electronic components within the city,
- Ensuring adequate ventilation in storage and dismantling areas,
- Mandatory use of personal protective equipment (chemical-resistant gloves, safety goggles, masks),
- Clear warning signage at collection and sorting sites.

1.2 Storage procedures

- Batteries and power sources (e.g., lithium batteries) stored in insulated metal containers to prevent leakage or ignition,
- Broken screens and mercury-containing lamps not stored in open areas,
- Maximum storage duration limited to three months before processing or export.

1.3 Hazardous component management

Components such as capacitors, batteries, and fluorescent lamps are classified as hazardous waste and must be separated immediately upon receipt, labeled with identification tags indicating date, quantity, and chemical type where possible.

2. Training and Local Capacity Building

2.1 Core training program

A 20–30 hour training program is recommended, covering:

- Safe manual dismantling principles,
- Identification of reusable and hazardous components,
- Documentation and reporting methods,
- Circular economy concepts.

Training should be delivered through vocational training centers or environmental NGOs in cooperation with local experts or international organizations such as UNEP and UNDP.

2.2 Supervisor training

Supervisors should receive an additional 10 hours of training on risk assessment, emergency procedures, and response to electrical fires or chemical leaks.

3. Initial Infrastructure Requirements

3.1 Collection sites

- Minimum area of 20 m² per collection point,
- Metal roofing or canopy for weather protection,

- Concrete flooring to prevent soil contamination,
- Color-coded containers:
    - **Blue:** small devices,
    - **Red:** batteries and hazardous components,
    - **Grey:** metals and plastics.

3.2 Sorting and pre-processing center

- Area of 100–200 m² with natural or mechanical ventilation,
- Stable power source (preferably a small solar system),
- **Basic equipment:** metal tables, electric screwdrivers, scales, storage racks, paper-based or electronic documentation system.

4. Documentation and Reporting Mechanism

A simple e-waste tracking system should be adopted at three levels:

1. Collection logs at collection points,
2. Transport records documenting material movement,
3. Processing records documenting dismantled, reused, or exported quantities.

Monthly reports submitted to the supervising authority should include collected quantities (kg), reused devices, and exported or externally treated materials. Standardized electronic templates (Excel or Google Sheets) are recommended.

5. Logistics and Export Plan

5.1 Internal transport

- Use of covered vehicles to prevent material loss,
- Bi-weekly transport during initial phases,

- Drivers trained in handling hazardous waste.

5.2 External treatment and export

In the absence of advanced local facilities, cooperation with regional private sector facilities (Lebanon, Turkey, Jordan) or UN-coordinated programs is recommended, in compliance with the Basel Convention on the transboundary movement of hazardous waste.

6. Awareness and Behavioral Guidelines

Concurrent awareness campaigns should include:

- Simplified brochures on e-waste hazards,
- Encouraging residents to deliver obsolete devices to collection points,
- Partnerships with schools and universities.

A three-month pilot campaign under a unified slogan is recommended, such as: **“Your Old Devices Are New Energy for Your City.”**

7. Scalability and Sustainability

Pilot evaluation after six months should be based on indicators such as collected quantities, reused components, compliance levels, and community satisfaction. Based on results, gradual expansion across Aleppo and neighboring governorates can be pursued.

Chapter Four Summary

International experience confirms that effective e-waste management relies more on organization, awareness, and training than on large-scale investment. In Aleppo, tangible results can be achieved rapidly if these guidelines are adopted as a phased action plan supported by cooperation between municipalities and development organizations.

Chapter Five: Entry Points and Strategic Recommendations

This chapter identifies key stakeholders in Aleppo's e-waste management landscape and proposes realistic coordination mechanisms to ensure efficiency, safety, and sustainability, while laying the groundwork for integrating e-waste management into local and sectoral plans.

1. Entry Points for Local Authorities

Municipalities

- Classify e-waste as special waste within sanitation plans,
- Allocate temporary storage areas within existing landfills,
- Issue time-limited permits for compliant dismantling workshops,
- Integrate project outputs into municipal digital tracking systems.

Environmental Directorates

- Develop a simplified national guideline based on Aleppo's experience,
- Coordinate with international organizations on safe export protocols,
- Conduct periodic inspections of collection and processing sites.

2. Role of Humanitarian and Development Organizations

- Lead awareness campaigns,
- Establish neighborhood collection points,
- Train local cadres in cooperation with vocational education initiatives,
- Fund pilot sorting and processing centers,
- Integrate e-waste into green reconstruction programs.

3. Role of the Private Sector

- Participate in take-back schemes with consumer incentives,
- Co-finance collection centers,
- Promote responsible product importation and repairability,
- Support local repair workshops to extend device lifespans.

4. Strategic Recommendations

Key recommendations include launching a one-year pilot phase in three major districts, establishing a local coordination committee, standardizing safety procedures, encouraging applied academic research, integrating e-waste management into sustainable development plans, and launching public awareness campaigns framing e-waste as an economic resource rather than an environmental burden.

5. Future Vision (2026–2030)

The Aleppo experience can serve as a foundation for a national e-waste management system in Syria, based on decentralized city hubs, a national data platform, extended producer responsibility legislation, and the development of a green recycling market generating sustainable employment.

Overall Conclusion

This paper demonstrates that e-waste management in Aleppo is not solely a technical issue, but a developmental, economic, and environmental challenge. Even in the absence of formal infrastructure, a simple, low-cost, community-based system can significantly reduce pollution while creating new livelihood opportunities—provided gradual implementation, institutional support, and public awareness are sustained.

References

[1] E. V. C. B. I. N. R. K. G. Ia¬oni, “REGIONAL E-WASTE MONITOR for the Arab States,” 2021.

[2] C. P. Baldé, R. Kuehr, T. Yamamoto, R. McDonald, E. D’Angelo, S. Althaf, G. Bel, O. Deubzer, E. Fernandez-Cubillo, V. Forti, V. Gray, S. Herat, S. Honda, G. Iattoni, D. S. Khetriwal, V. L. di Cortemiglia, Y. Lobuntsov, I. Nnorom, N. Pralat and M. Wagner, "THE GLOBAL E-WASTE MONITOR," 2024.

[3] ب. ع. رفيقة, "إدارة النفايات الإلكترونية والتنمية المستدامة: فرص الاستثمار والتحديات الاقتصادية", *مجلة شعاع للدراسات الاقتصادية*, pp. 148-164, 2024.

[4] "West Jordan E-Waste collection," [Online]. Available: https://youtu.be/i12c8WyLkIc?si=kz6ZN5nFi06naj5X.

[5] "Lebanon e-waste shredding line," [Online]. Available: https://youtube.com/watch?v=42KIJbD_Ah0&feature=shared.

[6] "Egypt's first Legitimate E-Waste Recycling Factory," 2014. [Online]. Available: https://youtu.be/JXet6fBGONw?si=_g5ovEXF0ox6Zybf.

[7] United Nations, "United Nations System-wide Response to Tackling E-waste," 2017.

[8] V. Forti, C. P. Baldé, R. Kuehr and G. Bel, "The Global E-waste Monitor," 2020.

[9] United Nations Environmental Programme Division of Technology, Industry and Economics International Environmental Technology Centre Osaka/Shiga, "E-waste Volume II E-waste Management Manual," 2007.

[10] "Basel Convention on the Control of Transboundary Movements of Hazardous Wastes," [Online]. Available: https://www.basel.int.

[11] Z. Fahed, D. Tavera, R. Craizer and G. Asaad, "PROVISION OF SERVICES FOR THE ASSESSMENT OF E-WASTE & BATTERIES IN LEBANON," United Nations Development Programme (UNDP), Delegation of the European Union to Lebanon (EU), United Nations Development Programme, Lebanon, Lebanon, 2023.

[12] United Nations Environmental Programme Division of Technology, Industry and Economics International Environmental Technology Centre Osaka/Shiga, "E-waste Volume I Inventory Assessment Manual," 2007.