



From Worst to Good Practices in Secondary Metals Recovery

FACT SHEETS



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FACT SHEETS

Developed to support the implementation of
The Guidance Principles for
Sustainable Management of Secondary Metals
ISO IWA 19: 2017 (E)



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Front cover, from top, clockwise: 1) Waste containing metals: circuit boards ©Empa; 2) Worst Practice: Sulphuric acid baths to recover copper from printed circuit boards ©Empa; 3) Worst practice: Street workers dismantling materials ©Empa; 4) Worst Practice: Burning of plastic from cables to recover copper ©Empa

Back cover, from top, clockwise: 1) Proper collection in Accra ©WRF; 2) Upcycling of waste metal drums into sofas ©WRF 3) Copper piping 4) Recovered iron cast into balls © Monika Fluekiger

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Notes to the Reader

The Sustainable Recycling Industries (SRI) Roundtable, an initiative led by the Sustainable Recycling Industries Programme, addresses the sustainability criteria in secondary resources management in developing countries. The SRI programme is built on the success, for more than a decade, of the implementation of e-waste recycling systems in various developing countries. The programme is funded by the Swiss State Secretariat of Economic Affairs (SECO) and is implemented by the Swiss Institute for Materials Science & Technology (Empa), the World Resources Forum (WRF) andecoinvent.

In order to develop the Guidance Principles for Sustainable Management of Secondary Metals (Guidance Principles), in accordance with the International Workshop Agreement (IWA), the SRI Roundtable consulted key and affected stakeholders by means of workshops and local and public consultations.

This fact sheet collection is the result of an extensive and comprehensive stakeholder-consultation process conducted by global experts who serve the SRI Roundtable. These individuals have also agreed to voluntarily form a dedicated work group in order to provide specific input (based on both their academic knowledge and practical experience) to this summary of most prevalent **Worst Practices** concerning the recovery of secondary metals.

Therefore, the documented **Worst Practices** are described for unsound, and often also uncontrolled, operational aspects related to *collection, transportation and trading, manual dismantling, mechanical processing, and metallurgical processing as well as disposal of metal-bearing waste and 'end-of-waste fractions or materials'*.

The fact sheets presented to the Reader are structured as follows:

- a. Description of Worst Practice.
- b. Description of the impacts, clustered in four groups, according to the first four Principles elaborated on in the source document '*Guidance Principles for the Sustainable Management of Secondary Metals*':

- Safe, healthy and equitable working conditions
 - Community relations and resilience
 - Environment and natural resources
 - Recovery of secondary metals
- c. A section on **Good Practices** in which an attempt is made to point out improvements that should be undertaken and/or alternatives.

The authors and contributors hope to be of service to the Reader by publishing this collection of **Worst Practices** fact sheets as a means of sharing knowledge that will ultimately lead to an accelerated learning curve to benefit all affected and concerned stakeholders.

These stakeholders include, but are not limited to the economic operators conducting such activities, product manufacturers and metallurgical processors sourcing materials from them, government authorities and other stakeholders which wish to gain full insight into the nature and complexity of the problems (from human health and environmental perspectives) associated with **Worst Practices** in secondary metals recovery.

The authors and contributors of these fact sheets do not claim in any way that the described **Worst Practices** are comprehensive or provide full coverage of all problems caused by them. The authors recommend that the fact sheets information be used as a starting point while gathering more details through personal research, with the aim to:

- Validate the identification of **Worst Practices** in the value chain concerned, while acknowledging that there might be other **Worst Practices** of major concern
- Find additional resources in support of the implementation of the **Good Practices** suggested
- Identify alternatives that are available or better accessible in the country concerned.

Acronyms

BAT	Best Available Technology
CFC	Chlorofluorocarbons
CFL	Compact Fluorescent Lamp
CRT	Cathode Ray Tube
EHS	Environmental Health and Safety
EPR	Extended Producer Responsibility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
OBA	Official Business Activity
ODS	Ozone Depleting Substances
(PAH)s	Polycyclic Aromatic Hydrocarbons
(PBT)s	Persistent Bio-Accumulative Toxic Substances
PCB	Printed Circuit Board
PCBs	Polychlorinated Biphenyls
POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
SA	Subsistence Activity
SRI	Sustainable Recycling Industries
UBA	Unofficial Business Activity
ULAB	Used Lead Acid Battery
WEEE	Waste Electrical and Electronic Equipment
WRF	World Resources Forum

Contents

Sustainable Recycling Industries (SRI).....	2
Notes to the Reader.....	3
Acronyms	4
Overview of <i>Worst Practices</i> in Secondary Metals Recovery.....	6
1. What is <i>Worst Practice</i> ?	6
2. Where and Why Do <i>Worst Practices</i> Exist?.....	6
3. Motivation: Filling the Gap.....	7
4. Criteria Used to Identify <i>Worst Practices</i>	7
5. Clusters of Practices of Major Concern and Worst Practices	8
<i>Fact Sheets of Worst Practices</i> in Secondary Metals Recovery	14
A. Poor Housekeeping during Collection: Handling, Logistics and Facilities	14
B. Non-compliant trading and poor housekeeping in transportation	18
C. Unsafe Manual Dismantling	24
D. Low-quality Segregation during Mechanical Processing	29
E. Low-tech, Unsound Smelting and Off-Burning	33
G. Other Low-tech, Unsound Chemical Leaching	41
H. Open Burning	45
I. Open Dumping	49
References.....	52

1. What is Worst Practice?

According to the definition developed as part of the *Guidance Principles for the Sustainable Management of Secondary Metals* (ISO IWA 19), **Worst Practices** are described as:

practices that are known or suspected to have severe (typically multiple) negative impacts on the environment, workers/ community health and safety, and quality and quantity of recovered secondary metals, when applied by any economic operator in any of the processes concerned (collection, manual and mechanical processing, metallurgical processing and disposal).

Some of these **Worst Practices** can be altered and their potentially negative impact can be thus mitigated to an acceptable level (through introducing certain technical, operational or housekeeping improvements) to become **Good Practices**, whilst others cannot be accepted from the outset and therefore should be abandoned and subsequently banned. The sound transportation, treatment and disposal practice and technology requirements on which **Good Practices** are largely based on, are described through a range of conventions and supporting documentations, including the Basel Convention and the Basel R4 Guidelines (Basel Convention, 2004), the Stockholm Convention (2004), the Minamata Convention (2013) and the Montreal Protocol (1989).

WORST PRACTICE



Ghanaian boy off-burning plastics from copper cables and a girl bringing water, Accra, Ghana ©Empa

2. Where and Why Do Worst Practices Exist?

These undesirable practices are globally widespread and typically take place in economic environments and political climates that show an absence of control mechanisms (such as legislative enforcement of minimum standards to ensure the protection of both human health and environmental systems integrity). Individuals and local communities might be forced to engage in **Worst Practices** in subsistence activities (SA)¹ due to the lack of other local income opportunities and despite their often-tangible negative human health impacts.

To this end it is of great importance to rather develop financial incentives and source the required funds (and other support mechanisms) to motivate and encourage **Good Practices** (in parallel to combating the described **Worst Practices**).

Poor education and lack of training also contribute to engaging in risky practices in the *informal sector* (typically without sufficient protection for the workers or the receiving environment). Often there is a complete lack of awareness found in people engaged in any aspect of the described **Worst Practices** and, as a result, there is little understanding on how badly these practices can harm the environment and, ultimately, anyone involved in such unsound activities (workers) or involuntarily affected by them (e.g. neighbouring communities).

Some economic operators are also broadly applying **Worst Practices** in conducting their unofficial business activities (UBA)² and profiteering from ill-gotten economic gains.

While prevalence can be observed in the informal sector (UBA and SA) in developing and emerging economies, **Worst Practices** can also occasionally be found in the otherwise 'formal sector'

¹ **subsistence activities (SA)** - activities that can be found in both the formal and the informal sectors, and are conducted by economic operators (mostly individuals and families) who earn a wage that is barely sufficient to support or maintain themselves and is below the minimum tax threshold required per national laws and regulations to pay taxes.

² **unofficial business activities (UBA)** - activities that are conducted by economic operators not constituted as legal entities, with income above the living wage as well as the minimum tax threshold and that purposely desire to bypass national and/or local laws and regulations.

described by official business activities (OBA³), e.g., if control mechanisms are not in place.

To raise awareness and strengthen their capacities to move away from **Worst Practices**, workers engaged in SA, UBA and OBA and their leadership need support with targeted capacity building and coaching programmes.

The need for guidance on how to overcome **Worst Practices** has been identified as a priority matter. However, as of now, there is a gap as there is very limited literature describing practices of major concern and options for improvement.

3. Motivation: Filling the Gap

In response to the identified need for guidance on how to overcome **Worst Practices**, this collection of fact sheets was developed to serve as a reference document and guide for economic operators, users, government authorities and other stakeholders which wish to get full insight into the nature and complexity of **Worst Practices** linked to secondary metals recovery.

The collection of fact sheets provides a basic description and overview of selected **Worst Practices** and related processes observed in the recovery of secondary metals. With a view to improve them where possible, this collection spells out and describes a sequence of options for **Good Practices**.

³ Official business activities (OBA) -economic activities that are conducted by economic operators constituted as legal entities and, thus, are subject to government regulation, taxation and observation.



Aluminium recovered from metal scrap in Ghana ©WRF



Metal recovered: Copper ©WRF

Certain **Worst Practices** and related steps to **Good Practices** are locally more predominant than others. However, based on the strong international consultation process conducted during the identification period, it can be confirmed that this **Worst Practices** selection is of global relevance.

4. Criteria Used to Identify Worst Practices

The criteria according to which **Worst Practices** were selected and described in this document are as follows:

- They occur in secondary metals recovery from any waste and end-of-waste that contains metals
- They are globally widespread (mostly among economic operators involved in SA and UBA), often in emerging and developing economies
- They are known for their severe (typically multiple) negative impacts on the environment, workers/community health and safety, as well as the quality and quantity of recovered secondary metals.

5. Clusters of Practices of Major Concern and Worst Practices

Based on the criteria established, the following *Worst Practices* were identified (see second column of **Table 1**) which correspond to six **Clusters of Worst Practices** or practices of major concern (see first column). Recommendations on *Good Practices* were drawn up based on contributions of the work group and according to the Basel Convention Guidelines (2004) (see last column).

Table 1: Clusters of Practices, Worst Practices and Good Practices

Clusters of Worst Practices	Worst Practices	Good Practices
A. Unsound collection practices	Poor housekeeping during collection: handling, logistics and facilities	<ul style="list-style-type: none"> • Provision and use of personal protective equipment (PPE) • Adequate storage practices, facilities (with a licence to operate) and layout (allowing, e.g., sufficient operational space) • Dedicated safe storage space for batteries and other hazardous waste, fractions or materials • Resolution of non-compliance with regulations governing any aspect of collection-related practices • Prevention of selective harvesting/-cherry-picking of valuable components/-fractions during 'collection' • Awareness raising on risks to health and the environment and provision of training in Good Practices (e.g., classification and handling of hazardous wastes)
B. Unsound transportation and trading	Non-compliant trading and poor housekeeping in transportation	<ul style="list-style-type: none"> • Resolution of non-compliance with transportation and trade-related regulations and international agreements • Implementation of a traceability scheme such as chain-of-custody • Awareness raising on risks to health and the environment, and on organisational and other kinds of risks associated with non-compliant and unsound transportation and trading • Provision of training in Good Practices, covering general housekeeping and compliance with regulations and international agreements for transportation and trading, with the focus on transportation and trading of hazardous substances and wastes
C. Dangerous manual dismantling practices	Unsafe manual dismantling	<ul style="list-style-type: none"> • Provision and use of PPE • Suitable and safe working environment • Provision of proper dismantling tools and technologies • Safe removal of hazardous components (depollution) and discharge of electrical components • Resolution of non-compliance with regulations governing any aspect of manual dismantling-related practices • Awareness raising on risks to health and the environment and provision of training on Good Practices, covering general housekeeping and safe depollution/discharge steps

Clusters of Worst Practices	Worst Practices	Good Practices
D. Inefficient mechanical processing	Low-quality segregation during mechanical processing	<ul style="list-style-type: none"> • Provision and use of PPE • Suitable and safe working environment • Safe removal of any hazardous components (complete depollution) • Recovery of valuable components/-fractions for re-use prior to mechanical shredding • Appropriate technical setup and regular maintenance of mechanical shredding machines • Resolution of non-compliance with regulations governing any aspect of mechanical processing-related practices • Awareness raising on risks to health and the environment, and on negative impacts on the quality and quantity of materials and fractions recovered • Provision of training on Good Practices, covering general housekeeping, personal protection and equipment requirements and the safe removal of valuable hazardous components/fractions and their effective recovery for re-use
E. Inefficient and dangerous metallurgical processing	Low-tech, unsound 'smelting' and 'off-burning'	<ul style="list-style-type: none"> • Cessation of uncontrolled off-burning practices • Resolution of any non-compliance with regulations governing any aspect of low-tech smelting practices • Awareness raising on risks to health and the environment, and on negative impacts on the quality and quantity of materials and fractions recovered • Use of safe, efficient and legally authorised facility for smelting practices and any kind of alternative pyrometallurgical processing to off-burning, with proper emission controls of hazardous substances and waste management systems. • Training on improved or alternative pyrometallurgical processing
	Amalgamation	<ul style="list-style-type: none"> • Cessation of amalgamation practice • Awareness raising on risks to health and the environment • Use of safe, efficient and legally authorised facility for any kind of alternative gold recovery processing with proper controls of pollutants to soil and air, and waste(-water) management systems.
	Other low-tech, unsound chemical leaching	<ul style="list-style-type: none"> • Resolution of non-compliance with regulations governing any aspect of low-tech chemical leaching and related practices • Awareness raising on risks to health and the environment, and on negative impacts on the quality and quantity of materials and fractions recovered • Use of a safe, efficient and legally authorised facility for any kind of chemical leaching processing with proper controls of pollutants to soil and air, and waste(-water) management systems.

Clusters of Worst Practices	Worst Practices	Good Practices
F. Unsound disposal	Open burning	<ul style="list-style-type: none"> • Cessation of uncontrolled open burning practices • Awareness-raising on the dangers associated with open burning practices and existing alternatives • Use of safe, efficient and legally authorised facilities for alternative thermal and non-thermal treatment and disposal of wastes such as controlled incineration or granulation, among others
	Open dumping	<ul style="list-style-type: none"> • Closing of uncontrolled open dumping sites • Awareness raising on the dangers of uncontrolled open dumping and existing alternatives • Use of legally authorised facilities that provide sound disposal methods

Unsound Collection

Collection is the first stage in recycling and consists of the gathering of waste, including the preliminary sorting and storage, for the purposes of transport to storage, manual or mechanical processing, metallurgical processing, or to the next economic operator (ISO IWA 19:2017: 3.6). **Collection** aims to identify and gather materials with valuable metals to be recovered.

Unsound and therefore often uncontrolled (and even) dangerous **Collection Practices** hamper reaching this goal. These practices are in place whenever an economic operator poorly runs the systems and facilities linked to the accumulation of metal-bearing materials, and include the sorting, harvesting and cherry-picking, storing, preparation for transportation, and internal movements at the facility. Signs of poor housekeeping include unsafe handling and management practices and keeping the required collection infrastructure and tools in a permanent state of decay and disrepair.

Such poorly managed working conditions and unsafe activity areas pose human health risks to unprotected and exposed workers, cause environmental pollution dangers and jeopardise an efficient downstream metal recovery system.

More background information and a description of good practices to improve the housekeeping practices are presented in the Fact Sheet A on 'Poor Housekeeping during Collection: Handling, Logistics and Facilities'.

Unsound Transportation and Trading

Transportation and trading take place along the entire value chain of secondary metals recovery by passing materials – downstream – from one distinct processing area to the next:

- Collection
- Manual and Mechanical Processing
- Metallurgical Processing
- Consumption/Manufacturing
- Disposal

Unsound **transportation and trading** (movements of fractions and wastes) occur when two or more actors in different locations or countries in an articulated way deliberately engage in illegal trading by ignoring and/or neglecting legal requirements. This is often facilitated by mislabelling/misdeclaring goods and by bribing officials (charged to properly enforce shipment regulations) in order to:

- Avoid financial liabilities for proper treatment in countries from which the wastes stream materials originate, and to therefore externalise such costs
- Cut costs for transportation
- Facilitate the trade (export and import over borders) of otherwise banned materials, typically to countries lacking control and protection mechanisms
- Shorten trading transaction times
- Sell with maximum profit to non-compliant end-use facilities that are ill-equipped to

WORST PRACTICE



Metallurgical processing ©Empa

properly treat such shipments according to the required minimum environmental, health and safety (EHS) standards.

Trading and transportation that are non-compliant with the legal requirements put concerned businesses at risk, contribute to unfair competitive behaviour, support inefficient recovery practices with huge losses of valuable materials, and increase the probability of undetected incidents and emergencies with negative impacts on the environment and human health, with no chance of timely mitigation by the authorities or civil society.

With the aim to provide a more detailed background on issues of concern and describe good practices to move away from unsound transportation, a Fact Sheet on 'Non-compliant Trading and Poor Housekeeping in transportation' has been developed. See Fact Sheet B.

There are also poor housekeeping practices in transportation that are of a similar nature to those described in **Unsound Collection** in Fact Sheet A: 'Poor housekeeping during the collection: handling, logistics and facilities'.

Dangerous Manual Dismantling

Manual dismantling processes aim to separate, accumulate, and therefore concentrate, metals from waste materials received as feedstock into

different waste and end-of-waste fractions and components for further processing (ISO IWA 19: 2017, 3.23). In this context, dismantling includes manual sorting, separation, cleaning, emptying, depollution and segregation.

Dangerous manual dismantling practices are typically done in unsound, uncontrolled and often unsafe (and typically very crude) ways.

Such processes can be especially dangerous to workers, who are prone to injuries when there is a lack of personal protection equipment (PPE), but also to the environment. These processes also contribute to a loss in value of the original materials to be recovered.

For more detailed examples of dangerous manual dismantling practices and options to improve them, see Fact Sheet C on 'Unsafe Manual Dismantling'

Inefficient Mechanical Processing

Mechanical processes aim to separate and concentrate metals from waste materials received as feedstock into different waste and end-of-waste fractions and components for further processing (ISO IWA 19: 2017, 3.23). In this context, **mechanical processes** include shredding, milling and grinding, as well as mechanical segregation by, for example, eddy current or air stream classifiers.

However, inefficient mechanical processing, such as poor mechanical shredding practices, is often practised, which leads to a low-quality segregation outcome with the loss of valuable free-of-pollutants metal fractions that could have been recovered, as well as to a high concentration of contaminants in the desired metal-bearing fraction that is retrieved.

Any fractions or dust generated in the shredding of such hazardous materials obviously carry similar chemical properties, with subsequent human health and environmental hazards.

More background information and a description of good practices to improve the housekeeping practices are presented in the Fact Sheet A on 'Poor Housekeeping during Collection: Handling, Logistics and Facilities'.

In Fact Sheet D on 'Low-quality Segregation during Mechanical Processing', several examples of inefficient mechanical processing practices are presented as well as options to improve these practices.

Inefficient and Dangerous Metallurgical Processing

Metallurgical processing of fractions that contain metals aims to obtain further fractions of higher and valuable metal content and to separate and refine metals with specified properties. Common metallurgical processes include hydro-, pyro- and electro-metallurgical

processes that involve chemical reactions such as pyrolysis, smelting and chemical leaching. Due to the types of emissions and pollutants generated, these processes typically require a local and/or national licence.

In the worst-case scenario, inefficient and dangerous metallurgical processing take place including, either in isolation or in combination, the application of crude and typically unprotected (for the worker and the environment) hydro-, pyro- and electro-metallurgical processes (involving complex chemical reactions caused by smelting and off-burning, chemical leaching, and/or amalgamation).

These practices inevitably lead to a loss of valuable metal-bearing fractions which become solid waste dispersed into the environment.

It is worth noting that practical experience at international level has shown that only facilities that treat large amounts of fractions and materials are economically feasible, which puts in disadvantage facilities with limited capacities aiming at only serving local markets.

To address the general issues raised before, three groups of metallurgical processes were selected based on the experience of the authors and contributors as well as on recommendations gathered from the international literature. They were further developed in form of Fact Sheets which include specific examples for each group and recommendations of good practices. See the following:

WORST PRACTICE



Aluminium ingots produced in open soils (Ghana) ©WRF

WORST PRACTICE



Lubricant leakage from unsafe dismantling of a fridge compressor (Ghana) ©WRF

WORST PRACTICE



Open burning ©Empa

- Fact Sheet E on 'Low-tech, unsound 'smelting' and 'off-burning''
- Fact Sheet F on 'Amalgamation'
- Fact Sheet G on 'Other low-tech, unsound chemical leaching'

Uncontrolled Disposal

Disposal is the final or temporary placement of waste that is not salvaged for further metal reuse or recovery purposes.

However, especially in developing and emerging economies, this practice is done in an uncontrolled way, e.g. by the uncontrolled and unprotected release of potentially hazardous wastes, domestic or industrial, into the environment in the form of solids, liquids (effluents) and gases (emissions). More specifically, uncontrolled disposal can occur through burying (or open dumping) or exposing waste materials (e.g. metal-containing municipal wastes) to heat sources (typically fires at low, smouldering temperatures) in an open and therefore unprotected environment, for the primary purpose of the reduction of waste

WORST PRACTICE



Open dumping ©Empa

volume or energy recovery (open burning).

Often, it is a lack of awareness that leads to such dangerous and reckless practices, because people simply do not know they are harming the environment and themselves.

Open burning or **open dumping** may contaminate air (via volatilisation and fugitive dust emissions); surface water (from surface runoff or overland flow and groundwater seepage); groundwater (through leaching/infiltration); soils (due to erosion, including fugitive dust generation/deposition and tracking); sediments (from surface runoff/overland flow seepage and leaching) and biota (due to biological uptake and bioaccumulation).

More detailed description of open burning or disposal cases, impacts and good practices to move away from these practices are accessible in the following Fact Sheets:

- Fact Sheet H on 'Open Burning'
- Fact Sheet I on 'Open Dumping'

A. Poor Housekeeping during Collection: Handling, Logistics and Facilities

Identified cases

Worst Practices related to poor housekeeping in collection practices related to the quality of handling, logistics and facilities include, but are not limited to:

- Unsafe handling practices after collection and prior to transport (e.g., uncontrolled removal of acids from used lead acid batteries – ULABs)
- Unsafe handling practices in preparation for storage (failure to isolate battery contacts) pose a fire hazard
- Improper storage methods (e.g., overstacking of unsecured piles that can collapse on workers and damage materials)
- Selective harvesting and cherry-picking of the easily accessible value fractions – e.g. copper in cathode ray tube (CRT) monitors – and disregarding (wasting) other valuable fractions
- Using collection vehicles that are not roadworthy or not designed as fit for purpose (e.g., uncovered loads)
- Lack of proper equipment, such as forklifts and cranes to facilitate the safe loading and unloading of metal-bearing materials
- Storage facilities without protection against climate conditions that may affect the quality of materials
- No separate and safe (temperature-controlled) storage for combustible fractions, such as lithium-ion batteries and certain lamps (compact fluorescent lamps – CFLs) and items (such as fridges) posing potential health and hygiene hazards
- No separate storage for hazardous fractions and wastes

WORST PRACTICE



Informal collection of hazardous waste with metals in Lima, Peru ©WRF

WORST PRACTICE



Poor house-keeping and risks of environmental pollution due to inappropriate management of hazardous materials at an informal site in Cambodia ©WRF

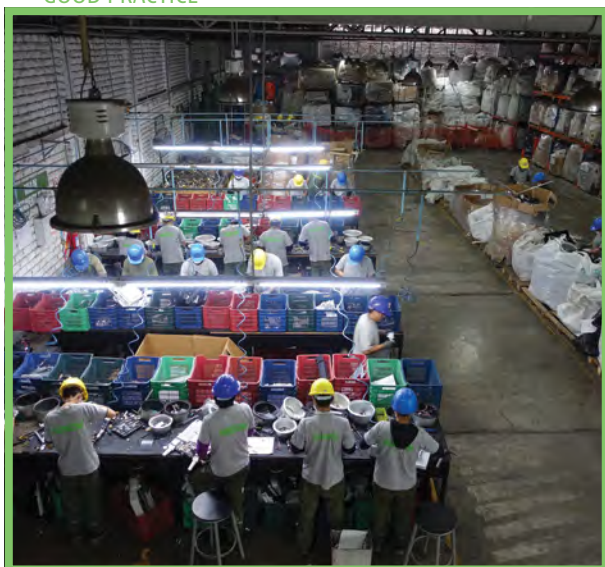
A. Poor Housekeeping during Collection: Handling, Logistics and Facilities

Impacts

The following table lists the impacts of poor housekeeping during collection.

<p><i>Safe, healthy and equitable working conditions</i></p> <p><i>&</i></p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none"> • Cross-contamination of pollutants from broken, leaching, poorly sorted and stored materials can make otherwise clean and unpolluted metal-bearing fractions a health risk to workers and the wider environment when the latter are accessed and treated for metal recovery downstream. • Poorly stored and handled items, in being moved about, might disintegrate (break) and pose a danger to health (due to exposure to chemicals) or injury (e.g. due to broken-off shards of the substance) when operators are not wearing PPE. Poorly secured loads, in storage and when transported on vehicles, can be dislodged and fall, injuring operators or passers-by. • Collection vehicles that are not roadworthy might lead to accidents.
<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> • Storage of metal-containing wastes in environments open to the elements (rain, heat and UV radiation) might mobilise soluble heavy metals and other toxic substances, which can then be transported into surrounding eco-systems, e.g. through run-offs reaching stormwater systems.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> • Poor sorting and grading outcome, but poor sorting and storage practices might also result in the damage and co-mingling of metal and non-metal-bearing fractions, which can then negatively affect their reuse potential and the overall metal recovery efficiency downstream.

GOOD PRACTICE



Adequate layout including proper ventilation and lighting and protection from the weather, and proper use of PPE by workers) ©WRF

GOOD PRACTICE



Authorised collectors with proper vehicles and uniforms ©WRF

A. Poor Housekeeping during Collection: Handling, Logistics and Facilities

Steps to Good Practices

All distinct activities and services grouped under Collection should be conducted in an acceptable and responsible manner with good housekeeping practices in place. In order to avoid any accidents threatening human health or harming the environment, this includes the provision and proper use of personal protective equipment (PPE), relevant and regular training of workers and adequate, suitable, safe and licensed storage facilities. The summary of key points noted below unpacks some of the requirements to transform any Worst Practices types of collection into Good Practices.

1. Provide workers with good and safe personal protective equipment

Good collection practices require that PPE is in place and properly used for all collection and handling activities described above. Workers should therefore always be provided with functional PPE items, such as gloves, safety glasses, safety shoes, work overalls, and also respiratory masks where fine dust is generated.

2. Provide sufficient storage facilities and operational space

The storage facility used as the endpoint of any collection activity should be located in an area that is suitable for the purpose (e.g. not located directly next to an environmentally sensitive area) and be licensed/zoned accordingly.

Regulatory aspects and local requirements

In addition to zonification requirements, most local regulations and technical requirements (in national Standards) for licensing facilities as sound for environmental, health and safety (EHS) principles, typically include the proof of availability of:

- Building security features (e.g. fire extinguishers)
- PPE
- Regular workers' training
- Access to water, sanitation and electricity, and good, natural light and ventilation

Minimising dispersion of pollutants

Storage of secondary metal carriers and wastes should be in a closed-off space, protected from the elements by a roof and an impermeable (sealed) floor, with all necessary infrastructure in place for workers to conduct first value-adding pre-treatment and pre-processing steps, such as the unpacking, repacking, sorting and grading of materials and wastes into various high-value fractions.

In tropical climates with high humidity and temperature levels, the storage of fridges, freezers and other cooling appliances should be temperature controlled since the formation of water pools (e.g. in the defrosting phase) could cause problems of hygiene and disease (mosquito breeding grounds).

Facilitating movements of materials and workers, and the maintenance

The layout of a facility is also important and should allow for the necessary space and movement for the purposes of storing and handling materials. For example, the workroom for manual dismantling and disassembly should be kept as free as possible of storage and open shelves (containing e-waste, tools, etc.). This would facilitate cleaning the workshop and the complete removal of any accumulated and potentially health-impacting dust.

To avoid the danger of dislocation and accidents due to collapsing piles of material, the facility needs dedicated and sufficient space within the collector's storage facility to receive materials, to apply value-adding pre-processing steps and for safe storage prior to dispatch.

A. Poor Housekeeping during Collection: Handling, Logistics and Facilities

Steps to Good Practices

3. Ensure hazardous waste is handled with care

Certain metal-bearing parts and components, such as batteries, are a potential fire-hazard and could release mercury-containing compact fluorescent lamps (CFLs) when exploding. Therefore, such items should be identified, separated at the first point of reception for temporary storage, and properly managed, e.g., by packaging them (Li-Ion batteries) in such a way (e.g. by isolating and wrapping the contacts/terminals with tape) to avoid short-circuiting and fires, and against exposure to extreme temperatures and the elements (which might induce leakage). Caution should be taken to ensure that battery transportation complies with all applicable regulations or courier requirements, i.e., the International Air Transport Association (IATA) regulations for the handling of lithium metal and lithium-ion batteries.

Caution should also be taken, in the case of other hazardous waste, fractions or materials that arrive at the facility, against them becoming hazardous during processing. They need to be stored, and handled according to the local and international recommendations for this kind of waste, fractions or materials.

4. Identify, report and take action on non-compliance

Any identified form of non-compliance linked to any collection activity (e.g. with regards to any regulatory storage limits, such as maximum time limits and the quantities allowed in storage) needs to be identified, reported to the relevant parties, rectified, and documented towards the establishment of a compliance check list used for future compliance monitoring and evaluation.

5. Prevent cherry-picking of valuable components

There is a warning against the selective harvesting/cherry-picking of valuable components/fractions – which greatly diminishes the value of the remaining material that a downstream operator can retrieve. This is a learning process that will need guidance and feedback from the next actors in the value chain. Basically, a quick assessment of the best way to select waste and components is required. Based on that, guidance is needed on how to best separate, or not, the valuable parts without any of this being at the expense of the potential reuse and repair of equipment and its components.

6. Raise awareness, inform and train your workforce

The aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of the risks of unsound collection practices by value-chain actors and economic operators who are concerned or involved in these practices.

In order to reach this goal, workers need access to adequate and user-friendly information materials in their local language as well as teaching materials, and to receive regular training to learn about safe collection practices (including the proper way to wear their PPE where and when required and the proper handling and maintenance of all equipment). The many environmental, health and safety (EHS) risks associated with poor housekeeping need to be clearly pointed out in order to create awareness and the subsequent willingness to switch to the suggested Good Practices.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals provide directions on sustainability criteria to protect workers and the environment when implementing these practices (IWA 19:2017). It can be a part of the information material for awareness raising.

B. Non-compliant trading and poor housekeeping in transportation

Identified cases

There is a wide range of actors potentially involved in non-compliant trading locally, nationally and internationally, as well as in unsound transportation via road, water or air. These include: producers, distributors, traders (importers and exporters), consumers, collectors, refurbishers, waste brokers, shipping companies, shipping agents, terminal operators, environmental inspectors, customs officials, police officers, organised crime groups, recyclers, downstream vendors, and final disposal service providers.

The usual actors are involved in official business activities (OBAs), incurring non-legal compliant practices, or in unofficial business activities (UBAs).

Examples of non-compliant trading and poor housekeeping transportation and trading practices include, but are not limited to:

- Unsafe handling practices prior to transport (e.g. uncontrolled removal of acids from used lead acid batteries – ULABs)
- Selling on processed fractions to a downstream vendor who is operating in a non-compliant and dangerous manner, with dire consequences to worker safety and the receiving environment
- Violating the applicable global (Basel Convention) or local (WEEE Directive) legislation that limits and prescribes the modus operandi for acceptable trading and transportation practices
- Non-existent or incomplete documentation of accurate shipping records and/or forgery of the relevant export and import permits, where the latter are typically obtained by bribing officials
- Trading of cargo that is deliberately falsely labelled and wrongly declared to avoid local costly and legally prescribed waste treatment obligations (such as safety disposal costs) and import duties
- Improperly packaged cargo that does not comply with the required minimum standards set by international transportation regulations in order to avoid costs
- Utilisation of equipment, facilities and transportation vessels that are unsound and unsafe to use with regards to structural integrity and the technical standard required, such as unroadworthy trucks and unseaworthy ships
- Utilisation of fly-by-night types of transportation services that typically employ an untrained, unprotected workforce operating in a non-compliant (e.g. unlicensed), unprotected (accident-prone) and uninsured manner.

WORST PRACTICE



Informal (with illegible vehicle number plate) and unsafe transportation of used computers to a recycling plant (China) ©Empa

WORST PRACTICE



Barrel containing fuel is mislabelled. As this was imported by a recycling plant, it was done on purpose to avoid the Basel Convention procedures ©WRF

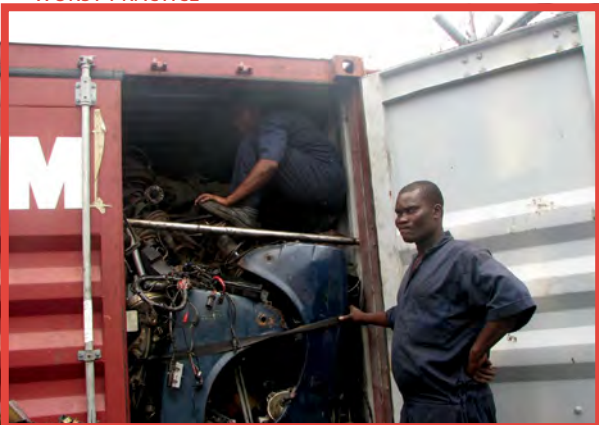
B. Non-compliant trading and poor housekeeping in transportation

Impacts

A description of impacts on the following areas as a result of non-compliant trading and poor housekeeping transportation and trading practices are presented below.

<p><i>Safe, healthy and equitable working conditions</i></p> <p>&</p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none">• As these practices deliberately escape the radar of the authorities, the environmental and economic impacts remain undetected for longer periods and tend to be of larger magnitudes, with more dramatic consequences. Impacts are only detected when damages are visible and of great proportions (e.g. when environmental emergencies occur) – even with fatal personal consequences. These may also occur in international jurisdiction areas (e.g. in ports or in international waters), where access to these sites is difficult and expensive and they therefore lack adequate damage control or mitigation.• Unroadworthy vehicles, unseaworthy ships and technically obsolete aircraft used in non-compliant transportation might lead to serious accidents and the loss of many lives.• Dangerous or unsafely packaged goods could leak or spill and even cause explosions (e.g. lithium-ion batteries as cargo in aircraft are now heavily restricted by UPS), with serious negative impacts on the environment as well.• Hazardous goods falsely declared as ‘non-dangerous’ can also unknowingly be handled wrongly, with dire consequences.• Faulty operational equipment and/or the use of untrained workers to move or load goods are another potential source of fatal accidents.• Non-compliant end-users of goods are typically not operating according to any legally demanded minimum health and safety requirements and, as such, in being received, these goods (often containing elements of concern such as heavy metals and chemical flame retardants) pose a tremendous health and safety risk to workers exposed to them in the absence of protection measures.
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WORST PRACTICE



Mixed and non-labelled scrap exported from Europe to Nigeria non-compliant with the Basel Convention Guidelines ©Empa

WORST PRACTICE



Untested second-hand screens and TVs imported by Ghana which might soon become waste ©Empa

B. Non-compliant trading and poor housekeeping in transportation

Impacts

<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> Equipment and transportation vehicle failure and accidents can have dire consequences for the environment when leaks and explosions take place, subsequently releasing toxic spills and emissions to the unprotected environment.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> A less obvious impact of unsound transportation and trading practices is that they affect the optimum recovery efficiencies of end-users when the latter are not able to offer a high grade and multiple-element recovery-based metallurgical processing system, e.g., as is provided by the services of a fully compliant state-of-the-art smelter based on best-available technologies. The overall secondary metal-recovery efficiency (from collection, to dismantling and any pre-processing to the actual materials-recovery facility) is determined by the efficiency of the weakest link in the value and processing chain. Compared to a state-of-the-art smelter, recovery efficiencies of informal backyard recycling and smelting typically do not exceed 25% of the efficiency of state-of-the-art smelters. Subsequently, there are other related negative effects in the processing of any secondary metal-bearing fractions, mainly through a chain of non-compliant service providers (as is the case when such cargo is illegally transported to localised informal processing hubs). These effects include unacceptably high health risks for workers involved in the final metal extraction steps in substandard facilities, and unabated pollution that can severely harm the surrounding environment.

GOOD PRACTICE



Authorised vehicle for transportation of second-hand computers for re-use in Ghana ©Empa

GOOD PRACTICE



Instructions for proper identification and sorting of materials, in particular to segregate hazardous components ©WRF

B. Non-compliant trading and poor housekeeping in transportation

Steps to Good Practices

Activities related to trading and transportation should be conducted in an acceptable and responsible manner with **good housekeeping practices** in place during the transportation, and in due compliance with the international and national requirements related to trading and transportation. The following key points describes some of these requirements to transform any unsound-transportation-and-trading-type *Worst Practices* into *Good Practices*.

1. Identify, report and take action on non-compliance

Firstly, international agreements or conventions and local regulations related to **transportation and trading** need to be identified, including:

- Transportation and trading laws in all countries involved in any aspect of the concerned value chain
- Transportation and trading obligations linked to a specific actor in the value chain
- Transportation and trading requirements linked to the nature of materials transported, traded and/or transferred (e.g. through transboundary shipments and restrictions thereof as stipulated by the Basel Convention).

As per identified requirements, an assessment of compliance needs to be done.

Any non-compliant **trading and/or transportation** activity identified and practised by any actor anywhere along the entire value chain of secondary metals recovery, at any scale and in any location observed, needs ultimately to be stopped and replaced with a practice that is compliant with all relevant legal minimum requirements identified.

Any observed non-compliance needs to be reported to the relevant parties, rectified, and documented towards the establishment of a compliance check list used for future compliance monitoring and evaluation.

2. Implement a chain-of-custody scheme

Regular verification of compliance forms part of a verifiable, traceable and transparent list of checks and balances measures that support chain-of-custody schemes.

There are few certification systems that support the monitoring of compliance of outgoing quantities of material (including monitoring, measurement and documentation) for specific accounting periods, and that then balance all these with the corresponding outgoing shipping records for the same quantities and materials (for example, through the e-Steward Standard and recently launched ISO IWA 19:2017).

3. Raise awareness and inform

The aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of the value-chain actors and economic operators concerned about the risks and multiple negative consequences, direct and indirect, of non-compliant trading and transportation practices.

Manufacturers need to understand that it is in their interests to ensure that their end-of-life and metal-containing wastes are processed and subsequently traded through a compliant chain of service providers in order to maximise and optimise recovery efficiencies.

Workers need to understand that (no matter where they are located in the value chain and from which global location they operate), it is their intrinsic human right to be fully insured, fairly paid and to work in appropriate, licensed facilities. This includes that the required environmental, health and safety (EHS) measures, such as personal protective equipment (PPE), are firmly in place where the concerned activity is conducted.

B. Non-compliant trading and poor housekeeping in transportation

Steps to Good Practices

To achieve this goal, all actors in the value chain linked to **transportation and trading** of metals-bearing waste, fractions or materials need freely accessible information and materials that explain these risks.

Training manuals such as the Basel Convention Training Manual on Illegal Traffic for Customs and Enforcement Agencies provide excellent resources to ensure that awareness linked to all aspects of non-compliant trading and transportation is growing and spreading.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment when implementing these practices (IWA 19:2017).

Awareness-raising campaigns should also include civil society, represented by not-for profit organisations, to ensure citizens are given the opportunity to put pressure on national decision-makers to increase their efforts to tackle this environmental crime.

4. Train your workforce on compliant housekeeping during transport

Tailored training aims to impart knowledge on how to do proper housekeeping during transportation, as well as the international and national legal trading-related requirements that need to be observed.

Training needs to be provided that points out transportation practices (and general poor examples of housekeeping during transportation) that are likely to damage certain equipment (e.g., the cooling coil in fridges) or could otherwise compromise the quality of metal-containing fractions in transit. Most importantly, the training needs to inform learners what the required **Good Practices** for trading and transportation look like instead. The summary of key points below, describing compliant trading and shipping practices, lists some of the elements that form part of the expected training:

5. Train your workforce on hazardous materials management

As part of the training required for traders and transporters of secondary metal containing wastes with any (potential) hazardous components, what needs to be described is that an individual might be involuntarily or accidentally exposed to danger. Such detailed descriptions should include the exact nature and appearance of the materials and the inherent environmental, health and safety risks involved in handling such items as well as the appropriate protection mechanism required.

Therefore, clear instructions must be provided according to the relevant practical technical and, if required, legal reporting formats. Proper training needs to be in place, e.g., in the form of **illustrated operational standard procedures** and in the relevant local language, to inform workers handling such materials (such as when items are loaded for shipping) on the safest practices to do so. This would include how to avoid any contamination of non-hazardous fractions, and the mixing of clean materials destined for processing.

6. Make sure to duly document and maintain shipping records

Workers' skills need to be developed on how to produce verifiable records of incoming and outgoing shipments or transfers of any secondary metals containing waste or materials, which should include a complete data set for all:

- Shipping logs
- Invoices
- Bills of lading/waybills
- Other commercially accepted documentation of transfers
- The corresponding acknowledgements of receipt from receiving facilities

B. Non-compliant trading and poor housekeeping in transportation

Steps to Good Practices

Workers should also learn how to fill in and keep track records of:

- Weights of materials and/or piece/unit counts
- Dates
- Particulars of the consignee (typically the buyer who is the receiver) and consignor (the seller or donor initiating the transition), and verifiable contact information for the entity that transfers shipment (the freight forwarder is thereby assuming the role of an intermediate consignee)

7. Ensure proper packaging

Workers should learn how to safely separate, consolidate and contain such materials and wastes, in a manner that prevents leaching, leakage, spills, dispersal, and the release of vapours, fumes, particulates, dust, liquids, and/or other forms of dangerous materials, and how to use containers that:

- Protect human health and the environment during storing and shipping of each material
- Meet the packaging and shipping requirements of respective downstream processors

Concerned economic operators should know how to accurately and visibly label containers according to their contents and packaging type, and prevent container damage, collapse, and contamination.

8. Classify and label properly

For the exact classification of secondary metal-containing wastes, different classification systems exist. The Basel Convention uses a system with Y, A and B codes (waste classification codes) for hazardous and non-hazardous wastes as well as hazardous characteristics. Other waste classification systems used worldwide are the OECD Waste Lists and the European Waste Catalogue (EWC).

It must be noted that waste classification codes do not always have a corresponding entry in the goods nomenclature of the World Customs Organization Harmonized System (WCOHS), which serves as the global system for customs authorities. In these cases, concerned economic operators will find guidance in the E-waste Inspection and Enforcement Manual (2012) compiled by the Secretariat of the Basel Convention (SBC) together with the United Nations Environment Programme (UNEP), the United Nations (UN), the European Union (EU) and the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL). This document lists classification systems for various types of e-waste (as a prime source of secondary metals), and their corresponding customs codes.

9. Hire only authorized transporters

Only logistic service providers with all the legal authority and adequate insurance or financial guarantees to cover costs in the event of an accident or injuries can be considered for the transportation of any secondary metals-containing materials.

It needs to be pointed out that safe end-use treatment facilities (offering the required treatment standards by operating according to the necessary, highly specified and sophisticated technologies) might not be available in every country or even on every continent from where secondary metal-containing waste/material stream originates. Such materials might therefore have to be exported to a foreign pre-authorized facility with the best available technologies. In these cases, it is recommended to establish and utilise a fast-track mechanism as part of the trading channel.

C. Unsafe Manual Dismantling

Identified cases

Common specific activities under this Worst Practice include, but are not limited to:

- Forced opening (by smashing and/or breaking the plastic casings of monitors and plastic or metal-encasing structures of items such as fridges, instead of using safer devices to facilitate a controlled opening (e.g., a screwdriver)
- Not wearing the required PPE
- Breaking and crushing inside parts of fridges, cathode ray tube (CRT) glass, flat screens and mercury-containing lamps without wearing PPE and without the proper separation and containment of hazardous constituents being released, such as could emanate from non-functioning batteries, capacitors, barium-getter pills, mercury-bearing relays, heavy metal containing powders
- Shattering carriers with polychlorinated biphenyls (PCBs) from which valuable parts (e.g. chips) are extracted for the purpose of the downstream recovery of the function (chip remanufacturing) or the material (secondary metal recovery) without using PPE and/or failing to safely remove potentially hazardous constituents
- Uncontrolled removal of acids from used lead acid batteries (ULABs)
- Cutting open ULABs with cutlasses to gain access to the lead without using PPE

WORST PRACTICE



Worker with no protection sawing scrap fridge compressors resulting in soil pollution from used oil (Cambodia) ©WRF

WORST PRACTICE



Child dismantling used motherboards in India ©Empa

C. Unsafe Manual Dismantling

Impacts

A description of impacts on the following areas as a result of unsafe manual dismantling practices are presented below.

<p><i>Safe, healthy and equitable working conditions</i></p> <p>&</p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none">• Uncontrolled smashing and shattering, or the misuse of tools to force the instantaneous opening of otherwise undamaged, intact and therefore benign systems and components, can accidentally activate, mobilise and release harmful chemicals and damage the environment with hazardous substances, or produce injury-causing shards of broken-off pieces (e.g. glass and plastic).• The exposure of operators to inhalation of emitted dust and fumes containing mercury, cadmium, nickel, lead and dioxins, and halogen-containing flame retardants and phosphor dust (CRT monitors).• Explosions caused by combustible fine dusts (e.g. from toners) can pose a severe injury risk.• Skin exposure to a wide range of heavy metals (e.g. mercury, lead, cadmium) and flame-retardant treated components can cause severe skin irritation and such poisons can enter the body.• Shards that fly loose due to the smashing or shattering process, e.g., of CRT glass or polychlorinated biphenyls (PCBs), can cause serious physical injuries and make workers prone to both eye damage and skin cuts through which pollutants and toxicants can readily enter.• Surrounding communities of areas where smashing and breaking operations occur are typically affected by the dust, waste and noise caused by these activities.• Leaking acid and acidic waste water run into drains and/or ground from the improper draining of ULABs.• Acid spills: using primitive tools in manual battery breaking can result in acid spilling on workers in the dismantling process.• Contaminated oil from the improper dismantling of compressors from refrigerators and air-conditioners.
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GOOD PRACTICE



GOOD PRACTICE



Extraction of cooling gases before fridge dismantling for recycling (Ghana) ©WRF

C. Unsafe Manual Dismantling

Impacts

<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> • Small material pieces, generated in open environments due to any uncontrolled smashing and bashing and forced opening, can find their way into the soil and waterways from where they are rapidly dispersed. Because none of these materials is generally biodegradable, any hazard-bearing powder, chemical, or heavy metal will transfer its properties straight into the receiving environments, thereby adversely affecting flora and fauna over long periods. Some practices – e.g., ripping out condensers and cooling fluid/gas pipes in ‘end-of-life cooling equipment’ and burning oil contaminated by refrigerants – can result in the release of ozone-depleting substance (ODS) chemicals, which aggravate climate change. • When dismantling fridges, the following wastes are produced: foaming agents like polyurethane, polyvinyl chloride (PVC), high impact polystyrene and rubber which are typically incinerated in an uncontrolled open burning process. In addition, the refrigerant used as the cooling agent, the so-called hydrofluorocarbons (HFCs), is released uncontrolled (due to venting) during the dismantling process. Such gases are considered to be harmful and are extremely potent in terms of their global warming potential (up to more than 5,000 times more potent than CO₂). The main impacts therefore come from the venting of the HFCs during the unsafe dismantling, as well as from the open burning of the plastics and polymers.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> • Crude dismantling does not only involuntarily mobilise certain pollutants, but due to the lack of proper disassembly also results in the loss of valuable materials and fractions, or their contamination, when smashed up with other low or no-value materials and/or contaminants, hence significantly reducing the efficiency of secondary metals recovery. • Using fit-for-purpose and correct tools, such as screwdrivers and pliers, to aid manual disassembly can recover working components for reuse as well as a range of clean material fractions for recycling (next to secondary metal-bearing carriers).

GOOD PRACTICE



Proper use of equipment to extract copper from cables in South Africa ©Derek Main

GOOD PRACTICE



Organized disassembly with proper tools and PPE of computer parts in Lima, Peru ©WRF

C. Unsafe Manual Dismantling

Steps to Good Practices

Activities related to manual dismantling need to be implemented in an acceptable and responsible manner, with good housekeeping practices in place and in due compliance with the related international and national requirements. This should include the provision of proper personal protective equipment (PPE), suitable and safe working environments and dismantling tools and technologies. Special attention should be given to the proper handling of hazardous and dangerous components. The following key points describe some of the requirements needed to transform any unsafe types of manual dismantling from Worst Practices into Good Practices.

1. Provide workers with good and safe personal protective equipment

Good preparation practice requires that PPE is in place and properly used in dismantling activities for the latter to be well-controlled and properly executed. Workers shall therefore always be provided with functional PPE items such as gloves, safety glasses, safety shoes, working overalls and respiratory masks where fine dust is generated.

2. Provide a suitable and safe working environment

Manual dismantling activities (especially those that by nature remain 'crude' because time constraints determine financial viability) should be conducted in an enclosed space that is protected from the natural elements. This makes it possible to contain and hence control the spread of any potential pollutants, including dust accidentally released in the process.

Storing materials in boxes (made of cardboard, wood, metal, etc.) or bags improves the general hygiene level as it prevents the accumulation of generated dust in the materials. It also prevents the dispersion of dust from the materials in the workshop.

3. Provide workers proper tools and technologies

Tools such as screwdrivers and pliers generally allow for better material recovery and should therefore be encouraged for manual dismantling and disassembly. Such refined and controlled disassembly methods should reduce the need for crude dismantling practices (e.g. the use of a crowbar, hammer and chisel). Separation with hammer and chisel usually does not produce clean material, but rather parts attached to pieces of other materials and hence leads to a lower resale price than the price of the clean parts obtained by disassembly using screwdrivers and pliers.

To increase productivity, the use of electrical or pneumatic screwdrivers is recommended; however, this requires additional investment.

From a health and safety perspective, any form of smashing and bashing should be stopped. Therefore, activities such as smashing lead glass-containing CRT monitors or mercury-containing lamps must be stopped due to the imminent, and typically uncontrolled, release of heavy metals and other mobilised pollutants (typically in the form of dust).

Instead, the economic operator should use the appropriate mechanisms and specialised technology for such separation processes as CRT lead glass removal, CFL lamp crushing and ULAB lead recovery. All the required environmental, health and safety (EHS) precautionary measures should be in place.

C. Unsafe Manual Dismantling

Steps to Good Practices

4. Remove hazardous components and discharge electrical ones

A document with recommendations on good dismantling practices should be made available. This needs to include guidelines for the complete removal of hazardous components (depollution) as part of the controlled disassembly process, before any downstream mechanical shredding of the non-hazardous parts takes place. Hazardous components include batteries, capacitors, getter pills, chlorofluorocarbon (CFC) gases, transistor oils, leaded cathode ray tube (CRT) monitor glass, used lead acid batteries (ULABs), mercury-bearing relays/thermostats/lamps and any other components containing heavy metals or dangerous chemicals. All these components must be carefully removed in order to avoid uncontrolled toxic emissions in the form of gases, substances or fluids. Hazardous components have to be treated as hazardous waste in an appropriate facility, instead of simply being resold as 'metal scraps' to a downstream mechanical shredder.

Next to ensuring the safe removal of any hazardous components, the danger of potential electrical shocks, e.g., when dismantling CRTs or microwaves, also needs to be addressed by following the correct steps to safely discharge capacitors.

5. Identify, report and take action on non-compliance

Any identified form of non-compliance of any manual dismantling practice (e.g. accessing high hazard fractions such as a radioactive element containing sensors and the failure to fully depollute) needs to be identified, reported to the relevant parties, rectified, and documented towards the establishment of a compliance check list used in future compliance monitoring and evaluation.

6. Raise awareness, inform and train your workforce

The aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of actors and economic operators in the value chain about the risks of unsafe manual dismantling faced by those involved in these practices.

As part of the awareness raising required, any (potentially) hazardous components a manual dismantler might involuntarily or accidentally be exposed to (e.g., through poor housekeeping), need to be described in detail with regard to their exact nature and appearance as well as the inherent environmental, health and safety risks involved and the appropriate protection mechanism required.

Clear training instructions must be given on how to safely and efficiently dismantle and remove components manually when there are no available mechanical tools. Techniques to access the desired materials without workers being exposed to hazardous components need to be part of this training. Proper training needs to be in place, e.g., in the form of illustrated operational standard procedures that inform workers in their local language on the 'how-to' items listed above. Some readily available, free training materials providing step-by-step photographic dismantling guidance have been published by both Sustainable Recycling Industries (SRI), titled Dismantling Guide for IT Equipment, and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), titled Guideline on the Manual Dismantling of Refrigerators and Air Conditioners: Guiding principles applicable to the Colombian case.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment when implementing these practices (IWA 19:2017).

D. Low-quality Segregation during Mechanical Processing

Identified cases

There are three main reasons why mechanical processes such as crushing, grinding or shredding metal-bearing wastes can result in a **worst-practice** scenario when done in an inefficient way:

- Either the shredding equipment (coarse, medium or fine particle shredder) is in a state of disrepair, thereby operates poorly and/or is malfunctioning
- The feedstock is of bad quality due to the lack of proper pre-treatment (e.g. depollution and manual segregation) prior to the actual mechanical shredding process
- Workers are insufficiently trained to identify which materials can or cannot be fed into the machine to prevent malfunctioning

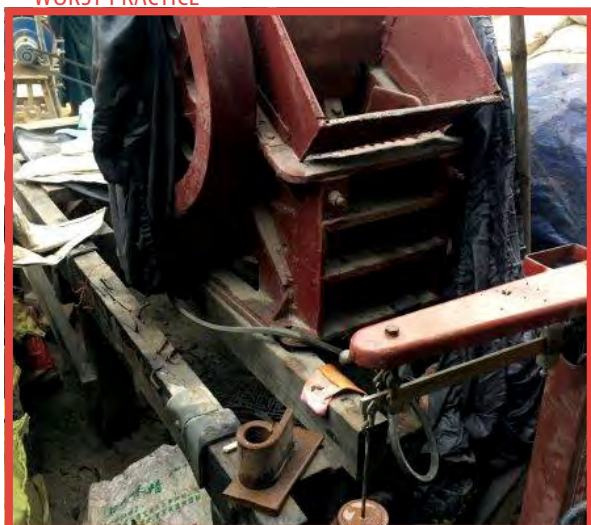
Typical symptoms of an inferior-operating size-reduction and segregation technology (such as in the use of hammer mills, impact crushers, chippers, and different cutting mills like rotor scissors, rasp mills and rotary drum cutters) are:

- Blunt cutting blades or shears, prone to producing unevenly sized shredding particles result in more shrapnel (that can become mobilised and increase injury risks) and excess dust. These dusts, if not controlled, can present both explosion and inhalation hazards
- Missing shields mean that stray pieces of metal scraps are not blocked from flying out from the machines and can cause injuries to workers

The quality of feedstock is the most significant factor in determining both recovery efficiency and the level of contamination. Feedstock that is improperly depolluted prior to feeding it into a shredder can contain hazardous substances and is thus considered to be hazardous material. Processing such material can result in small and heavily contaminated (coated) particle fractions containing various chemicals and heavy metals, including, but not limited to:

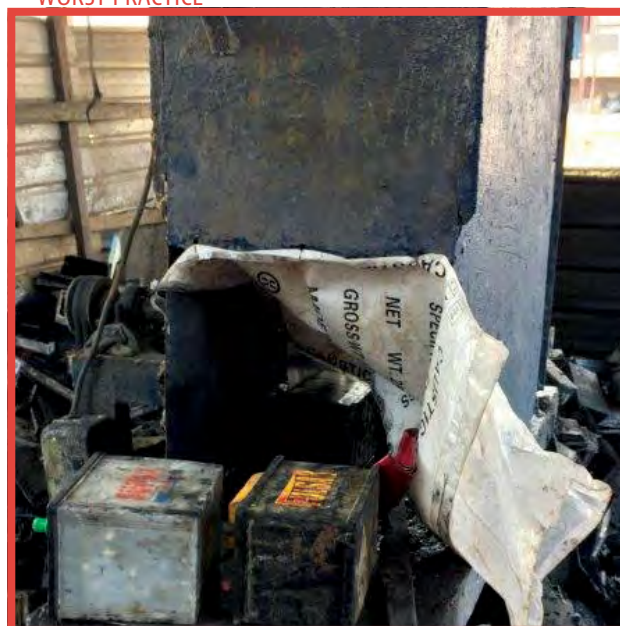
- Mercury-containing components including batteries, accumulators, relays, thermostats, lamps
- Capacitors possibly containing polychlorinated biphenyls (PCBs)
- Barium-containing getter pills
- Lead-containing CRT screen glass
- Flame-retardant treated plastics

WORST PRACTICE



Mill for metals shredding in state of disrepair
©Oeko Institut

WORST PRACTICE



Battery saw without proper protections and controls for hazardous substances ©Oeko Institut

D. Low-quality Segregation during Mechanical Processing

Impacts

A description of impacts on the following areas as a result of inferior-operating size-reduction and segregation technologies are presented below.

<p><i>Safe, healthy and equitable working conditions</i></p> <p>&</p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none"> If feedstock is not sufficiently depolluted, operators are exposed to the inhalation of dust emitted during the mechanical shredding process – dust with severe toxicants injurious to human health . Skin exposure to a wide range of heavy metals (e.g., mercury, lead and cadmium) and components treated with flame retardant chemicals. Danger of combustible fine dusts (e.g., from toners), which are also toxic when inhaled. Shards with sharp edges that become airborne during shredding can cause serious physical injuries, making workers operating the machine (or close to it) prone to eye injury and skin cuts, through which pollutants and toxicants can then readily enter. Surrounding communities are typically affected by the dust, waste and noise created by such operations. In the case of shredding, this can also result in the risk of injuries from flying or scattered shards and pieces.
<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> Small material pieces are generated by various shredding steps and can find their way into the soil and waterways, from where they are rapidly dispersed. Because none of these materials is generally biodegradable, any coating-bearing powder, chemical, or heavy metal will transfer its hazardous properties straight into the receiving environments, thereby adversely affecting flora and fauna over long periods.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> Failure to depollute causes both contamination and dilution of value fractions, and therefore typically causes a loss in sale value due to the resulting mix in materials. Poorly functioning shredders produce unevenly sized particles which prevent further steps for optimal separation and concentration downstream, thus reducing the efficiency of secondary metals recovery.

GOOD PRACTICE



Properly functioning fridge components disassembly line, Switzerland ©Empa

GOOD PRACTICE



Cable stripper avoiding air pollution (Morocco) ©Empa

D. Low-quality Segregation during Mechanical Processing

Steps to Good Practices

Activities related to **mechanical processing** and segregation need to be implemented in an acceptable and responsible manner with **good housekeeping practices** in place and in due compliance with related national requirements. This should include the provision of proper personal protective equipment (PPE), a suitable and safe working environment and technical setup and the maintenance of shredding machines. Special attention should be paid to the proper handling of hazardous and dangerous components. This should be complemented with training on the effective removal of hazardous and valuable components/fractions. The key points below describe some of the requirements to transform low-quality types of segregation from **Worst Practices** into **Good Practices**.

1. Provide workers with good and safe personal protective equipment

All workers, including those who operate the shredder or are working in the same facility, should be provided with a change of clothes (to minimise the transfer of pollutants and dust to outside the premises) and equipped with functional personal protective equipment (PPE) items such as gloves, safety glasses, safety shoes and respiratory masks where fine dust is generated.

2. Provide a suitable and safe working environment

Any mechanical shredding activity should be conducted in an enclosed space that is protected from the natural elements and where the spread of any potential pollutants, including dust routinely released during the process, can be contained and controlled. The workspace should be well lit, well aerated, and kept clean. Dust emissions can be optimally reduced by installing vacuum or filter systems at all working units that generate dust, e.g., chiselling, printed circuit board (PCB) grinding, or cutting of cathode ray tube (CRT) glass.

3. Remove hazardous components

As described in the **Unsafe Manual Dismantling** fact sheet, before undertaking mechanical shredding as a value-adding step, it is necessary to first manually remove all components that are hazardous and which can subsequently break and release, in an uncontrolled way, toxic emissions in the form of gases, substances or fluids.

It is recommended, for the hazardous fractions below, to apply depollution standards that satisfy the best international practices:

- Mercury-containing components – recovery
- Batteries and accumulators – recovery
- Non-recoverable batteries – treatment, recycling and disposal as hazardous waste
- Printed circuit board (PCB) capacitors – thermal treatment
- Electrolyte capacitors – recovery or thermal treatment
- PCBs with components – dismantling of components or thermal treatment
- Picture tube coatings, screen coatings and broken glass with screen coatings – treatment, recycling and disposal as hazardous waste
- Liquid crystal displays (LCDs) – treatment, recycling and disposal as hazardous waste

D. Low-quality Segregation during Mechanical Processing

Steps to Good Practices

4. Remove valuable components/fractions prior to mechanical shredding

Components and items that are still functional and/or of high market value (e.g. PCBs) should be removed before the metal-containing feed is added to the mechanical shredder. This will maximise their reuse potential and financial value recovery. The main, primary mechanical separation step should yield the separation of wirings, metals and plastics, while further separation technologies, in sequence, need to be in place to optimise the purity of the various fractions.

To this end, and after the **particle size separation** is facilitated through a vibrating screen, magnetic separators are employed for the separation of all ferrous metals, while eddy current separation facilitates non-ferrous metals separation. Metals are sorted from plastics by using air density separation.

Only devices suitable for a specialised activity, and that are optimally linked to a certain feedstock composition, should be used in order to minimise the loss of precious metals as well as reduce dust emissions.

A routine maintenance plan should be implemented, including the scheduled checking of all moving parts and their full functionality, as well as proper protection measures, such as shields, overfeeding lock systems, etc.

5. Identify, report and take action on non-compliance

Any identified form of non-compliance in mechanical processing (e.g., lack of protection measures) needs to be identified, reported to the relevant parties, rectified, and documented towards the establishment of a compliance check list used in future compliance monitoring and evaluation.

6. Raise awareness and inform

When low-quality and inefficient segregation is applied, the aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of the actors and economic operators in the value chain concerned with regard to the loss of value of recovered fractions or metals.

To prevent the possibility of involuntary or accidental exposure to any (potentially) hazardous components, awareness should be raised about the exact nature, appearance and the inherent environmental, health and safety risks to the operators of mechanical shredding equipment. The appropriate protection mechanisms must be described as well.

7. Train your workforce

Proper routine training should be in place in the form of 'illustrated standard operation procedures' to explain to workers how to implement good housekeeping practices, safely operate mechanical shredders and other equipment utilised, and properly maintain equipment after the removal of any hazardous components.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment when implementing these practices (IWA 19:2017).

E. Low-tech, Unsound Smelting and Off-Burning

Identified cases

Low-tech smelting practices of concern include (but are not limited to) activities such as (re)melting and desoldering, while off-burning describes the practice of (selective) metals recovery through the use of fire that removes any unwanted material by burning off the latter, e.g., in cables and tyres.

These are all dangerous metal isolation, liberation and recovery practices and are typically performed unlicensed (hence non-compliant), manually and without using the proper equipment or temperature control (and therefore devoid of any critical pollution control measures), both in the absence of PPE and executed by unskilled, unauthorised operators.

Smelting

Secondary metal-containing wastes and materials are exposed to localised, high heat sources such as an electric stove, a blowtorch or a grill grid on a coal fire to facilitate various forms of smelting.

Worst Practice is observed, for example:

- In the form of melting (e.g., to extract metals from an alloying process such as gold recovery by amalgamation (see Fact Sheet F below)
- In the form of remelting, e.g., as is done for the purposes of desoldering valuable components, such as chips on polychlorinated biphenyls (PCBs), by immersion in a lead bath or by exposure to high heat in order to crack up/break away desired parts and pieces through the induced thermal stress
- In illegally run lead smelters that extract lead from car batteries

Off-Burning

For the purposes of metal recovery and selective isolation of metals such as copper, steel, lead and aluminium, the wide-spread worst practice of off-burning is applied by setting a pile of metal-containing materials on fire at a fairly high temperature.

To facilitate basic temperature control (and therefore prevent metals to gasify or go into a state of gasification, ending up as part of the slag), operators typically 'modulate' the temperature through the chosen feed composition. If the burn-off temperature needs to be raised, car tyres and fridge foams are routinely used in the fuel mix, while flame-retardant plastics are added in small pieces to cool the fire down. The resulting emissions contain an unspecified cocktail of various highly toxic substances, such as dioxins, gasified flame-retardants and released ozone-depleting substance (ODS) chemicals – apart from larger particulates, soot and ashes.

WORST PRACTICE



'Fuelling the fire' with highly flammable fridge insulation materials to recover metals in Agbogbloshie, Accra, Ghana
©Oeko Institut

WORST PRACTICE



Unsafe melting in a recycling company in Lima
©Monika Flükiger

E. Low-tech, Unsound Smelting and Off-Burning

Identified cases

Off-burning has been observed to be applied in order to:

- Remove obstructing polyvinyl chloride (PVC) plastic matter surrounding the copper in cables
- Recover and separate the copper from the aluminium in fridge cooling grids
- Recover aluminium from capacitors, with the danger of the simultaneous release of PCB oils and electrolytes
- Recover the steel mesh that is contained in waste tyres
- Recover an alternative fuel mix

Off-burning to recover energy has been observed in informal energy-intensive industrial processes (informal cement kilns and clay tile manufacturing) to modulate the required temperature ranges for specific heat processes, e.g., related to metals extraction practices.

Secondary metals recovery of ALL these practices is limited to a few of the easier recoverable, but low-value, metal fractions.

WORST PRACTICE



De-soldering of a motherboard in China ©Empa

WORST PRACTICE



Unsafe informal lead smelting from acid batteries resulting in soil and air pollution (Agbogbloshie, Ghana) ©Empa

WORST PRACTICE



Tyre burning to recover iron and steel ©iStock

E. Low-tech, Unsound Smelting and Off-Burning

Impacts

A description of impacts on the following areas as a result of low-tech **smelting** and off-burning practices are presented below.

<p><i>Safe, healthy and equitable working conditions</i></p> <p>&</p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none"> • Softened/remolten solder on circuit boards and from lead baths will continuously give off lead fumes, which workers may breathe in if the smelting and off-burning activities are done in an open and unprotected environment and without any air filtration or proper ventilation in place for fume diversion. • Such fumes are typically inhaled by workers and the surrounding communities while fire residues (ash, soot and burnt off parts) are loaded with toxic chemicals that can then easily accumulate in the soil or waterways adjacent to where such activities are conducted. • Lead causes damage to the central and peripheral nervous systems, blood systems and kidney and reproductive systems. Impacts on the endocrine system have been observed and its serious negative impacts on brain development in children are well documented and proven. Substances in circuit boards such as tetrabromobisphenyl A (a brominated flame-retardant additive) may be released along with many other airborne hazards from the resulting fumes – especially if such materials are burnt off – to form a complex and very toxic mix of airborne chemicals including dioxins and other persistent organic pollutants (POPs). • The heat source may be a small charcoal or coal fire, which can cause severe burns to workers and give off hazardous and cancer-causing particulates. • Particularly dangerous emissions can be caused when specific types of waste of no or low value (often with hazardous properties but with desirable calorific value properties) are blended together (off-burning) to provide an alternative fuel mix. • Communities where such activities routinely take place are often collectively affected by the emissions into air and onto the land.
<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> • Spilt lead, which is bio-accumulative, has acute and chronic impacts on plants, animals and micro-organisms. Contaminated soils, if used for agricultural purposes, will yield crops with the release of high levels of lead and other heavy metals. Water resources may also continuously and chronically be contaminated by such heavy metals. A range of airborne persistent organic pollutants (POPs) is likely to be released during the smelting and off-burning activities, and can easily travel and pollute the receiving environments.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> • As described above, desoldering (as a form of smelting) is a processing step typically used to recover chips for remanufacturing and resale (often disguised as 'new' parts with pins being recoated). However, direct high-heat impact is likely to destroy the functionality of parts that may still work. The metal recovery potential that can be salvaged through backyard recycling-based smelting and off-burning activities is very limited with regards to the quantity and type of metals.

E. Low-tech, Unsound Smelting and Off-Burning

Steps to Good Practices

Any type of metallurgical processing needs to be implemented as licensed operations in an acceptable and responsible manner and in due compliance with the related national requirements. These should include the provision of training in safe and appropriate housekeeping, as well as efficient techniques to recover any functional system components. Unsound and low-tech smelting and off-burning – a type of metallurgical processing – is considered a **Worst Practice** requiring transformation into **Good Practice**. The key points below describe some measures to facilitate the transformation.

1. Identify, report and take action on non-compliance

In light of their unacceptably severe environmental, health and safety impacts, all crude thermal practices used as a preparatory step to metallurgical processing that are unauthorised, uncontrolled and a threat to environmental health and safety (EHS), should be prohibited. Any identified form of non-compliance needs to be identified and reported to the relevant authorities. Any type of **metallurgical processing** needs to take place in a properly licenced and fully compliant facility, where suitable technologies (to enhance component removal/metal feed and risk/pollution control systems) are in place.

2. Raise awareness and inform

The aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of the respective actors and economic operators in the value chain about the dangers associated with low-tech smelting and off-burning, and about the negative impacts on the quality and quantity of materials and fractions recovered. Ultimately, the aim is to promote the voluntary cessation and, most preferably, the banning of such practices when the full extent of the associated risks becomes evident.

The informal sector – both the subsistence activity (SA) and unofficial business activity (UBA) types of economic operators – which is predominantly involved with non-compliant, low-tech **metallurgical processing** activities, needs to be made aware of how these activities critically endanger the health of people, the wellbeing of surrounding communities and the integrity of the living environment. This can be done, e.g., by means of educational campaigns in the local language, co-run by the private sector and the government.

In the awareness-raising campaigns, government officials and local authorities should also be addressed since they will be instrumental in introducing the banning of these practices and in the move towards licensed operations.

3. Use safe, efficient and authorised facilities for any kind of metallurgical processing

As highlighted, any **pyro-metallurgical and/or hydrometallurgical processing** considered as alternative options need to be conducted in a properly licensed and fully compliant facility.

Metal-bearing parts (e.g. chips) need to be removed in a workspace equipped with a controlled extraction hood, or at least a fan, to draw away all the hazardous emissions. It is most preferable to install a collection/filtration system.

The workplace should ensure that lead and other resulting fumes cannot contaminate the environment and that any accidental pollution remains contained. Therefore, a suitable and acceptable workspace should be equipped with at least basic protective measures, such as:

- A roofed and enclosed facility with concrete flooring
- An appropriate ventilation system
- A basic air filtration system

E. Low-tech, Unsound Smelting and Off-Burning

Steps to Good Practices

Any form of pyro-metallurgical metal recovery replacing the unacceptable worst practice of **off-burning** needs to take place in a facility adhering to the minimum technical and operational requirements, such as an enclosed and fully controlled environment with air emission filtration systems, temperature controls and calorific-value optimised, non-toxic feed sources.

Workers need to be equipped with PPE irrespective of the chemical leaching method(s) applied in order to be protected from any fumes or effluents resulting from chemical leaching activities.

Practical experience at international level has shown that only facilities that treat large quantities of fractions and materials (probably fed through imports) are economically feasible, which puts facilities with limited capacities that aim to serve only the local market at a disadvantage.

4. Train your workforce

Formal and regular training is part of what a legally authorised facility needs to provide for workers so that they can implement the safest, best housekeeping and most efficient techniques to recover any functional system components and other value-bearing materials.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment when implementing these practices (IWA 19:2017).

Amalgamation in terms of metal recovery is the practice of bringing free gold particles into contact with mercury. Mercury is combined with gold-carrying components (shredded/ground to particle size) to form a hardened amalgam that picks up most of the gold metal dust. The amalgam is later heated with a blow torch or over an open flame to evaporate the mercury, leaving small gold pieces as residue.

GOOD PRACTICE



Safe metal smelting ©iStock

F. Amalgamation

Identified cases

Alternatively, a distillation process is conducted to remove all the dissolved/amalgamated metals from mercury. Using nitric acid is an alternative to dissolving small amounts of amalgam, since gold, unlike mercury, is not soluble in nitric acid. Below are the steps involved:

- Grinding
- Amalgamation: sometimes done by hand; washed to remove impurities – generating mercury-contaminated water
- Heating and mercury evaporation: mercury vapours are released when mercury-gold amalgam is heated in the open in an unenclosed vessel to separate the gold
- Distillation or nitric acid treatment

Amalgamation is considered to be possibly one of THE worst metal-extraction practices known. The Minamata Convention therefore calls for it to be banned in the light of numerous cases proving its adverse and very severe impacts on human health and the environment.

A description of impacts on the following areas as a result of **amalgamation** practices to extract gold are presented below.

WORST PRACTICE



Mercury used for amalgamation to recover gold
©Empa

F. Amalgamation

Impacts

<p><i>Safe, healthy and equitable working conditions</i></p> <p><i>&</i></p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none"> • Practices associated with amalgamation carry concerns about unacceptably severe environmental and health risks. • Gaseous mercury might be inhaled by operators and people in the surrounding area. Mercury and its more lethal and very mobile derivative methyl mercury, attack the central nervous system and organs in humans and are a particular threat to foetal development.
<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> • Mercury that is not inhaled during the burning process often settles in the surrounding environment or circulates globally for future deposition far from the site. The deposited mercury is absorbed by a variety of living organisms, which transform elemental mercury into methyl mercury. Methyl mercury is one of the most dangerous neurotoxic substances to contaminate the food chain through bio-accumulation. As such, mercury and any derivatives thereof are: <ul style="list-style-type: none"> • Water, soil and air pollutants • Accumulative in the entire human food chain
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> • Amalgamation is not as resource-efficient in terms of gold recovery potential in comparison to electrolytic or biological treatment options. The formation of amalgam can be inhibited due to poor contact between the gold and mercury. This occurs most commonly when the gold is very fine or when it is tarnished by surface substances or film. Moreover, the feed material may be contaminated with grease, oil, or any other inhibiting agent.

F. Amalgamation

Steps to Good Practices

Any type of metallurgical processing for gold recovery needs to be conducted in a properly licensed, fully compliant facility, in an acceptable and responsible manner, and in due compliance with the related national requirements. Amalgamation for gold recovery is considered a **Worst Practice** and should be banned, as established by the Minamata Convention. The key points below describe some measures on how to facilitate the transformation from **Worst Practice** into **Good Practice**.

1. Stop amalgamation practices

If an economic operator is conducting an amalgamation process to recover metals (gold), this needs to cease. This is in accord with the recommendations of the Minamata Convention, as subscribed to by governments, and which establishes a timeline for governments towards phasing out the process.

2. Raise awareness and inform

The aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of the actors and economic operators in the value chain concerned on dangers associated with gold recovery through amalgamation, and on the negative impacts on the quality and quantity of materials and fractions recovered. Ultimately, the aim is to promote the voluntary cessation of this practice by economic operators and a ban by the authorities, if the latter has not yet occurred.

Awareness-raising activities should target the informal sector – operators engaged in subsistence and unofficial business activities – predominantly involved with amalgamation-processing activities. They should be made aware, e.g., through informative and sensitisation campaigns run by the private sector and the government in their local language, of the risks associated with such practices that critically endanger the health of people, well-being of surrounding communities and the integrity of the living environment

3. Use safe, efficient and authorised facilities for any kind of gold recovery processing

Alternative options include acid bath leaching and cyanide leaching (see Fact Sheet G). Any alternative metallurgical processing applied needs to be conducted in a properly licensed and fully compliant facility, while ensuring that all the required risk/pollution control and reporting systems are in place.

If fully compliant gold recovery facilities are not available in the country from where the secondary metal-containing waste/material stream originates, such fractions or materials need to be exported to a fully compliant facility in another country to finalise the gold recovery processing and thus ensure that **Good Practices** are applied.

GOOD PRACTICE



Safe and well-ventilated manual dismantling to separate materials containing gold to be sent to a licensed metallurgical processing facility ©WRF

GOOD PRACTICE



Smelting of gold in an oven with emissions controls ©iStock

G. Other Low-tech, Unsound Chemical Leaching

Identified cases

In addition to poor smelting, off-burning and amalgamation, there are other types of low-tech, unsound **chemical leaching** practices that need to be addressed. They apply, for example, a poorly controlled hydrometallurgical process, which typically describes manual operations conducted without access to proper facilities, equipment and/or PPE and by unauthorised and unskilled workers. Such practices may cause varied environmental, health and safety (EHS) risks.

Common specific activities under this Work Practice include:

- **Acid bath leaching and cyanide leaching.** Both are based on applying (in a particular sequence) a range of chemicals that are by nature highly reactive (hydrogen peroxide), corrosive (aqua regia), acidic (nitric and sulphuric acid) and/or toxic (cyanide). These are applied to secondary metal-containing parts, shredded particles or pulverised fractions for the recovery of metals such as copper and gold from their carriers, typically printed circuit boards (PCBs).
- The PCBs are kept in vats of sulphuric acid for several hours and heated to create distinctive blue copper sulphate crystals. Elemental copper is recovered through a variety of techniques, including mixing in iron scraps, often followed by an electrolysis process.
- The range of metals recoverable through low-tech chemical leaching is very narrow, and hence only a low level of overall metal-recovery efficiency is achieved by such dangerous, environmentally harmful practices.
- Without protective equipment for individuals and proper ventilation systems in the workplace, this practice will release toxic and acidic fumes, exposing workers to a high risk of skin burns and lung damage.
- In the presence of mercury-containing fractions, cyanide leaching can lead to the formation of soluble mercury-cyanide complexes that mobilise mercury, and which can then easily enter the human body and an unprotected environment.

WORST PRACTICE



WORST PRACTICE



Preparation for sulphuric acid baths to recover copper from printed circuit boards ©Empa

G. Other Low-tech, Unsound Chemical Leaching

Impacts

A description of impacts on the following areas as a result of amalgamation practices to extract gold are presented below.

<p><i>Safe, healthy and equitable working conditions</i></p> <p>&</p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none"> • When highly corrosive acid baths are used to extract precious metals such as gold, a lack of protective equipment (clothes, eye protectors and respiratory masks) put workers at a high risk of chemical injury or intoxication. Cyanide is poisonous, especially in the form of hydrogen cyanide; and aqua regia is very corrosive and requires very careful handling. The latter also gives off chlorine gas and its reactions with metals create nitrogen oxide emissions.
<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> • The initial carrier of the secondary metal and any employed process chemicals (highly concentrated acids, alkalis and salts typically saturated with dissolved heavy metals) are often discarded by operators after the desired (precious) secondary metals have been recovered. They are then routinely released (dumped) into the environment, such as rivers or groundwater. • Many of the chemicals employed for chemical leaching are potent water, soil and air pollutants.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> • Some of the precious secondary source metals (e.g., gold) typically contained in carriers such as circuit boards are not visible as they are embedded in hard-to-access ceramics and plastic parts. • Low-tech acid leaching is an inefficient method with a gold recovery rate as low as 20-25%. Silver and palladium, often present in circuit boards, are generally not recovered.

G. Other Low-tech, Unsound Chemical Leaching

Steps to Good Practices

Any type of metallurgical processing for recovery of any kind of metal needs to be conducted in a properly licensed and fully compliant facility, in an acceptable and responsible manner and in due compliance with the related national requirements. This should include the provision of an appropriate workspace with protective measures and protective equipment for workers, along with training in safe and appropriate housekeeping as well as in efficient techniques to recover any functional system components. Low-tech and unsound chemical leaching is considered a **Worst Practice** that requires transformation into a **Good Practice**. The key points below describe some measures to facilitate the transformation.

1. Identify, report and take action on non-compliance

In the light of their unacceptably severe environmental, health and safety (EHS) impacts, all unauthorised, uncontrolled, and environmental and health-threatening low-tech chemical practices should be prohibited. Any identified form of non-compliance needs to be identified and reported to the relevant authorities.

This follows the recommendations of the Basel Conventions R4 Guidelines, which states e.g., that any type of *pyro-metallurgical and/or hydrometallurgical processing* is defined as a **reclamation process** and should therefore only be conducted in a properly licensed and fully compliant facility, where suitable technologies to enhance component removal/metal feed and risk/pollution control systems are in place.

2. Raise awareness and inform

The aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of the actors and economic operators in the value chain concerned about dangers associated with any kind of **low-tech and unsound chemical leaching**, and on negative impacts on the quality and quantity of materials and fractions recovered. Ultimately, the aim is to promote the voluntary cessation and, most preferably, the banning of such practices when the full extent of the associated risks becomes evident.

The informal sector is predominantly involved with low-tech chemical leaching processing activities that critically endanger the health of people, wellbeing of surrounding communities and the integrity of the living environment. Therefore, the wider public representing the subsistence and unofficial business activities (SA and UBA) economic sector should be made aware, for example, by means of educational campaigns co-run by the private sector and the government, of the dangers associated with such practices.

3. Use safe, efficient and authorised facilities for any kind of metallurgical processing

As highlighted in Fact Sheet E, any **pyro-metallurgical and/or hydrometallurgical processing** considered as alternative options needs to be conducted in a properly licensed and fully compliant facility.

Metal-bearing parts (e.g. chips) need to be removed in a workspace equipped with a controlled extraction hood, or at least a fan, to draw away all the hazardous emissions. Most preferred is the installation of a collection/filtration system.

G. Other Low-tech, Unsound Chemical Leaching

Steps to Good Practices

The workplace should ensure that lead and other resulting fumes cannot contaminate the environment and that any accidental pollution remains contained. Therefore, a suitable and acceptable workspace should be equipped with at least basic protective measures, such as:

- A roofed and enclosed facility with concrete flooring
- An appropriate ventilation system
- A basic air filtration system

Any form of pyro-metallurgical metal recovery needs to take place in a facility offering the minimum technical and operational requirements, such as an enclosed and fully controlled environment with air emission filtration systems, temperature controls and calorific-value optimised, non-toxic feed sources.

Workers need to be equipped with personal protective equipment (PPE) irrespective of the chemical leaching method(s) applied in order to be protected from any fumes or effluents resulting from chemical leaching activities.

4. Training on improved metallurgical processing

Formal and regular training on how to implement the safest and best housekeeping, and most efficient techniques to recover any functional system components and other value-bearing materials is part of what a legally authorised facility needs to provide to workers.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment when implementing these practices (IWA 19:2017).

GOOD PRACTICE



Safe manual dismantling of end-of-life computers to separate materials containing precious metals (e.g. circuit boards) and copper, to be sent to a licensed metallurgical processing facility ©WRF

H. Open Burning

Identified cases

Open burning typically means to start a fire somewhere in an open field or elsewhere outdoors for the purposes of reducing waste volumes that have to be further managed.

- Burning takes place regularly and some fires are kept alive for weeks in a smouldering state through the systematic feeding of new domestic and industrial-sourced waste
- Plastic casings, tyres and halogenated foams from fridges are commonly used as fuel to keep such fires alive
- After being in 'cold' fires for so long, any metallic residues, e.g., in the form of cans or nails, are baked into the remaining ash and are routinely retrieved, which exposes workers to soot and ash with a concentration of hazardous chemicals that are either NOT gasified or have been newly generated

Open burning typically leads to incomplete incineration as the combustion air is not effectively controlled and involves the low-temperature burning of materials with low calorific values, forming very crude ash particles. Many metals are lost as they melt or stick to other pieces that are not burnt up. Therefore, the rate of metal recovery is poor.

At the same time, the low-heat burning process forms excess soot and coarse and fine particulates with hazardous constituents (e.g. cancer-causing dioxins). This poses high risks to human health and the environment since such toxic fumes are released without any emission control.

WORST PRACTICE



Smouldering landfill towards waste reduction ©Oeko Institut

H. Open Burning

Impacts

A description of impacts on the following areas as a result of open burning are presented below.

<p><i>Safe, healthy and equitable working conditions</i></p> <p>&</p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none"> • As described above, any uncontrolled burning process is bound to emit substantial volumes (in the form of ash, soot and smoke) of mixed, harmful chemicals, including varied heavy metals, dioxins, beryllium and polycyclic aromatic hydrocarbons (PAHs). Lead, mercury, cadmium, and polybrominated flame-retardants are all persistent and bio-accumulative toxic substances (PBTs), which are then passed on to the entire human food chain. • Combustion of e-waste creates fine particulate matters, which are linked to pulmonary and cardiovascular diseases. • Surrounding communities are likely to be heavily affected by the typically acrid and black smoke carrying some of the most toxic and cancer-causing substances known to date.
<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> • Burnt products resulting from typically incomplete open-air combustion contaminate air, water and soil with high concentrations of environmentally toxic substances. Particulate matters (soot) and ash residues often contain very high concentrations of heavy metals and other chemicals, such as flame retardants, and are easily spread over long distances by the wind into the environment and bio-accumulated in both flora and fauna.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> • Open burning and its generation of smoke, soot and toxic ash residue and particulates do not only involuntarily mobilise some very toxic pollutants; the practice also shows poor efficiency in secondary-metals recovery when compared to, for example, a proper metal extraction in a smelter, or via an electrolytic process. Particulate matters that are not completely burnt typically contain a large amount of metals that are lost during open burning.

GOOD PRACTICE



Awareness Raising of waste-pickers and municipality representatives in Lima (2016) ©WRF

H. Open Burning

Steps to Good Practices

Disposal of any type of waste needs to be conducted in a properly licensed and fully compliant facility, in an acceptable and responsible manner and with due compliance with the related national requirements. Open burning is considered a **Worst Practice** that should cease and be banned by the authorities. The key points below describe some measures to facilitate the transformation of **Worst Practice** into **Good Practice**.

1. Stop open burning

According to the Stockholm Convention on Persistent Organic Pollutants, it is acknowledged that persistent organic pollutants (POPs) such as hexachlorobenzene, pentachlorobenzene, polychlorinated biphenyls, and polychlorinated dibenzo-p-dioxins and dibenzofurans may unintentionally be formed and released during any uncontrolled incineration process, such as in open burning of waste and burning on landfill sites, to reduce volume. Therefore, **Open Burning** must be stopped and banned. Capacitors, which commonly contain printed circuit boards (PCBs), need to be sent for proper disposal (such as high-temperature, controlled-emission combustion at a specialised and licensed PCB destruction facility), to avoid the formation of dioxins and furans.

2. Raise awareness and inform

The aim of awareness-raising activities is to contribute to a change in behaviour patterns and improve the understanding of the actors and economic operators in the value chain concerned about dangers associated with open burning. Ultimately, the aim is to promote the cessation of this practice by these economic operators and the enforcement of controls by the authorities.

The informal sector is predominantly involved with illegal burning activities that critically endanger the health of people, wellbeing of surrounding communities and the integrity of the living environment. Thus, the wider public representing the subsistence and unofficial business activities economic sector should be made aware, e.g., through sensitisation campaigns run by the private sector and government, in the local language, of the dangers associated with such practices. Existing and feasible options, including non-thermal technical alternatives, need to be pointed out as part of the awareness-raising exercise.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment which can be the basis for the awareness raising activities (IWA 19:2017).

3. Use safe, efficient and legally authorised facilities for thermal and non-thermal technology treatment and disposal of waste

From an environmental, health and safety risk perspective, open burning cannot ever be conducted in an acceptable manner, and should therefore, be replaced by an alternative process, e.g. with a risk-controlled incineration technology in the form of a closed kiln with a filter and scrubber system. Controlled incineration is only possible when done by OBA type economic in possession of and run according to an operational license and fully compliant with the laws.

H. Open Burning

Steps to Good Practices

Thermal Alternatives

There are other high-tech thermal alternatives for recovering energy or materials from wastes which might be suitable for OBAs and include:

- Gasification: produces combustible gas, hydrogen, synthetic fuels
- Thermal depolymerisation: produces synthetic crude oil, which can be further refined
- Pyrolysis: produces combustible tar/bio-oil and chars
- Plasma arc gasification

Non-Thermal Alternative

Granulation is a technology suitable for SA, UBA or OBA sectors that can replace burning of cables altogether. The recovered copper will be also of a much better grade and is likely to fetch subsequently a much higher price than 'burnt copper'. To this end, tightening market control to reject burnt copper can greatly assist to stimulate the demand for alternative technologies.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment, which can be the basis for the awareness-raising activities (IWA 19:2017).

4. Use safe, efficient and legally-authorized facilities for alternative thermal and non-thermal technologies

From an environmental, health and safety risk perspective, **open burning** cannot ever be conducted in an acceptable manner, and should, therefore, be replaced by an alternative process, e.g. with risk-controlled incineration technology in the form of a closed kiln with a filter and scrubber system. Controlled incineration is only possible when done by official business activity (OBA) types of economic operators in possession of an operational licence and who are in full compliance with the laws.

Thermal Alternatives

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Non-thermal Alternative

Granulation is a technology suitable for the subsistence, unofficial business or official business activity (SA, UBA or OBA) sectors that can replace the burning of cables altogether. The recovered copper will also be of a much better grade and is likely, subsequently, to fetch a much higher price than **burnt copper**. To this end, tightening market controls to reject burnt copper can greatly assist in stimulating the demand for alternative technologies.

I. Open Dumping

Identified cases

Open dumping is the practice of the uncontrolled, haphazard release of both solid and liquid wastes (and materials of no/little perceived value) into the unprotected receiving environment, with no intention of further treatment. The 'open' dumping environment can be, for example, a street, river inlet, ditch or any type of water body; or a hole dug specifically for the purpose of 'dumping'.

Open dumping as a disposal solution is typically associated with SA and UBA economic activities, but it is evidentially also common among representatives of unscrupulous OBA economic operators.

The main key drivers for uncontrolled **open dumping** include:

- A lack of public awareness on how harmful such practices are to human health and the receiving environment
- The high cost of legally compliant and safe disposal
- The absence of suitable facilities (e.g. buy-back centres, drop-offs, recycling centres, metallurgical processing facilities) and services (e.g. take-back services) to recover, collect, treat and dispose of such wastes responsibly
- A lack of financial incentives (or any other motivational strategy) to recover such wastes for reuse or recycling

Types of waste disposed via uncontrolled open dumping include:

- Acidic, alkaline effluents from chemical leaching activities
- Particulate matters (coarse and fine particles, plus valueless 'scrap' components) and garbage from dismantling/extraction/shredding activities
- Fly and bottom ashes from burning activities

Typically, fractions disposed of after other inefficient, **Worst-Practice**-type upstream metal-recovery steps still contain high concentrations of metals, which are then lost to any further recovery when dumped.

This practice is likely to cause contamination of ground and receiving water systems (both directly and indirectly through leaching), and can pollute the air through emissions formed during and after the dumping process. Contaminants formed then reach people through the food chain where, for example, heavy metals such as mercury, accumulate in the fatty tissues and continue to poison the body.

WORST PRACTICE



Dumping of old computers (Abgobloshie, Ghana)
©Empa

WORST PRACTICE



Dumping site in Morocco ©Empa

I. Open Dumping

Impacts

A description of impacts on the following areas as a result of open dumping are presented below.

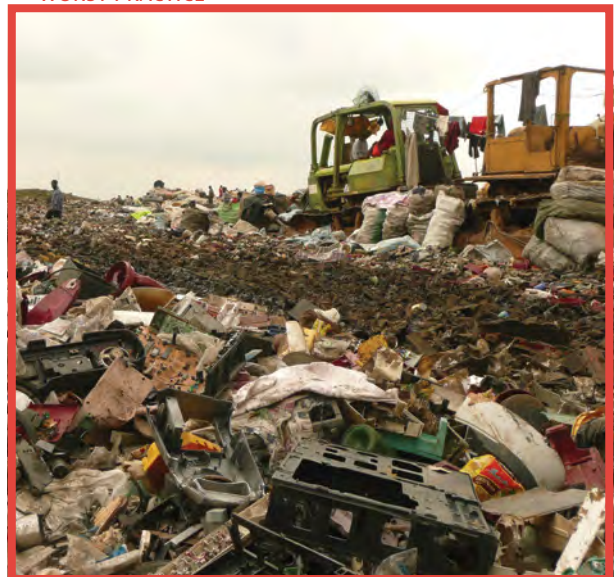
<p><i>Safe, healthy and equitable working conditions</i></p> <p>&</p> <p><i>Community relations and resilience</i></p>	<ul style="list-style-type: none"> • Apart from the operator’s direct exposure to any solid, liquid or airborne hazardous constituents in waste, uncontrolled open dumping often negatively affects the entire surrounding community. • Persistent, bio-accumulative toxic substances (PBTs) are carried over to the human food chain and ingested through food crops grown on contaminated grounds and irrigated with contaminated water. Body burden reports conducted show alarming levels of chemicals of high concern in the bloodstream – even of people NOT directly involved in (e-)waste recovery activities. This may also affect normal life expectancy negatively.
<p><i>Environment and natural resources</i></p>	<ul style="list-style-type: none"> • General and hazardous waste types of varying combinations and concentrations can greatly affect the entire biosphere. Heavy metals and dioxin from ash residues are potent soil contaminants. Failing to neutralise acidic or alkaline effluents can severely affect aquatic life in receiving water systems. Drinking-water aquifers and wells can easily be polluted through lead-bearing waste such as cathode ray tube (CRT) glass.
<p><i>Secondary metals recovery efficiency</i></p>	<ul style="list-style-type: none"> • Open and uncontrolled dumping of solid and liquid waste does not only involuntarily mobilise some very toxic pollutants, it also shows very poor efficiency in secondary metals recovery. Particles and ashes dumped still contain high concentrations of ‘hidden’ metal contents that could be unlocked by a downstream separation process, and process chemicals are saturated with metals in soluble form that could be recovered through electrolytic processes.

WORST PRACTICE



Dumping of effluents of sulphuric acid leaching in China ©Empa

WORST PRACTICE



Disposal of undeclared hazardous materials (e.g. e-waste) in a landfill (Nigeria). ©Empa

I. Open Dumping

Steps to Good Practices

The disposal of any type of waste needs to be conducted in a properly licensed and fully compliant facility, in an acceptable and responsible manner and in due compliance with the related national requirements. **Open dumping** is considered a **Worst Practice** that should cease and be banned by the authorities. The key points below describe some measures to facilitate the transformation into **Good Practice**.

1. Stop open dumping

Uncontrolled, unprotected **open dumping** does not comply with the minimum requirements defined and referenced for **sound disposal** by the Basel Convention (for the disposal of hazardous materials) and the Stockholm Convention (for the disposal of POPs). This practice must therefore be stopped and ultimately banned by the authorities. Existing sites have to be identified, closed and rehabilitated as best as possible.

2. Raise awareness and inform

The aim of awareness-raising activities is to contribute to a change in behaviour patterns and to improve the understanding of the actors and economic operators in the value chain concerned on dangers associated with open dumping. Ultimately, the aim is to promote the voluntary cessation of this practice by the economic operators concerned and the enforcement of controls by the authorities.

Economic operators engaged in unofficial business and subsistency activities (UBA and SA, in the informal sector) are predominantly involved with illegal burning activities that critically endanger the health of people, wellbeing of surrounding communities and the integrity of the living environment. Government officials, again, are instrumental in the process of closing illegal open dumping sites. Therefore, awareness-raising activities should target both audiences and make them aware of the resulting risks for the environment and population. Awareness of the dangers associated with such practices can be raised, for example, by means of sensitisation campaigns run by the private sector and with government support, in the local language. Existing fully compliant disposal sites need to be pointed out as part of the awareness-raising exercise.

Industries generating waste that is likely to be dumped is asked to support these awareness-raising activities.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals also provide directions on sustainability criteria to protect workers and the environment, which can be the basis for the awareness-raising activities (IWA 19:2017).

3. Use legally-authorized and sound disposal sites

In accordance with the requirements stipulated by both the Basel and Stockholm conventions, sound disposal, where required as the last resort, can only be done in a properly licensed facility operated by fully legally compliant official business activity (OBA) representatives. Such facilities should undertake environmentally sound management (ESM) in their operations, in compliance with all applicable environmental laws.

4. Apply the waste hierarchy and consider landfilling as the last option

Modern waste management is based on the waste hierarchy where disposal in landfills is regarded the least preferred option after avoiding, reducing, reusing, recycling and recovering. Nevertheless, in certain circumstances such as the disposal of selected hazardous residues, hazardous waste disposals are still regarded as the most appropriate management path.

GOOD PRACTICE



Properly built disposal sites ©iStock

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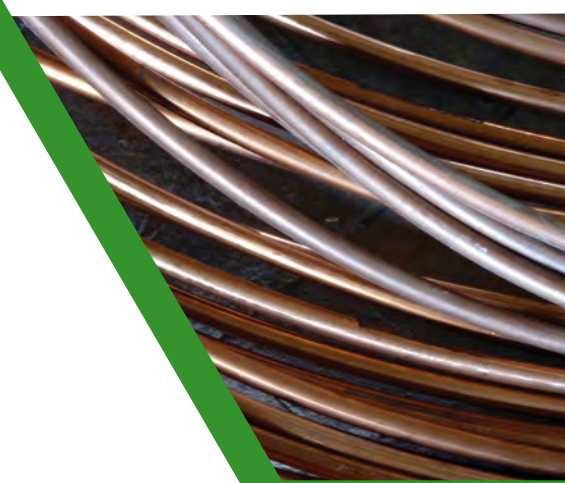
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The sustainable, profitable reuse, recycling or disposal of waste that contains metal has long been a matter of grave concern worldwide. Raising awareness of the dangers metal recovery poses to human and environmental health, especially in developing countries, requires urgent action. Guidance Principles for a Sustainable and Inclusive Recycling (ISO IWA 19:2017) are available which identify Worst Practices at different steps of recovery processes and recommend steps for moving away from them.

In this publication you will find an overview of most common Worst Practices, the pertinent facts on impacts and, most important, the Good Practices to replace Worst Practices in form of fact sheets. They were developed as part of the Sustainable Recycling Industries (SRI) Programme.

These fact sheets target all operators in the metal recycling process, be they producers, distributors, traders (importers and exporters), consumers, collectors, refurbishers, waste brokers, shipping companies, shipping agents, terminal operators, environmental inspectors, customs officials, police officers, organised crime groups, recyclers, downstream vendors, and final disposal service providers.



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