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BASEL CONVENTION

MOBILE PHONE PARTNERSHIP INITIATIVE (MPPI) - PROJECT 3.1

GUIDELINE ON MATERIAL RECOVERY AND RECYCLING OF END-OF-LIFE MOBILE PHONES

Revised and Approved Text
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Foreword

The previously approved Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones has been reviewed in a facility type of environment to reflect the practical situation. The Mobile Phone Working Group would like to express its appreciation to UMICORE and HOBI International for evaluating the guideline and proposing revisions to the previously approved guideline.

In addition, special thanks is extended to the chair of the Project Group 3.1, Mr. Robert Tonetti from US Environmental Protection Agency, for ensuring that all proposed changes and comments from the Project Group 3.1 participants have been reviewed and incorporated in the revised guideline.

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PROJECT GROUP 3.1 ACTIVE PARTICIPANTS

Christian Hagelueken - UMICORE, Belgium
Cindy Thomas - Noranda, Canada
Daniel Cheret - UMICORE, Belgium
Francoise Salame - SECO, Switzerland
Gareth Rice - Panasonic, UK
Gerry Straus - ReCellular, USA
Gordon Shields - Shields Environmental, UK
Gregor Margetson - Samsung, UK
Helena Castren - Nokia, Finland
Ingrid Sinclair - Noranda, USA
Jack Rowley - GSMA, UK
John Bullock - IPMI, USA
Mats Pellback-Scharp - Sony Ericsson, Sweden
Peter Hine - Sharp, UK
Robert Tonetti - EPA, USA
Ross Bartley - BIR, Belgium
Stephane Burban - Noranda, Switzerland
Wen-Ling Chiu – IER, Taiwan
Milton Catelin – SBC, Switzerland
John Myslicki - Consultant to SBC

EXECUTIVE SUMMARY

1. Scope of the Project

The primary objective of Project 3.1 is to provide best practice guideline for the environmentally sound material recovery and recycling of end-of-life mobile phones. This guideline does not cover the reuse, refurbishment (Project 1.1), collection and transport of end-of-life mobile phones (Project 2.1), as other project groups of the Mobile Phone Partnership Initiative are addressing these areas. However, robust collection of used mobile phones is strongly endorsed, as the necessary first step in material recovery. Mobile phones that are not collected - and the vast majority are not - can not provide a source for material recovery. Thus, this guideline presumes that the separate collection of used mobile phones, and their segregation for reuse and refurbishment, has already taken place.

The guideline addresses the recycling of all three of the basic components of mobile phones, including (1) the handset, (2) the battery and (3) the battery charger and other accessories.

The guideline also addresses the adequacy of the present recycling infrastructure and its capacity for handling the increasing number of mobile phones that will become obsolete.

Finally, the guideline includes recommendations to national authorities regarding programs and policies that can be implemented to ensure that material recovery and recycling of end-of-life mobile phones is conducted in an environmentally sound, as well as economically efficient, manner.

2. Characterization of Mobile Phones

Although mobile phones consist of materials that differ from model to model and manufacturer to manufacturer, the guideline provides data characterizing the typical content of a mobile phone. The substances identified include primary constituents, minor constituents and micro or trace constituents. Typically, about 40% of the weight of a mobile phone (including handset, battery and accessories) is plastics, while 20% is glass and 10% copper.

3. Environmental and Health Concerns Related to the Management of End-of-Life Mobile Phones

Like other electronics, mobile phones contain a variety of substances that require sound handling and processing during material recovery and recycling, to prevent risks to workers, the public and the environment. The report identifies a variety of metals, plastics and other organics, as well as corrosive substances, which require sound management during material recovery and recycling.

This section of the guideline addresses the exposures and risks to human health and the environment that are posed by various processes for mobile phone material recovery and recycling—specifically, the exposures that may occur during recovery of metals and plastics. The report notes that particular care is necessary to prevent exposure of workers and the general public to substances of concern during material recovery and recycling processes that involve the generation of dust and fumes. Dusts may be generated during the shredding of mobile phones, during the subsequent handling of shredder outputs and during the handling and/or processing of smelter slags. The use of appropriate dust abatement techniques should be applied to ensure protection of workers. Fumes may be generated during metal sampling and smelting processes, as well as during certain steps in plastics recycling, such as granulation. The report notes that exposures to several substances are of particular concern: beryllium in dusts and fumes, and dioxins and furans generated from the burning of plastics.

This section also briefly addresses potential exposures to substances of concern from landfilling and incineration of mobile phones. This is particularly relevant since mobile phone material recovery and recycling processes, such as smelting, result in the generation of some residues that require disposal.

4. Environmentally Sound Material Recovery and Recycling Practices

Environmentally sound material recovery and recycling of end-of-life mobile phone handsets focuses on recovery of metals. It always includes recovery of copper and precious metals, such as gold, silver and palladium, due to their value. Some material recovery and recycling processes also result in the recovery of materials such as steel, aluminum/magnesium, tin, cobalt, lead and plastics, amongst others. Batteries, which must always be removed from the handset in the early stages of any environmentally sound material recovery and recycling process, can be safely recycled to recover iron, aluminum, copper, nickel, cobalt and cadmium, depending upon the battery type, as well as the particular recovery process.

The guideline provides general facility guidelines for all types of facilities engaged in the pre-processing, material recovery and recycling of end-of-life mobile phones, as well as more specific guidance on the separation of components and materials, battery recycling, the recovery of metals via smelting and refining, and the use of hydrometallurgical recovery processes.

All mobile phone pre-processing, material recovery and recycling facilities should have an environmental management system in place to ensure adequate control over the impact of the facility on worker and public health, as well as the environment. This EMS could include, but is not limited to, ISO 14000 certified management systems. The facility should operate pursuant to written procedures regarding operating methods for the plant and equipment, systems for management, control of site activities, measurement and record keeping and implementation of site safety rules. The facility must comply with all applicable health and environmental regulations and be properly licensed by all appropriate governing authorities. Written plans regarding emergency preparedness and financial assurance for emergencies and facility closure should also be maintained. The guidelines also address the need for plant personnel to be properly trained, as well as provided with appropriate personal protective equipment.

A prerequisite step in the material recovery and recycling of end-of-life mobile phones is the manual separation of batteries, in order to minimize contamination of other materials in subsequent material recovery and recycling stages as well as to maximize recovery of the substances contained in the batteries. Manual separation may also be used to separate certain accessories from mobile phone handsets and, in some cases, plastic parts may be separated for recycling. Mechanical separation, including shredding, crushing and size reduction followed by various separation techniques, can also be used. However, if these mechanical means are utilized, only devices that are designed for the processing of electronic scrap should be used, so that the loss of precious metals, as well as the emission of dusts generally, will be minimized.

Recovery of plastics from end-of-life mobile phones for material recycling is not widely practiced at this time due to the lack of viable techniques for separation of a plastic fraction of marketable quality. There is, however, ongoing research on the recycling of plastics from electronic waste that could make this option technically feasible and economically viable in the future.

The environmentally sound material recovery and recycling of end-of-life mobile phones (minus batteries and accessories) can be achieved by using either manual or mechanical separation of components or material followed by processing in specialized smelters or by direct smelting in specialized smelters. Mechanical separation includes shredding and size reduction followed by separation techniques that enable the separation of plastics, as well as the separation of iron and aluminium/magnesium. After separation of these components, the remainder of a mobile phone handset, particularly the circuit board, will be most efficiently recycled in a smelter, where precious metals and most other metals in the mobile phones will be recovered. Direct smelting of end-of-life mobile phones will permit the recovery of metals such as copper, precious metals (such as gold, silver and palladium) and most other metals (except iron, magnesium and/or aluminium); plastics will be used as a source of heat and also as a reducing agent. Smelting of electronics, including mobile phones, requires specialized equipment. Most smelters do not have the proper pollution control systems for the environmentally sound material recovery and recycling of electronics. Electronic scrap, including mobile phones, contains plastics and halogens (i.e., chlorine and bromine) which, when burned, lead to the formation of dioxins and furans, which are highly toxic and carcinogenic. However, with proper smelter operation and pollution control equipment, controls can be put in place to assure the environmentally sound material recovery and recycling of metals from end-of-life mobile phones.

Although the environmentally sound management of end-of-life mobile phones includes the recovery of materials, particularly including copper and precious metals, it does not necessitate the recovery of every substance. Mobile phones are small, their disassembly is expensive, and even in large quantities they do not contain many substances that can be efficiently recovered in amounts that are economically significant. There is ongoing eco-efficiency research that examines the environmental and economic dimensions of the recovery process.

5. Material Recovery and Recycling Capacity

There are a relatively small number of smelters and refiners (both large and small) in the world that have the specialized material handling equipment and pollution control systems that are appropriate for metal recovery and recycling from end-of-life mobile phones. The building of new smelters would necessitate a great amount of investment. Furthermore, the annual recycling of mobile phones is estimated to provide not more than 65,000 tonnes worldwide, which raises the question of the appropriateness of the building of such facilities in most countries. Mobile phones are one type, among others, of electronic wastes and the quantity of all such electronic wastes (if collected for recycling) may justify the building of additional smelting/refining capacity. However, we do not see such a need, in view of existing capacity at current smelters and refiners that have the specialization necessary for environmentally sound material recovery and recycling of electronics.

Pre-processing (e.g., separation and/or shredding) capacity may be constructed where it does not exist, depending on the collection of mobile phones and domestic demand for such capacity. As with smelting facilities, other end-of-life electronics may add to local demand for such processing capacity.

Because of the unlikely creation of pre-processing and smelting facilities in every country, it will be necessary, in order to achieve environmentally sound management, that end-of-life mobile phones that are intended for material recovery and recycling, whether whole or pre-processed, be exported by many countries to other countries where such facilities exist.

6. Proposal for Environmentally Sound Management (ESM) of End-of-Life Mobile Phones (MPs) in the Recycling Phase to Designated Governmental Authorities.

In order to further develop the environmentally sound management of mobile phones by material recovery and recycling facilities, a regulatory framework must exist that establishes a balance between the necessity of environmentally sound management and economic efficiency. Thus, in developing the appropriate regulatory infrastructure for mobile phone material recovery and recycling facilities, Parties should take into account the size of the enterprise, the type and amount of waste or scrap materials, as well as the nature of the operation. Further, the regulatory infrastructure should:

- Be developed at an appropriate governmental level and be composed of legal requirements such as authorizations, licenses, permits or standards. The legal requirements should address facility operation, workers' health and safety, control of emission to air, land, water and waste management. The license or permit should describe and authorize specific facility capacities, processes and potential exposures;
- Require that facilities operate according to best available technologies, while taking into consideration the technical, operational and economic feasibility of doing so;
- Encourage the development and implementation of environmental liability regime for material recovery and recycling facilities to prevent environmental damage;
- Encourage information exchange between facility managers and governmental authorities in order to optimize recovery operations;
- Move toward internalization of the costs of the environmentally sound management of end-of-life mobile phones;
- Encourage facilities to utilize environmental management systems, such as ISO 14000 series, EMAS or other similar programs;
- Recommend that material recovery and recycling facilities develop adequate monitoring, recording and reporting programmes;
- Encourage material recovery and recycling facilities to set up adequate employee training programs;

- Require that material recovery and recycling facilities have an adequate emergency plan;
- Require that material recovery and recycling facilities establish an appropriate plan for closure and after-care, ensuring the financial means for such closure.

It is recognized that developing countries, as well as those with economies in transition, have the greatest challenges ahead in building the governmental and industrial infrastructures necessary, in order to achieve the environmentally sound management of end-of-life mobile phones. In this regard, critical technical assistance can be provided by Parties and Signatories who represent developed countries, as well as the Secretariat of the Basel Convention and its Regional and sub-regional training centers.

RECOMMENDATIONS

Goals and Objectives

1. Parties and Signatories of the Basel Convention are encouraged to implement policies and/or programs which promote the environmentally and economically sound material recovery and recycling of end-of-life mobiles phones.

2. Consistent with the Basel Ministerial Declaration on Environmentally Sound Management, used mobile phones should be diverted from disposal practices, such as landfilling and incineration, by a robust collection program, to the more environmentally sound practices of reuse, refurbishment, material recovery and recycling.

3. It is very important that end-of-life mobile phones be collected effectively (which is usually not the case today, even in industrialised countries), taking into consideration the Guideline on Collection of Used and End-of-Life Mobile Phones, developed by the MPPI Project Group 2.1. Environmentally sound material recovery and recycling of mobile phones requires setting up an effective recycling chain, comprising the steps of robust collection of used phones, testing/refurbishment/reuse if appropriate, preparing/dismantling of non-reusable phones or parts, and recycling of handsets and batteries.

4. Environmentally sound material recovery and recycling of mobile phones and associated accessories such as chargers, plugs, cigarette lighter adapters, Bluetooth devices, headphones, hands-free car sets, protective cases and belt clip/holders, consistent with the practices contained in this guideline, should be utilized. All steps should be taken to ensure that unsound mobile phone material recovery and recycling practices are avoided, such as those where proper worker and environmental protections are not implemented (e.g., primitive and “backyard” operations) and those where there is no attempt to maximize material recovery.

5. Priority should be given to eco-efficient material recovery and recycling processes which achieve high recovery yields of the various materials contained in mobile phones and associated accessories such as chargers, plugs, cigarette lighter adapters, Bluetooth devices, headphones, hands-free car sets, protective cases and belt clip/holders, and to minimise losses of valuable materials, while reducing the environmental impact of their production.

Development of Recycling Infrastructure

6. The Basel Principles of self sufficiency, proximity and least transboundary movement, as well as the necessity of economic efficiency, should be taken into account when considering investments in mobile phone material recovery and recycling facilities or operations, as well as when developing domestic policies for environmentally sound material recovery and recycling.

7. Because conformance with this guideline may mean an increase in recycling costs, Parties, industry and other interested persons should collaborate to ensure that there is adequate financing for mobile phone material recovery and recycling.

Facility-Level Guidelines

8. Mobile phone material recovery and recycling facilities should be certified by an independent environmentally sound management system, like ISO 14000 series and the European Eco-Management Audit Scheme (EMAS), or by an equivalent system. The procedures needed for pre-processing facilities to achieve certification/registration for international environmental sound management systems should be simplified.

9. The General Facility Guidelines of Section 4.1 of this guideline should be implemented by all pre-processing, smelting, refining and other processing facilities that are involved in any aspect of mobile phone material recovery and recycling.

10. If shredding is utilized, mobile phone batteries should be removed prior to shredding. Batteries should also be removed prior to any smelting or refining. Mobile phone batteries should be sent to an authorized battery recycler.

11. Where mobile phones or their components are shredded or heated, appropriate measures to protect workers, the general public and the environment from dusts and emissions are especially important. Such measures include adaptations in equipment design or operational practices, air flow controls, personal protective equipment for workers, pollution control equipment or a combination of these measures.

12. Companies capable of pre-processing, smelting, refining or performing other steps in mobile phone material recovery and recycling should identify themselves to their competent authorities. Competent authorities should inspect and verify that these companies are practicing environmentally sound management consistent with this guideline.

13. Mobile phone collectors and pre-processors should perform due diligence to assure that subsequent handlers and processors operate consistent with this guideline.

Design for Recycling

14. The material recovery and recycling phase of end-of-life mobile phones should be taken into account by manufacturers during product design, by considering the issues of increased

recyclability and reduction in toxicity. (See the guideline of the Project Group 4.1 for greater detail.)

15. Beryllium and some flame retardants have been identified in this document as substances of particular concern during the processing of end-of-life mobile phones. Manufacturers should give consideration to the use of substitute materials that perform the same function.

16. Mobile phone manufacturers should collaborate to address the recyclability of plastics in mobile phones. Specifically, consideration should be given to greater consistency in material selection during the design stage for all mobile phones, which would allow plastics recyclers to eliminate sorting steps necessary to achieve compatibility of plastics types.

Future Collaborative Steps

17. Parties of the Basel Convention are encouraged to extend the role of the Basel Convention Regional Centers to develop training and technology transfer regarding the environmentally sound material recovery and recycling of end-of-life mobile phones, in order to help developing countries and countries with economies in transition implement regulatory frameworks for the environmentally sound management of end-of-life mobile phones.

18. An audit checklist or similar tools should be developed to assist parties and others in performing inspections and due diligence audits based on this guideline.

19. Further eco-efficiency analyses should be performed to greater inform decision making by Parties, as well as other interested persons, regarding optimal approaches for the material recovery and recycling of end-of-life mobile phones.

1. SCOPE OF THE PROJECT (how Project 3.1 addresses the recycling of mobile phones)

The primary objective of Project 3.1 is to provide best practice guideline for the environmentally sound material recovery and recycling of end-of-life mobile phones. . Because other projects of the Basel Mobile Phone Partnership Initiative (MPPI) address the reuse, refurbishment (Project 1.1), collection, and transport of used mobile phones (Project 2.1), this guideline does not provide best practice guidelines in those areas. However, robust collection of used mobile phones is strongly endorsed, as the necessary first step in material recovery. Thus, this guideline presumes that the separate collection of used phones, and their segregation for reuse and refurbishment, has already taken place.

Mobile phones are commonly segregated from other electrical and electronic waste streams for economic reasons. This is not necessary for environmental reasons.

The report addresses the material recovery and recycling of all components of end-of-life mobile phones. The three basic components of a mobile phone include (1) the handset, which includes a case (usually plastic), display screen, keypad, antenna, printed wiring board, microphone and speaker, (2) the battery and (3) the battery charger and other accessories (such as a carrying case, earphones and connecting cables).

The guideline also addresses the adequacy of the present material recovery and recycling infrastructure and its capacity for handling the increasing number of mobile phones that will become obsolete and will, it is hoped, be directed to material recovery and recycling rather than landfill, incineration or some form of improper disposal.

Finally, the guideline includes recommendations to national authorities regarding programs and policies that can be implemented to ensure that material recovery and recycling of end-of-life mobile phones is conducted in an environmentally sound, as well as economically efficient, manner.

2. CHARACTERIZATION OF MOBILE PHONES (MPs)

2.1 Substances contained in MPs

Mobile phones may differ from manufacturer to manufacturer, and from model to model. Thus the substances in any mobile phone will be somewhat different from the substances in another, dependent upon design, manufacturer, and age of product. For example, in larger parts such as the case, most mobile phones have a plastic case, but some might use aluminum, or magnesium. For microelectronic components, quite different substances might be added by a manufacturer in extremely small quantities. However the general composition is similar among all mobile phones, and is similar to other types of small electronic equipment. The following table indicates substances in three categories that may be useful: primary constituents, minor constituents, and micro or trace constituents. (Note that not all substances are used in every mobile phone, e.g. nickel or lithium battery, so numbers will not add to 100%, and numbers may not be the same as those in a typical newer mobile phone as reported by Project 4.1 manufacturing partners in the Guideline on Awareness Raising-Design Consideration, Annex I).

Name of substance	**Location in mobile phone**	**Typical % content of a mobile phone (including battery)**
Primary Constituents:		
Plastics	Case, circuit board	~40%
Glass, ceramics	LCD screen, chips	~20%
Copper, compounds	Circuit board, wires, connectors, batteries	~10%
Nickel, compounds	NiCd or NMH batteries	~2-10% *
Potassium hydroxide	battery, NiCd, NiMH	<5%*
Cobalt	Lithium-ion Battery	1-5% *
Carbon	Batteries	<5%
Aluminum	Case, frame, batteries	~3% **
Steel, ferrous metal	Case, frame, charger, batteries	~10%
Tin	Circuit board	~1%
		* only if these battery types are used, otherwise minor or micro constituent
		** if aluminum case used, amount would be much larger, ~20%
Minor Constituents		(typically less than 1%, more than 0.1%)
Bromine	Circuit board	
Cadmium	NiCd battery	
Chromium	Case, frame	
Lead	Circuit board	
Liquid crystal polymer	LCD screen	
Lithium	Lithium-ion battery	
Manganese	Circuit board	
Silver	Circuit board, keypad	
Tantalum	Circuit board	
Titanium	Case, frame	
Tungsten	Circuit board	
Zinc	Circuit board	
Micro or Trace Constituents		(typically less than 0.1%)
Antimony	Case; circuit board	
Arsenic	Gallium arsenide LED	
Barium	Circuit board	
Beryllium	Connectors	
Bismuth	Circuit board	

Calcium	Circuit board	
Fluorine	Lithium-ion Battery	
Gallium	Gallium arsenide LED	
Gold	Connectors, circuit board	
Magnesium	Case	Note: If Mg used for phone case, amount would be much larger, ~20%
Palladium	Circuit board	
Ruthenium	Circuit board	
Strontium	Circuit board	
Sulfur	Circuit board	
Yttrium	Circuit board	
Zirconium	Circuit board	

3. ENVIRONMENTAL AND HEALTH CONCERNS RELATED TO THE MANAGEMENT OF END-OF-LIFE MPs

3.1 Substances of potential concern in end-of-life management of MPs

- **Lead**

Lead is commonly found in electrical and electronic devices, used in very small quantities, in tin-lead solder, which very efficiently bonds components into integrated electronic devices. Tin-lead solder has been used in almost all mobile phones in their electronics, typically less than one gram per phone. However, the major mobile phone manufacturers have long sponsored fundamental research and co-operative work with suppliers to identify lead-free alternatives that can maintain the quality and reliability needed in hand-held electronics. Since lead based solder is now banned in Europe (and is being phased out in other regions around the world), most new mobile phones will not contain lead based solder; however, older end-of-life mobile phones that are being sent for material recovery may contain lead based solder.

Lead can be reclaimed from solder wastes, but recycling lead/tin solders can be extremely dangerous without appropriate technology because emissions of dioxins, beryllium, arsenic, isocyanates and lead are likely. Some integrated smelters recover lead.

Small quantities of lead compounds are used in some plastics, although this use is being phased out. Lead is still used extensively in PVC coated wires (2 – 5%) and this use of lead is not being phased-out as yet. This lead is not recycled but is released if the wires or insulation are burned. Lead may also be found in lead-acid gel batteries used in larger, older mobile phone devices. This lead can be recovered through battery recycling.

Lead: (Y31 Lead; lead compounds, Annex I, UNEP Basel Convention) (CASRN 7439-92-1). Lead is a cumulative neurological poison and a probable human carcinogen (U.S. EPA B2). The U.S. EPA requires lead in outside ambient air not to exceed 1.5 micrograms per cubic meter (1.5µg/m3) averaged over 3 months. The U.S. EPA limits lead in drinking water to 15 µg per liter (15 ppb). The U.S. Occupational Safety and Health Administration (OSHA) limits workplace exposure to airborne lead to 50 µg/m3, and requires increased surveillance when workers are exposed to airborne lead above 30µg/m3.

- **Cadmium**

About three-fourths of cadmium is used in nickel-cadmium batteries. The use of cadmium as anticorrosive plating and in pigments and stabilizers is now banned in northern European countries, although there is still some use of cadmium for these purposes in other countries. Cadmium is also used in electronic components. As nickel-cadmium batteries are easy to collect for material recovery and recycling, most of the secondary cadmium comes from these spent batteries. Recovery of cadmium from batteries is complex and hazardous and must only be done in a specialized facility.

Some mobile phones use a nickel cadmium battery, which contains cadmium and cadmium hydroxide, typically less than 25% of the weight of the battery. Since the mid-1990s, nickel-cadmium batteries are being quickly phased out of all electronic devices in favour of NiMH and Li-ion batteries. Cadmium is also used in electronics in very small quantities as a surface finish on printed wiring boards, and in electrical contact alloys for relays and switches. Some cadmium may be used in these electronic applications in some mobile phones.

Cadmium: (Y26 Cadmium; cadmium compounds, Annex I, UNEP Basel Convention) (CASRN 7440-43-9). Cadmium is toxic, particularly by inhalation, to the respiratory tract, and to the kidney and liver, and is a probable human carcinogen (U.S. EPA B1). The U.S. EPA has set a limit of 5 ppb cadmium in drinking water. The U.S. OSHA limits cadmium in workplace air to 100 µg/m3 as fume and 200 µg/m3 as dust.

- **Mercury**

No current use of mercury in mobile phones is now known. However, certain old mobile phones may have contained mercury oxide or silver oxide button cell batteries with mercury content.

Mercury: (Y29 Mercury; mercury compounds, Annex I, UNEP Basel Convention) (CASRN 7439-97-6). Mercury is a neurological poison, and is not classifiable as to human carcinogenicity. The U.S. EPA has set a limit of 2 ppb for mercury in drinking water. Mercury vapors are a health hazard. The U.S. OSHA has set a limit of 0.05 mg/m3 of metallic mercury vapour for an 8-hour workday and 40-hour work week. Methyl mercury can form in nature from elemental mercury and is one of the most serious toxic threats known. It presents a serious liability and risk for mercury waste disposers/recyclers.

- **Chromium**

Chromium is used to plate metal, usually steel, to protect it from corrosion and give it a shiny appearance.

Almost all mobile phones have plastic cases that do not require corrosion protection. Chromium: (Y21 Hexavalent chromium compounds, Annex I, UNEP Basel Convention). The U.S. limits (MCL/MCLG) for chromium in drinking water is 0.1 mg/L. In very small amounts, Cr (III) is an essential nutrient in our diet, helping maintain normal metabolism of glucose, cholesterol, and fat in human bodies. All forms of chromium can be toxic at high levels, but Cr

(VI) is the most toxic. At short-term exposure levels above the MCL, chromium causes skin and stomach irritation, or ulceration. Long-term exposure at levels above the MCL can cause dermatitis, damage to the liver, kidney circulation and nerve tissue damage, and death in large doses. Skin contact with liquids containing Cr (VI) may lead to allergic reactions.

- **Beryllium**

Beryllium is used as an alloying addition to copper and nickel (up to a maximum of 2%) for springs and electrical contacts. The oxide, beryllia, is used in some electronic equipment as a heat sink. Some small amounts of the oxide may be encountered in the recycling of electronic goods and should be recovered or otherwise isolated from the environment.

A mobile phone may contain beryllium in a copper-beryllium alloy (98% copper, ≤2% beryllium) used at connecting points with external wires and devices, in an amount typically less than 0.1 gram per phone. Beryllium is contained in a copper-beryllium alloy with an elastic property that is useful in connectors. A modern mobile phone will contain approximately 3 mg of beryllium per handset, or about 40 parts per million. In the smelting process, this beryllium may be released from the molten mass as a fine particulate, and the prevention of worker inhalation of this particulate requires considerable attention and care, with engineered ventilation to remove and collect it from ambient air. The most proficient copper smelters have established an internal control of ambient beryllium at 0.01 µg/m3, which is 200 times lower than the current permitted exposure level allowed by the U.S. OSHA. To achieve this level, these smelters have not only implemented engineered emission control systems, but have also established an incoming feedstock beryllium limit of 200 ppm. A current design mobile phone meets this standard, so beryllium is not an absolute barrier to environmentally sound material recovery and recycling, but it is a consideration in selection of appropriate recovery processes and facilities.

Beryllium: (Y20 Beryllium; beryllium compounds, Annex I, UNEP Basel Convention) (CASRN 7440-41-7). Inhalation of beryllia or beryllium-containing dust, mist or fume may cause a chronic lung disorder called beryllicosis in susceptible persons, and beryllium is a probable human carcinogen (U.S. EPA B1). The U.S. EPA restricts the amount of beryllium that industries may release into the atmosphere to 0.01 µg/m3, averaged over a 30-day period. The U.S. OSHA sets a limit of 2 µg/m3 of workplace air for an 8-hour work workday. This is under regulatory review and is widely considered to be inadequately protective for very small particulate, such as fume.

- **Antimony**

Antimony is not used in pure form but as a minor (albeit important) alloying additive. The metal finds applications in solders. Antimony trioxide is the most important of the antimony compounds and is primarily used in flame-retardant formulations and may also be present in mobile phone plastic cases and circuit boards.

When antimony-containing alloys are reclaimed, the minor amounts of antimony are likely to remain with the base metal in the alloy. For example, if an antimony-lead alloy is melted, the air pollution control equipment is much more likely to capture lead than antimony. Lead melts at 327°C and antimony at 630°C. Some integrated smelters recover antimony as a product.

Antimony: (Y27 Antimony; antimony compounds, Annex I, UNEP Basel Convention). The U.S. limit (MCLG/MCL) for antimony in drinking water is 0.006 mg/L. Antimony, in short-term exposure levels above the MCL, leads to gastrointestinal disorders, nausea, vomiting, and diarrhea. Antimony, when left on the skin can irritate it. In long-term exposures at levels above the MCL, decreased longevity, cardiovascular problems, and altered blood levels of glucose and cholesterol can be expected. Antimony is beneficial when used for medical purposes. It has been used as a medicine to treat people infected with parasites. Antimony is not known to be or classified as a carcinogen.

- **Arsenic**

Arsenic, in minute quantities, serves a variety of functions in the electronics industry. It is used in the processing of gallium arsenide crystals (used in cell phones, lasers etc.), as a dopant in silicon wafers, and to manufacture arsine gas, which is used to make superlattice materials and high performance integrated circuits. Arsenic metal also increases the corrosion resistance and tensile strength in copper alloys. A mobile phone typically contains a minute amount of gallium arsenide in its microelectronic circuitry, of which the arsenic content is less than a milligram. Some integrated smelters recover arsenic as a product.

Arsenic: (Y24 Arsenic; arsenic compounds, Annex I, UNEP Basel Convention) (CASRN 7440-38-2). Arsenic is classified as a carcinogen (U.S. EPA A). The U.S. EPA has set a limit of 0.01 ppm for arsenic in drinking water. The U.S. OSHA limits arsenic in workplace air to 10 µg/m3 for an 8 hour workday and 40 hour work week.

- **Copper**

Copper is the most commonly used metal in a mobile phone's electronic circuitry. It can be reclaimed rather easily by appropriate metallurgical processes.

Copper from electronic scrap may contain beryllium (See beryllium), which because of its health hazard must be captured in the air pollution control equipment. If copper-containing electronic scrap is ground for material recovery, the dust must be controlled and captured. Grinding can release beryllium-containing dusts.

Copper (CASRN 7440-50-8). Copper is a required human nutrient, is not a significant health concern, and is not classifiable as a carcinogen. In high doses it can cause respiratory and intestinal irritation, and in very high doses it can cause liver and kidney damage. The U.S. EPA has set a drinking water limit of 1.3 ppm. The U.S. OSHA has set limits of 0.1 mg/m3 for copper fume and 1 mg/m3 of copper dust and mist in workplace air for an 8-hour workday and 40-hour work week.

- **Nickel**

Mobile phones may contain nickel as an alloying element in steel parts. A mobile phone may also contain nickel if it has a nickel cadmium battery, or if it has a nickel metal hydride battery, in the latter case the nickel is in the form of nickel hydroxide. Nickel is usually recovered in integrated smelters or specialized battery recycling processes.

Nickel (7440-02-0); nickel hydroxide (12054-48-7). Nickel refinery dust in refineries and smelters is classified as a human carcinogen (U.S. EPA A). The U.S. OSHA has set a workplace limit of l mg/m3 for nickel for an 8-hour workday, 40-hour workweek.

- **Tin**

A mobile phone typically contains a small amount of tin in solder used in its printed wiring board. Some integrated smelters recover tin as a product.

Tin (CASRN 7440-31-5). Inorganic tin is not a significant health concern, and is not classifiable as a carcinogen. The U.S. OSHA has set a workplace limit of 2.0 mg/m3 for tin and inorganic tin compounds.

- **Zinc**

Zinc may be contained in a mobile phone in a battery or in electronic circuitry. It can be recovered in appropriate metallurgical processes.

Zinc (CASRN 7440-66-6). Zinc is a required human nutrient, is not a significant health concern, and is not classifiable as a carcinogen. Zinc is the second most common trace metal, after iron, naturally found in the human body. Zinc oxide is used as a medicament. The U.S. OSHA has set a limit of 5 mg/m3 for zinc oxide fume in workplace air for an 8-hour workday and 40-hour work week.

- **Cobalt**

Cobalt is generally similar to iron and nickel in its properties. It can be recovered in specialized processes.

A mobile phone may contain cobalt in a lithium ion battery.

Cobalt (CASRN 7440-48-4). Cobalt is beneficial for humans, and is part of vitamin B12. Cobalt fume and dust is an irritant to lungs if inhaled, and cobalt is a possible human carcinogen (IARC 2B). The U.S. OSHA has set a limit of 0.1 mg/m3 for cobalt in workplace air for an 8-hour workday and 40-hour work week.

- **Silver**

Silver is utilised principally in industrial applications, including electrical and electronic uses.

A mobile phone typically contains several grams of silver in the electronics and keypad contacts, in elemental form. It is recovered in appropriate metallurgical operations.

Silver (CASRN 7440-22-4). Silver is not toxic to humans, and is not classified as to carcinogenicity (D), but, if bioavailable in ionic form, can be toxic to some animal species. The U.S. OSHA limits silver in workplace air to 0.01 mg/m3 for an 8-hour workday, 40-hour workweek.

Concerns with combustion of organic content

- **Plastics**

The case of a mobile phone is typically made of PC/ABS plastic, a mix of polycarbonate (PC) and acrylonitrile butadiene styrene (ABS). The case of the charging station is typically made of polycarbonate. While these plastics are not of concern as such, they contribute hydrocarbons to a combustion process, and require complete oxidation. The printed circuit board is typically epoxy resin or fibreglass. Both the cases and wiring board are likely to contain bromine in organic compounds used as a fire retardant, which may contribute to the formation of brominated hydrocarbons in poorly combusted and controlled exhaust gas streams.

- **Liquid Crystals**

The display screen in a mobile phone uses "liquid crystal" (LCD) technology. "Liquid crystal" is not liquid in the normal or scientific sense of that word, because it does not flow or deviate from a fixed shape. It is a solid form of polycyclic aromatic hydrocarbon (PAH, CASRN 130498-29-2) in which internal molecules have a limited mobility to twist under electrical stimulation. A typical mobile phone contains several milligrams of "liquid crystal" between thin glass panels. Burning or smelting of an LCD screen without appropriate gas cleaning raises concerns with products of incomplete combustion, in which PAHs may be released, and in the presence of halogens, dioxins and furans may be produced. PAHs have caused cancer in laboratory animals. The U.S. OSHA has set a limit of 0.2 mg/m3 of PAHs in workplace air.

- **Halogens/flame retardants**

Two brominated flame retardants are commonly used in current mobile phones, these are tetrabromobisphenol-A (TBBP-A or TBBA) and decabrominated biphenyl ether (DBBE). TBBP-A is reacted into the resins used to make printed circuit board substrates, and either TBBP-A or DBBE may be added to a mobile phone's plastic case. A flame retardant is used in a mobile phone case because of the possibility of an electrical malfunction, especially at the battery, if the phone is misused, with a larger than normal release of electrical current, and consequent fire. A flame retardant will not necessarily prevent such a fire, but will slow its initiation, and thus it adds a safety factor to mobile phone use. A current design mobile phone will contain approximately 2g of flame retardant.

A brominated flame retardant is unlikely to be released into the environment in recycling operations, including during the shredding of mobile phone plastic cases. When it is used as a reactant in a circuit board, TBBP-A combines chemically with the plastic of the board itself, and is unlikely to be released in its original form. However, for both types of brominated flame retardant, when mobile phones are oxidized during smelting, the bromine will be released. The released bromine may then recombine with unoxidized carbon under certain conditions in smelter emissions in the form of brominated dioxins and furans.

Smelters that use mobile phones as feedstocks therefore need to be particularly attentive to combustion conditions and emission control, and to install systems that prevent the formation of dioxins and furans. The potential for such formation in smelters is well known, as are the preventive process and emission controls, and such smelters are regulated by their competent authorities specifically for emissions of dioxins and furans.

Fluorine compounds are used in lithium ion batteries. These halogens are of concern because of the possibility that dioxins and furans may be created and released under inadequately controlled burning or smelting operations.

Some manufacturers have long been seeking substitute halogen-free flame retardants, as well as designs that do not require any flame retardants. This early work has resulted in some manufacturers producing mobile phones that do not use brominated fire retardants.

- **Concerns with corrosives**

The battery of a mobile phone is contained in its own sealed plastic case, and is removable from the mobile phone. Batteries may be one of three types, each named after the chemistry of the battery's active substances:

> --lithium-ion, which uses a lithium-cobalt compound, or lithium-polymer, having a similar battery chemistry, but uses a different electrolyte.
> --nickel-metal-hydride – using a nickel hydroxide compound.
> --nickel-cadmium – using cadmium. This older battery type is now rarely, if ever, used for mobile phones, but it is present in older phones that are still in use.

Lithium ion batteries contain lithium and manganese, cobalt or nickel. Nickel-metal-hydride batteries use an alloy based on lanthanum nickel, $LaNi_5$, or, less often, an alloy of vanadium-titanium-zirconium-nickel. The materials used in both these types of batteries, while not without environmental considerations, are less hazardous than lead or cadmium.

Shredding or breakage of a mobile phone with their batteries may raise concerns for corrosive constituents contained in batteries such as potassium hydroxide or lithium ion.

Potassium hydroxide (CASRN 1310-58-3). A mobile phone battery may use potassium hydroxide paste as an electrolyte. Potassium hydroxide is reactive with water and is a strong caustic, causing chemical burns on contact with skin.

Lithium ion (CASRN 12190-79-3). It is very corrosive, causing chemical burns on contact with skin. Lithium ion is not as reactive as elemental lithium, but there is also a potential for fire during shredding, producing toxic fumes.

3.2 Exposure to substances of concern in end-of-life management of MPs

3.2.1 Land disposal

Land disposal of mobile phones may place them in contact with co-disposed acids, and, over an extended period of time, the substances that are soluble in those acids may leach out. There has apparently not been research that indicates which substances will leach from a mobile phone, except for lead. There have been several studies indicating that electronic circuit boards will leach lead under landfill conditions simulated by the U.S. EPA Toxicity Characteristic Leachate Procedure (TCLP)[1].

If a landfill is not bound by an impermeable barrier, substances may migrate into ground waters, and eventually into lakes, streams, or wells, and raise a potential exposure to humans and other species. However lead does not tend to migrate in soil, but instead remains fixed to soil particles[2]. Thus lead exposure through drinking water due to leaching and migration to ground water is a minimal risk.

The greater risk of land disposal will be from direct ingestion of contaminants, contaminated soil and water in landfills that are not controlled. Some landfills, particularly in poor regions, are visited by people, including small children, looking for valuable materials. The route of exposure will be almost entirely by ingestion, either directly through drinking water or through food chain that has been contaminated by substances of concern.

3.2.2 Waste incineration

Waste incineration of mobile phones will oxidize the plastic in the case and in the circuit board. Depending on the conditions, the oxidation of plastics may be incomplete, and hydrocarbon particles and other soot may be produced. This would be particularly true if the waste incineration were informal and completely uncontrolled, such as in metal drums or open burning, which might occur in poor regions. People might burn circuit boards, for example, to concentrate the metals in ash, to sell for metal recovery.

Some metals, including cadmium and lead, have relatively low melting temperatures and may melt during incineration and form fume or minute metal oxide particles that will be carried into the incinerator exhaust with the air emissions. If these metals, and any other metals that are contained in mobile phones, do not melt at the temperatures of incineration, they will remain in bottom ash. That bottom ash, if disposed on land, may raise the concerns of exposure to hazardous substances described above. And leaching from ash in land disposal conditions may be substantially faster than leaching from solid mobile phones.

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[1] Environment Australia, Hazard Status of Waste Electrical and Electronic Assemblies or Scrap, Guidance Paper, October, 1999, paragraph 46.

[2] "When released to land, lead binds to soils and does not migrate to ground water. In water, it binds to sediments. It does not accumulate in fish, but does in some shellfish, such as mussels." US EPA, National Primary Drinking Water Regulations, Consumer Factsheet on Lead.

In addition, if incineration is not at a sufficiently high temperature and sustained for a sufficient time, the plastics and other hydrocarbons contained in a mobile phone may not be completely oxidized to carbon dioxide and water, and may combine with halogens to form new halogenated hydrocarbons, including dioxins and furans.

Whether waste incineration is informal and completely uncontrolled, or even somewhat better controlled, burning mobile phones will release substances of concern in air emissions, and to other environmental media in subsequent management of fly ash and bottom ash[3].

3.2.3 Metal recovery

Mobile phones, especially when processed in large volumes where economies of scale can be applied, are a good source of metals. The principal interest for metal recovery from mobile phones is in the recovery of the metal of greatest amount – copper – and the metals of greatest value – gold, palladium and silver. In addition, recovery of cobalt from Li-Ion batteries is also of economic interest. If mobile phone cases are made of aluminium or magnesium these metals are also of economic interest.

Processing for metal recovery may begin with shredding in dedicated ‘e-waste shredders’ to reduce a mobile phone to smaller size pieces, approximately 2 cm, if this is more suitable for feeding into a smelter. The shredding process will generate both high volume noise and some dust particles that may contain any of the substances in the mobile phone. Unless these particles are controlled, workers may be exposed to those substances by inhalation and ingestion. In normal shredding, however, the amounts of substances released in the shredding process are small[4]. If batteries have not been removed before shredding, they will release caustic substances, and may cause electrical short circuits and fire, which may cause its own releases of toxic emissions.

The shredding process may be followed by material separation steps, to separate metals one from another, and the non-metals one from another. There are a variety of technologies employed for material separation, such as, magnets, eddy-current separators, and flotation. The dust particles that were created in the shredding process will continue to be present and will require control to prevent worker exposure. Separated materials with no market value would require disposal in authorised landfills or incinerators as appropriate.

The smelting process, which separates copper, other metals and precious metals from other materials, is a high volume, high temperature operation. Metal fume and metal oxide particulate may be released, exposing workers and downwind communities unless the emissions are controlled. The most problematic metal emission from smelting may be beryllium, but the concentration of beryllium in mobile phones is low enough to be controlled at very low

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[3] Stewart, E. and Lemieux, P., Emissions from the Incineration of Electronic Industry Waste, IEEE Symposium on Electronics and the Environment, 2003, pp. 271-275. This paper describes experiments by the U.S. EPA using controlled combustion but with inadequate afterburner capacity and no other emission controls.

[4] TBBP-A and other brominated flame retardants used in electronic scrap have been found in the working environment at a Swedish shredding facility at only extremely minute concentrations. See Sjödin, A., Carlsson, H., Thuresson, K., Sjölin, S., Bergman, A., Ostman, C., *Flame Retardants in Indoor Air at an Electronics Recycling Plant and at Other Work Environments*, Environmental Science and Technology, 35, 448-454 (2001).

concentrations, far below air quality standards[5]. If hydrocarbons are present in materials being smelted, the process may release particles of incomplete combustion and, if halogens are also present, may release dioxins and furans. These releases can be controlled through properly engineered processes and emission control systems, but require attention and sound management[6].

Metal recovery from separated batteries will, like smelting, involve high volume, high temperature processes, and metal fume and metal oxide particulate may be released, exposing workers and communities. Cadmium is a component of NiCd batteries, has a low melting temperature, and will be easily emitted in furnace exhaust, most likely as cadmium oxide particulate. As with smelting, these releases can be controlled through properly engineered processes and emission control systems, but require attention and sound management[7].

Smelting will be followed by a number of metal-specific electro-refining, dissolution and precipitation processes (hydrometallurgical processes), in which individual metals are upgraded and refined to market grade. These steps may result in waste water that may contain high toxic metal concentrations and that, if not completely reused within the refining facility, will require attention and sound management.

The slag that is produced in the smelting process will also contain substances of concern. If it still contains relatively high concentrations of metals of economic interest, it should be reintroduced into the smelter, or into other smelting processes to recover these metals. Such continued smelting will have potential releases of fume and particulate, but will increase metal recovery and avoid landfill disposal. Slag may also be ground to a powder as a preparation for further metal recovery by selective leaching and precipitation of desired metals. These further processing steps may create potential exposures of workers to metal-containing dust, and waste water with high toxic metal concentrations, and should be controlled through properly engineered processes and sound management.

Slag is typically a silicate glass, and when it has been stabilized and made insoluble in high temperature processing it will not leach substances of concern, and may be safely used as a building or road construction aggregate. If slag has not been rendered stable and insoluble, its use on land or ultimate disposal in a landfill has the same potential for release of substances of concern described above.

3.2.4 Plastic recovery

Plastics from mobile phones have not been widely recovered as plastics yet, because few facilities can efficiently sort plastics into clean streams of a single type. In smelters with appropriate flue gas treatment, plastics may be utilised in the metal recovering process, where they serve as a source of heat and substitute for other hydrocarbon fuels and as a reducing agent. If mobile phone cases could be designed to be easily removed, and free of contaminating

[5] Ibidem
[6] OECD ENV/EPOC/WMP(97)4/REV2, Report on Incineration of Products Containing Brominated Flame Retardants, 1998. See also, e.g., Lehner, Theo, E&HS Aspects on Metal Recovery from Electronic Scrap, IEEE Symposium on Electronics and the Environment, 2003, pp. 318-322
7 see note 3

substances like paints, labels and metals, as well as collected in a reasonably large volume, the engineered plastics of mobile phones, usually an acrylonitrile butadiene styrene-polycarbonate (ABS-PC), could be recycled with a positive economic value. Manual demanufacturing of mobile phones prior to precious metal recovery can produce reasonably clean streams of such plastic. There is ongoing research on the identification and sorting of plastic, and this option may be economically viable in the future. Indeed, the well known German Frauenhofer Institute[8] has demonstrated in its pilot project launched in 2001/2002, called “RegioPlast”, that the recycling of plastic coming from electric and electronic waste is technically feasible and economically viable for larger and clean plastic parts [9].

The plastic recovery process would begin with sorting of plastic types, which would not involve any exposure to hazardous substances. Sorted plastic would then be granulated, a process that can generate heat and, if not properly managed, smoke and fire.

A plastic case may contain a brominated fire retardant, in all likelihood decabrominated biphenyl ether (DBBE). DBBE is an additive flame retardant, and some amount may be released from the plastic during the granulation process, but studies indicate that the amount would be small.

After granulation, the plastic will be moulded into a desired shape under elevated pressure and temperature, and there may be exposure to substances contained in the plastic, but this would be no different for the same type of plastic from other sources.

3.3 Recommendations on Section 3

1. Consistent with Basel Ministerial Declaration on Environmentally Sound Management, used and end-of-life mobile phones should be diverted from disposal practices such as landfilling and incineration to the more environmentally sound practices of reuse, refurbishment, material recovery and recycling.

2. Environmentally sound material recovery and recycling practices consistent with this guideline should be utilized. All steps should be taken to ensure that unsound mobile phone material recovery and recycling practices are avoided, such as those where proper worker and environmental protections are not implemented (e.g., primitive and “backyard” operations) and those where there is no attempt to maximize material recovery and recycling.

3. Priority should be given to eco-efficient material recovery and recycling processes which achieve high recovery yields of the various materials contained in mobile phones, and to minimise losses of valuable materials, while reducing the environmental impact of their production. For example the effective recovery of a small amount of gold may be more ecoefficient than the recovery of a large amount of iron or plastic/organic resins. However, the recovery process should not impede an effective recovery of other substances, as listed in the Section 3.1 table.

[8] Institute on Technique of production and automation (IPA) Stuttgart.
[9] For more details see section 4.4.5

4. Beryllium and some flame retardants have been identified in this document as substances of particular concern during the processing of end-of-life mobile phones. Manufacturers should give consideration to the use of substitute materials that perform the same function.

5. In order to prevent exposure of workers to substances of concern during material recovery and recycling processes that involve the generation of dust and fumes, appropriate abatement techniques should be applied (see chapter 4.1 Occupational health and safety).

6. If shredding with subsequent material sorting is applied, special attention must be placed on preventing the potential loss of precious metals, which are very valuable both from an economic and an ecological point of view. It is recommended to remove circuit boards before shredding and sorting processes and to sell the boards for reuse or treat them for recovery in appropriate metallurgical operations[10].

4. ENVIRONMENTALLY SOUND MATERIAL RECOVERY AND RECYCLING PRACTICES

End-of-life mobile phones are, when collected in sufficient volume, a useful source of metals, including copper, gold, silver, and palladium, amongst others. And from an environmental point of view, the recovery and recycling of these metals has the greatest positive impact (eco-efficiency) at this time. There is, however, ongoing research on the recycling of plastics from electronic waste that could make this option technically feasible and economically viable in the future. The plastic fraction contained in MP's can also contribute to energy efficient recycling processes by making use of its reducing properties and its caloric value as a fuel substitute in smelters and refiners.

The material recovery and recycling chain in general consists of the following main steps:

- Collection (not considered in this project)
- Segregation, i.e. sorting out MP's from other (electronic) wastes and possible reuse (not considered in this project)
- Separation of MP components
  - Separation of accessories
  - Battery removal from handset
  - Manual or mechanical disassembly of other parts (optional)
- Recycling of batteries
- Recycling of accessories
- Recycling of handsets
  - Shredding (optional) or shredding and separation of materials (optional)
  - Sampling and analysis for the determination of the individual material composition
  - Smelting, i.e. upgrading of metal contents
  - Metals refining, i.e. separation and purification of metals to marketable products.

[10] Precious metals in the circuit boards are contained not only in metallic alloys (contacts, solders etc.), but also in ceramics (ICs, Multi Layer Capacitors) and plastic parts or resins (coatings on the PWB, interboard layers etc.).

4.1 General facility guidelines

Mobile phones and their accessories will generally be treated by facilities that engage in raw material recovery, which will thus require a higher degree of governmental environmental oversight in accordance with the environmental risks associated with their processing systems. Environmental management systems become an important aspect of these operating facilities.

■ Environmental Management System :

The material recovery and recycling facility should possess and maintain a documented environmental management system to ensure adequate control over impact on the environment. This EMS could include, but is not limited to, ISO 14000 certified management systems.

The EMS system should also incorporate record keeping of shipping documents, bills of lading and chain of custody of material destined for downstream markets in the form of audits.

The facility should operate pursuant to written standards or procedures regarding operating methods for the plant and equipment, systems for management, control of site activities, site safety rules and requirements and methods for ensuring observation/monitoring (i.e., an overall operating/systems/safety manual).

■ Licensing/Permits:

The facility must comply with all applicable environmental regulations (international, federal, provincial and municipal).

Material recovery and recycling facilities must be licensed by all appropriate governing authorities.

Licensing and permits should be consistent with governmental, regional and local regulatory requirements. Specific permits required may include: storage permit, air emissions permit, water permit, hazardous waste permit, and those permits required to meet landfill and other disposal regulations. Processes should be in place to ensure continued compliance with the requirements of the permits.

■ Monitoring and Record Keeping:

A monitoring program should be maintained to track:
- key process parameters
- hygiene risk elements, such as beryllium
- compliance with applicable regulations
- generation of any emissions or effluents
- the movement and storage of waste, especially hazardous waste

The facility should have: adequate record keeping systems to ensure compliance; records of employee training, including health and safety; manifests; bills of lading; chain of custody documents for all materials; emergency response plans; closure plans (in the event a plant or operation closes); recordkeeping policies; fire prevention and suppression procedures; equipment failure backup plan; and security plans.

■ Emergency Planning:

The facility should have a regularly updated emergency plan that provides guidelines on how to react to emergencies such as fires, explosions, accidents, unexpected emissions, and weather related emergencies (e.g., tornadoes, hurricanes, etc). The emergency plan should also indicate what reporting and monitoring is required for specific instances.

This plan should be communicated with local emergency response authorities.

■ Occupational Health and Safety (Best practises to ensure worker safety):

The facility must comply with all applicable health and safety regulations (federal, provincial, and industry standards).

The facility must ensure occupational health and safety of employees by:
a) providing continuous health and safety training of personnel,
b) providing ergonomic work areas with safe and effective tools,
c) avoiding heavy lifting where possible, and train employees to lift in a safe manner. In some cases lifting tools may be required.
d) making available and enforcing the use of personal protection equipment,
e) labelling of all hazardous materials,
f) safeguarding of dangerous mechanical processes,
g) avoiding exposure to unacceptable occupational risk, such as airborne dust and fume, through process dust collection systems.
h) performing periodic air monitoring to monitor elements of risk, including but not limited to lead, cadmium and beryllium.
i) providing process fire suppression equipment and systems where appropriate,
j) considering policies that prohibit eating food or smoking in process areas.

In certain work conditions, personal protective equipment (PPE) must be worn to ensure employee safety. The degree of PPE required will depend on the level of potential risk that the employee is exposed to and the type of equipment the employee works with.

■ Personal Protective Equipment:

- Eye protection – safety glasses should be worn to prevent eye injuries. Eye wash stations should be available in areas easily accessible by employees, and as regulated by local laws.

- Head protection – hard hats may be required to be worn in certain areas, such as in proximity of overhead racks and around automatic dismantling machines and smelting furnaces.

- Hand protection – if opening boxes, using safety knifes, handling sharp objects or using pallet jacks, gloves may be required. When manually dismantling material or handling chemicals, gloves should be also be worn. Gloves will help protect hands from cuts, scrapes, chemical burns and infection from blood borne pathogens.

- Skin Protection – in certain conditions, such as working in proximity of furnaces, chemical equipment or some types of automated equipment, wearing a fire resistant work smock may be necessary to protect exposed skin from burns or chemical exposure.

- Foot protection – steel toe shoes should be worn to prevent foot injuries from falling objects, pallet jacks, chemical spills, etc.

- Hearing Protection – ear plugs should be worn in work areas where prolonged noise exposure would lead to hearing damage.

- Respiratory protection – dust masks or face masks should be worn in areas where there is a risk of dust inhalation.

■ Training:

The facility should provide employees with periodic training to safeguard the occupational health and safety of the employee. The training should address safe work practises, required safety precautions and required personal protective equipment. Employees should be trained in the proper identification and handling of any hazardous material that may be present in incoming waste material.

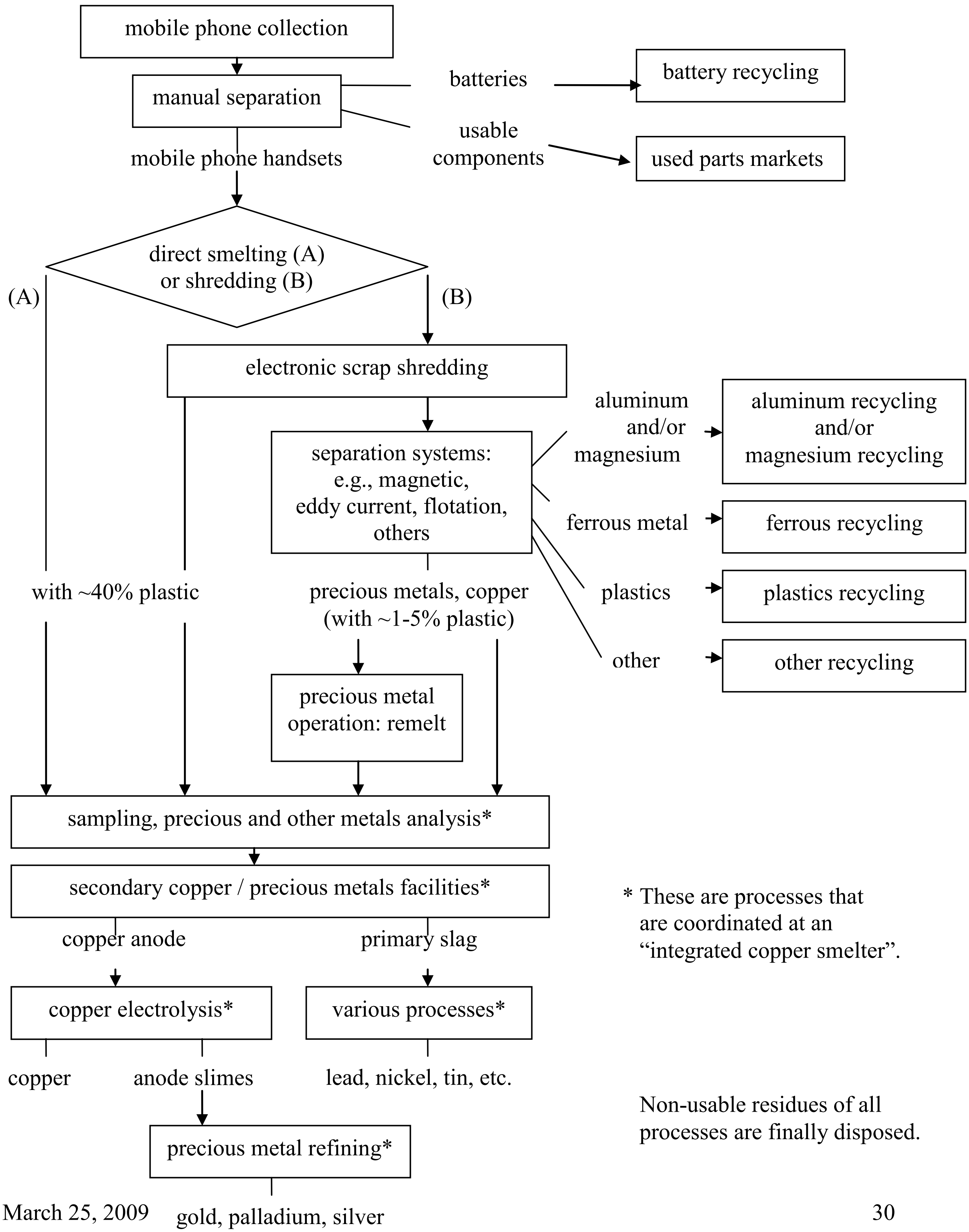
Training should be documented, recorded and updated as conditions merit.

■ Financial Assurance:

A financial instrument should be maintained that will assure that the facility is properly cleaned up in the case of:

- Major pollutant releases or gross mismanagement of end-of-life electronics equipment, components, and scrap, and
- Closure of the facility.

4.2 Flow Diagram – Recovery of Precious Metals and Other Materials from Mobile Phones



4.3 Potential Recovery from Mobile Phones Compared with World Production of Constituents

Material	Annual Primary Production	Estimated Content	Percent Use
	(approximate, tonnes)	1.15 Billion Phones	in Phones
		Sold in 2007 (tonnes)	
Steel, iron	1,300,000,000	11,500	0.00%
Plastics	100,000,000	46,000	0.05%
Aluminum	22,000,000	3,450	0.02%
Copper	16,000,000	11,500	0.07%
Tin	265,000	1,150	0.43%
Silver	20,000	400	2.00%
Gold	2,500	40	1.60%
Palladium	220	16	7.27%

4.4 Separation

4.4.1 Manual separation of components, accessories and materials

Prior to material recovery and recycling of end-of-life mobile phones, several items need to be separated and sorted. Batteries must be removed before mechanical or pyrometallurgical processing, i.e., prior to any shredding and/or smelting. Accessories may also be sorted and separated from the mobile phone handset. Plastic parts may be manually removed, if feasible or required, and recycled separately from the mobile phone.

The metals of economic interest and of environmental concern are primarily located in the electronic circuitry in the handset. However, the accessories must not be neglected: the charging base station will contain a small amount of copper, at contact points with the handset, and a transformer will contain copper wire. Other accessories such as earphones and connecting cables will contain a small amount of copper. These devices should be checked for potential continued use with a useable mobile phone, but if they are not suitable for such use, they should be processed in an appropriately controlled recycler and/or smelter for the economic and environmental benefit of recovered metal.

Mobile phone accessories tend to have a lower metallic value than the mobile phones. In this case, pre-sorting becomes an important step in the material recovery and recycling process. Examples of mobile phone accessories include chargers, plugs, cigarette lighter adapters, Bluetooth devices, headphones, hands-free car sets, protective cases and belt clip/holders.

Even though accessories are separated from the handset, accessories can still be sent to the same reclamation facilities as the handset.

Batteries need to be removed prior to handset recycling; otherwise little or no manual dismantling is probably required. The greatest element is plastic, which can be recycled back to plastic or used for its energy value as part of the smelter stream.

Shredding may be done for size reduction, for sample preparation or prior to separating metals and non-metals.

Batteries used in mobile phones include rechargeable nickel cadmium (Ni-Cd), nickel metal hydride (NiMH), lithium ion (Li-ion) and lithium-polymer batteries. These batteries should be removed prior to further processing of the handset. If removed manually in a dedicated dismantling process, care should be taken to avoid repetitive strain injury. Once removed, batteries should be managed with care to avoid breakage. While they are not fragile, they may break in rough handling, and leak caustic electrolyte or other substances. Batteries may still contain an electrical charge, and their handling must include appropriate measures to prevent any fire caused by short circuits. The removed batteries must be sent for material recovery and recycling to facilities using processes specific to each battery chemistry. Such facilities should be properly authorized to recycle batteries by local authorities.

Other parts: A mobile phone can be further disassembled after battery removal, using manual labour, and some components can be recovered for potential reuse. Disassembly of small devices, however, is very labour-intensive.

Manual separation of mobile phone components has the disadvantage of generating high costs (See Section 4.7 for further discussion and greater detail about costs). It is therefore recommended, that separation be limited to what is necessary for enabling subsequent eco-efficient recycling processes. This includes:

- Separation of accessories: if possible, they should be reused. Although they also can be treated in a smelter/refinery, they need to be isolated for sampling purposes and to avoid mechanical problems in the smelter feed stream (blockages caused by cables).
- Separation of batteries: an individual, appropriate treatment of batteries, especially for NiMH and Li-ion, achieves best material recovery and recycling efficiencies.

In regions with access to affordable and trained labour, it can also be beneficial to manually separate circuit boards from the mobile phones. This leads to reduced costs in the subsequent metallurgical treatment of the circuit boards, without risking losses of precious metals in the separation process. Prerequisite is that the other dismantled fractions (including the casing) can be directed to environmentally sound reuse/recycling processes as well.

4.4.2 Mechanical separation of components

Mechanical separation of components, i.e., by robots or automated processes, is under study, and may be possible when mobile phones have been designed with such separation in mind. To date, there do not appear to be any installations that have implemented an efficient mechanical separation of components.

4.4.3 Mechanical separation of materials

Mechanical separation is an alternative option to a direct feed of handsets into an integrated smelting and refining process. It aims to separate the materials of the handset (without the battery), one from another. The plastics to be separated from the metals, the plastics to be separated one from another, and the metals separated one from another, dependent on their properties that enable such separation and the technologies employed.

The advantage of pre-processing is to facilitate the separation and recycling of the plastic for subsequent recovery, and also separating iron and aluminium/magnesium that would otherwise be lost in the smelter process. Manual pre-processing of different fractions can provide an advantage by improving the subsequent mechanical separation of plastic, iron, aluminium/magnesium, and circuit boards, enhancing recovery efficiency and minimizing potential loss of precious metals into other output fractions, from which they cannot be recovered.

Mechanical separation includes coarse shredding, often followed by manual sorting and further size reduction and separation techniques. Size reduction is practised to reduce the size of products, residues or raw material so that is suitable for sale or further processing. Many types of crushers are used, including cone crushers and ball crushers. Electronic components are a source of several non-ferrous metals and these may be ground in shredders or mills to liberate the circuit boards and other material from the metallic components so that separation can take place. Separation techniques are more frequently used for secondary raw materials and the most common is magnetic separation. Heavy media and density separation (swim/sink) is used by the scrap processing industry but may also be encountered in the non-ferrous metals industry, for example, in the processing of battery scrap to remove plastic material. In this case, the density and size difference of the various fractions is used to separate metal, metal oxides and plastic components using a water carrier. Air classification is also used to separate metals from less dense materials such as the plastic and fibres from electronic scrap. Magnetic separation is used to remove pieces of iron to reduce contamination of alloys. Generally, over-band magnets are used above conveyors. Moving electromagnetic fields (eddy current separation) are used to separate aluminium from other material. Other separation techniques involve the use of colour, UV, IR, X-ray, laser and other detection systems in combination with mechanical or pneumatic sorters. These are used, for example, to separate Ni/Cd batteries from other battery types; these techniques are being developed for other applications as well.

If shredding of mobile phones handsets takes place, this only should occur in a device that is dedicated to treat electronic waste, so that the loss of precious metals will be minimized.

4.4.4 Availability of Markets

Presently there are pre-processing (mechanical processing) facilities in operation in a number of countries specifically for electrical and electronic equipment. The majority of these have been encouraged by domestic legislation already in place, and most such facilities appear to be in OECD member countries, though a number of others exist outside the OECD area. This is a rapidly growing sector where it is encouraged and supported by Extended Producer Responsibility type legislation.

The technology for pre-processing is readily available, and establishment of such facilities, with all appropriate protections of human health and the environment, is not necessarily capital intensive. Therefore, increased demand for such services will result in the establishment of new facilities or expansion of existing facilities.

4.4.5 Plastic recovery and recycling

As described before, for small devices such as mobile phones, the economically viable separation of a plastic fraction in a marketable quality is difficult to achieve. However, two approaches are available: manual or mechanical. A labour intensive manual dismantling and sorting process is necessary to gain clean plastic fractions, although it still remains questionable if a sufficient market demand for these exists. Alternatively, mechanical pre-processing, at the present time, generates a plastic fraction which is contaminated with metals and most probably not marketable for plastic reuse or recycling.

Such a metal contaminated plastic fraction could be treated in an integrated smelter and refinery, but in this case it would be much more (eco-) efficient to treat the entire handset in such a process and save the mechanical pre-processing step. The benefit of treatment of entire handsets in a pyrometallurgical process is that not only the metals are recovered, but also the caloric and reducing value of the plastic, as it serves as a fuel substitute. This requires the presence of highly efficient off gas and water treatment installations, as has been described before.

There is ongoing research in identification and sorting of plastics and this option may be economically viable in the future. Indeed, the well known German Frauenhofer Institute[11] has demonstrated in its pilot project launched in 2001/2002, called “RegioPlast”, that the recycling of plastic coming from electric and electronic waste is technically feasible and economically viable. The plastic fraction gained from electric and electronic waste[12] can be used as quality certified tablets for the production of new technical plastic building components. The types of plastic used in the pilot project are polypropylene, acrylonitrile butadiene styrene (ABS), polycarbonate (PC) and polystyrene. These are comparable to the types of plastic used in mobile phones, with ABS and PC representing the major types of plastic contained in mobile phones.

The ABS and PC plastics used in mobile phones cases could have a positive economic value. However, it would need to fulfil certain conditions: first it would have to be collected in a reasonably large volume and, second, it would need to be freed of substances that would make it unsuitable for the recovery process, such as paints, labels, and metal, which are difficult to remove.

As discussed in the review of the design of mobile phones,[13] the elimination of metal fasteners and the substitution of pigments within plastics for paint coatings could improve recovery

[11] Institute on Technik of Production and automation (IPA), Stuttgart.
[12] Mobile Phones are included in the definition on the electric and electronic waste of the Frauenhofer study.
[13] See report of project group 4.1 p.23-24.

economics by providing a cleaner stream of ABS and PC plastics. Plastic without paints can be recovered as black plastic, which has an important market share. Moreover, clean ABS and PC plastic recovered from mobile phones, could be combined with the same plastics from other electronic waste, so that greater volumes would be available for more economically-efficient plastic recycling.

4.5 Recycling of batteries

Today, as mobile phone handsets are getting smaller and smaller, batteries constitute 1/3 of their weight. Three types of rechargeable batteries can be found in mobile phones: NiCd, NiMH and Li-ion/Li-Polymer. A composition overview is given on the table below (all figures expressed in percentage of weight):

System	**Plastics (w%)**	**Fe (w%)**	**Al (w%)**	**Cu (w%)**	**Ni (w%)**	**Co (w%)**	**C (w%)**	**Cd (w%)**	**Electrolyte (w%)**
NiCd	5-15	45			20			15	15
NiMH	20	18	1		28	3		/	20
Li Polymer	/	16	13	16	1	20	15	/	/
Li-ion Al Can	10-30	1	35	8	2	16	10	/	10-15
Li-ion Steel can	10-30	35	5	8	1	15	10	/	10-15

The two systems mostly used in mobile phones applications are the NiMH and Li-ion. The last one, NiCd is an old product and is probably not used any more in new applications. However, it can be found in old end-of-life products and its recycling is, therefore, further discussed here. Also, it should be mentioned that management of end-of-life batteries should take into consideration the following:

- batteries should be separated from the handset
- batteries can be treated in mixed composition, but this is not recommended
- dedicated processes should be used
- as of today, dismantling batteries is not recommended (no valorization of plastics or electrolyte).

4.5.1 Separation of batteries from handset

The material recovery and recycling processes for handsets and batteries are totally different, as the metals contained are different and can not be recycled within the same flow sheet. The general objective of the separation of batteries is to recover the nickel, cobalt and/or other metals. So as a first step, the separation of the battery from the handset is a pre-requisite. Due to the composition of the batteries, crushing the whole material is also not recommended for environmental and safety reasons; thus, this has to be avoided.

At present, there is no alternative to the manual separation of batteries from handsets. A few industrial processes exist for mechanical separation, although the economics range from very negative to break even. Further design for recycling of mobile phones could give rise to a greater potential for automatic dismantling.

4.5.2 Recycling of electrolyte and plastics

Batteries generally contain electrolyte in a plastic can. These should be recycled or separated before recovering metals.

As there is no market for recycled electrolyte (which cannot be recovered as “pure” electrolyte) nor for the plastic can, there are three existing approaches:

- Manual separation of plastics. The recovered plastics are theoretically re-usable in the plastic recycling industry, but due to their contamination with metals, they are either separately incinerated (the added value of this extra step versus direct incineration of the whole battery is strongly questionable). In most instances, it is landfilled (no valorisation, no environmental nor economic added value).
- Thermal pre-treatment: a pyrolysis step or combustion of all these carbon-based materials. This requires energy and an up-to-date gas cleaning installation to avoid the generation of dioxins and furans. In that case, the valorisation of these elements is null.
- Internal valorisation of these carbon-based materials in a one-step pyrolysis process. Depending on the recycling installation used, carbon can be fully, partially or not at all valorised. In certain cases, it can replace normal fuel that would otherwise have to be added in the process.

This last approach, with full valorisation of carbon-based material, is strongly recommended.

4.5.3 Recycling of mixed batteries

The recycling of mixed types of batteries within the same process can be investigated. This can only be performed in a pyro-process where all batteries are melted together, producing an alloy containing all metals (Fe, Cu, Ni, Co), a slag with refractory elements (CaO, SiO_2, Al_2O_3) and a dust containing volatiles (combustion residue from plastics, zinc, and/or cadmium).

Given that cadmium, and possibly zinc, is not recycled in these processes, as well as the question as to whether plastics will be fully valorised, the recycling of mixed lots of batteries is not the most appropriate way, and a pre-sorting operation is recommended.

4.5.4 Recycling of sorted batteries

The objective here is to select a recycling technology per the type, or chemistry, of a battery. A first step for segregating batteries into Li-ion, NiMh and NiCd is consequently required.

Following the sorting of batteries into their types, three main processes can be used:

- semi-pyro with pre-dismantling
- pyro with pre-dismantling
- pyro without pre-dismantling

In the semi-pyro with pre-dismantling, batteries are first dismantled: plastic packs are removed and even sometimes the steel or aluminium can. The remainder is then heated in a furnace where all electrolyte and other “pyrolysable” constituents are eliminated. The pyrolised batteries then are to be either directly opened or shredded and further separated via magnetic and/or eddy current separators. The residual is a Fe/Ni based product that can be eventually purified to produce a Fe fraction (recycled in the steel industry) and a mixed fraction of Co and Ni recovered by selective leaching and precipitation. Other materials generated are the dust (that has to be landfilled), plastics (valorised for combustion or most of the case landfilled), and the steel can (that can be valorised as a Fe-scrap). This process generates low recycling rates and can potentially be hazardous for workers during the dismantling operation. In addition, it requires an up-to-date gas cleaning and water treatment installation as well as a sophisticated installation for a correct shredding and separation of all constituents (required for further valorisation).

In the pyro process with pre-dismantling, the plastic pack is first removed and eventually the steel or aluminium can. After that, the rest of the battery is smelted in an oven to form a (Fe) Ni/Co alloy that can be further valorised in a Co and Ni refinery. This process is efficient when well managed (gas and water treatment) and generates high recycling rates. However, plastics are generally not valorised.

The last process, pyro without pre-dismantling, is similar to that previously mentioned, but without the first calcinations or dismantling of plastic packs. Here the plastics are directly valorised as fuel or reactant (as a reductant) in the process and an alloy Fe/Ni/Co/Cu (in the case of a dedicated furnace) or a matte (in the case of nickel smelter) that has to be further refined is produced. After refining, all or part of the metals are recovered in a form suitable for re-use in battery or other applications. This process is the most efficient one (only one step) with the highest possible recycling and recovery rates and a high eco-efficiency value (with an efficient heat exchanger, most of the energy released by plastic combustion can be recovered).

However, in all cases, special attention is required for the use of plastics—for its calorific value or as a reductant in the reactor—in an environmentally sound way.

According to its real composition and its leaching characteristics, slag should be either landfilled, purified in another step or directly valorised in other applications such as construction or cement industry (for dedicated processes). The dust fraction cannot generally be valorised and will require landfilling.

Generally, these pyro processes, without dismantling, are recommended as they provide the most eco-efficient way of recycling end-of-life batteries.

4.5.5 Availability of markets

This guideline has stipulated the requirement to remove batteries from handsets. Separated batteries may then be sent on to material recovery and recycling facilities. Battery recycling facilities appear, based on current information, to be exclusively located in OECD countries, with locations in North America, Western Europe and Asia.

4.6 Recovery and Recycling of Metals

4.6.1 Smelting and Refining

After separation of components, accessories and materials that may be more efficiently recycled by other means, the remainder of a mobile phone handset, particularly the circuit board, will be most efficiently recycled in a smelter, where precious metals and most other metals contained will be captured. Smelting can take place in a variety of furnaces, including electric, blast, rotary, reverberatory furnaces or top blown rotary converters (TBRC). The most common form of smelting will be copper smelting, but lead smelting may also be used. Some precious metal recovery facilities also use initial smelting furnaces that can accept mobile phone handsets.

Smelting is a process in which metals and/or metal-bearing materials are melted at high temperature, and then, while molten, separated through oxidation and/or reduction[14]. The base metal, typically copper but sometimes also lead, when in a molten state, dissolves the precious metals – gold, silver and palladium – while other metals, such as cadmium and beryllium, are oxidized in the process. These metal oxides have limited solubility in the molten base metal, and are of lower mass density, so they either float to the top – forming the primary slag – or, if they have a high vapour pressure at smelting temperatures, are emitted as fume or stack particulate. In either case, the slag or particulate is captured and reprocessed in the same smelter, or processed in another smelter for further metal recovery.

The molten base metal in the smelter is poured out into shaped molds, and hardens into thin flat ingots that are suitable for use as anodes in the next metal recovery step – electro-refining. Alternatively, the metal from the smelter is granulated; the granules are subsequently leached with sulphuric acid in an electrowinning plant. Precious metals and some other elements remain for further treatment in the tankhouse slimes.

A smelter processes substances of concern at very high temperatures, and could present risks to human health and the environment. Emission of combustion gases and metal particulate at a number of points, including charging doors, slag tap, casting molds, and furnace stack, can be controlled, and must be captured and routed to a control system consisting of one or more devices, such as an acid gas scrubber, venturi, cyclone, electrostatic precipitator and fabric filter (baghouse). Worker safety is particularly important, and the areas of concern mentioned further down must be followed at smelters with great attention.

The detailed control of pollution from a smelter is beyond the scope of this guideline, and reference should be made to more detailed papers. The World Bank, the European Commission Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Non Ferrous Metals Industries[15] and the U.S. Environmental Protection

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[14] Analogous to mechanical pre-processing, in smelting, a chemical disintegration takes place at high temperatures, which liberates the different elements contained in a handset and enables a subsequent metallurgical separation of the metals from one another

[15] http://europa.eu.int/comm/environment/ippc/brefs/nfm_bref_1201.pdf

Agency have produced papers describing the copper smelting process in somewhat greater detail, giving specific pollution control guidance, and providing additional references.

However, one point of specific guidance regarding smelting of mobile phones is appropriate here. Smelting requires modification of pollution control systems specifically for electronic scrap and mobile phones, because the presence of plastics and halogens, i.e., chlorine and bromine, raises concerns about the possible creation of furans and dioxins. These chemicals are considered to be highly neurotoxic and carcinogenic. To prevent their formation, the oxidation of hydrocarbons should be at a temperature of 850 deg.C. (1600 deg.F.) or higher, with a residence time of 2 seconds, with excess oxygen. These smelting furnace conditions will assure thermal destruction of hydrocarbons and will substantially reduce the possibility of formation of furans and dioxins in the furnace emission stream. Halogens will be converted to acids, and then to salts in an acid gas scrubber. In addition, the smelter exhaust gas should be rapidly reduced to a temperature of 200 deg.C. (400 deg.F.) or less at the inlet to a very high efficiency dust removal system, such as a baghouse or electrostatic precipitator.[16]

In the electro-refining step, an anode from the smelter is dissolved in sulphuric acid, and the base metal is simultaneously electroplated onto a cathode. The resulting cathode, at a purity level of 99.5% or greater, is suitable for sale in international markets as the complete equivalent of metal produced from primary sources. The sulphuric acid bath can be reused, but must eventually be replaced. Used sulphuric acid can be used in other metallurgical operations, or can be neutralized and cleaned through precipitation and settlement or filtering, and discharged at high standards for purity. The precious metals that were dissolved in the anode – gold, silver, palladium – are not carried over into the cathode. They remain instead in the electrolytic cell, as insoluble precipitants known as cell slimes. Slimes are periodically collected and processed for recovery of desired metals. This processing may include a variety of steps, including additional melting and selective dissolution and precipitation, which upgrade and/or selectively remove specific metals to market standards, completely equivalent to products from primary sources. All of these metal-specific operations may create air emissions or waste waters, and require individual attention to appropriate control systems.

The slag that is removed in the smelting process typically contains lead, nickel, etc. and may still contain some copper and precious metals. It is fed into another smelting process, usually a lead blast furnace, where lead acts as a chemical collector metal for remaining precious metals and other metals such as tin, bismuth, and antimony. The lead bullion from the blast furnace is fed into the lead refinery, usually a Harris-process, where lead and other refined metals, including nickel, are produced. The slag from the lead smelter contains silica, alumina, other ceramic constituents as well as iron oxide and other oxidized metals. It usually is a glassy, chemically inert slag that can be further used for construction purposes.

Slag may also be ground to a powder, from which a desired substance can be leached. Slag from the smelting of mobile phones will contain, among other substances, lead, cadmium and beryllium oxide, which may concentrate in smelter slag. Therefore, reprocessing of smelter slag, particularly by grinding it to a fine powder, requires a very high degree of attention to the

[16] For additional information, see the European Commission Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Non Ferrous Metals Industries.

potential presence of these metals in workers' breathing zones. If the smelter slag does not contain metal concentrations of interest, it may be suitable for use as building or road construction aggregate. To be appropriate for such use, it must be stable and insoluble from high temperature processing so that it will not leach its constituents. Periodic testing for solubility should be conducted. As an alternative to use as a construction aggregate, smelter slag may be disposed in a controlled industrial landfill, with similar appropriate attention to the possibility of release of substances of concern.

Priority should be given to processes that can eco-efficiently recover a large range of elements from the feed, produce a final slag that can be further used as a product instead of disposal in a landfill, and secure an environmentally efficient offgas and effluent treatment and control. Some companies operate integrated copper smelters and refineries for processing handsets in an aligned flowsheet, which integrates various smelting and refining processes for copper, lead, precious metals and other metals[17], while making use of the caloric value and the reducing potential of contained plastic fractions.

4.6.2 Hydrometallurgical processes

Hydrometallurgical processes use cyanide, and/or strong acids such as aqua regia, nitric acid, sulphuric acid, and hydrochloric acid, to selectively dissolve metals and separate them from other substances. These processes are commonly used in many metal recovery and refining operations. However, there is no known hydrometallurgical process that can directly treat whole mobile phone handsets in an ecologically sound and economically viable way, because of their solid bulk and high plastic content. Hydrometallurgical processes normally require that substances be first prepared through removal of plastic content, and milling or grinding to a small particle size with a high surface area. Thus, a sound hydrometallurgical process for mobile phones will take place at later stages of selective metal recovery, to extract specific desired metals.

In some cases, hydrometallurgical processes are presently used in informal, unauthorized operations to recover precious metals from printed circuit boards, usually using cyanide, and/or strong acids such as aqua regia, nitric acid, sulphuric acid, and hydrochloric acid. These operations should be avoided. They present high risks of injury to workers, and environmental problems with untreated spent acids. They also recover only certain metals, whilst leaving other metals, as well as the plastic fraction, unrecovered and unstabilized, making their land disposal an even greater environmental and safety concern.

4.6.3 Availability of markets

There are smelters, both large and small, throughout the world, but only a limited number have the emissions control systems that can manage the plastics and halogens in mobile phones in an environmentally sound manner. These capable smelters, however, have more than sufficient existing capacity to recycle all mobile phones in use. The large capital investment needed to

[17] Such as tin, nickel, cobalt, bismuth, arsenic, indium, selenium, tellurium etc.

establish a new smelter will probably present obstacles to new smelters, unless there are very large volumes of additional compatible feedstocks.

4.7 Eco-efficiency of environmentally sound management practices

Studies on eco-efficiency of ESM practices in recycling of electronic waste are still relatively rare. On the precise issue of recovery and recycling mobile phones, only one study has been performed until now. This study, the QWERTY study, was performed in 2004 in Sweden.

The study, using an eco-efficiency approach, examines the environmental effectiveness of several waste management scenarios**,** ranging from disposal in a landfill to direct insertion into a metal smelter. The study considers the environmental losses of each scenario, e.g., landfill of mobile phones, and/or environmental gains, e.g., recovery of metals[18]. In doing so, it takes into account the different environmental characteristics of the materials contained in mobile phones, and assigns an 'environmental weight' to each material, rather than just a physical weight. This approach, for example, places a high environmental value on the recovery of gold from waste, because it avoids the significant environmental damage of gold mining and production of gold from ore.[19] Thus, it views recovery of a small amount of gold from mobile phones as carrying greater environmental benefits than recovery of, for example, a larger amount of steel or plastic. After applying these 'environmental weights' the study then compares the overall environmental losses and gains of a waste management scenario with the economic costs and benefits of that scenario.

The QWERTY study comes to the conclusion that, for mobile phones, the direct smelter route is more eco-efficient than the other waste management scenarios that were examined. Specifically, this study concludes that manual disassembly of mobile phones does not return significant environmental benefit, and its costs outweigh the economic benefits that might otherwise be achieved through efficient metal recovery in a smelter. However, unlike the findings for manual disassembly, the study found that the difference in eco-efficiency between the direct smelter route and one involving mechanical pre-processing (using shredding, mechanical separation, and separate recycling of the derived materials) is not particularly great. In fact, the study indicates that as the precious metal content of mobile phones decreases in the future (as is generally expected), the difference in eco-efficiency of the direct smelter route versus mechanical pre-processing and separation is no longer expected to be significant.

The QWERTY eco-efficiency study is cited here as an example of a valuable approach that can be helpful to reaching conclusions on best practices for environmentally sound and economically efficient management. This study would not necessarily reach the same conclusion for other types of electronic waste, such as personal computers, with different disassembly costs, and different types and amounts of materials recovered. Each type of waste should be examined for its unique characteristics – economic and environmental – to determine the most eco-efficient manner of its management. Furthermore, the study did not examine every waste management scenario and the results of other studies will vary according to different

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[18] For details on the scenarios see appendix.

[19] For details see: J. Huisman, The QWERTY/EE concept, Quantifying recyclability and eco-efficiency for end-of-life treatment of consumer electronic products, Ph.D. thesis, ISBN 90-5155-017-0, Delft university of Technology, May 2003, Delft, The Netherlands.

circumstances, including the particular recycler and smelter practices that are examined. In this study, the practices of several specific Swedish recycling and recovery facilities were examined.

The QWERTY study was reviewed by Ökopol[20] , the German Institute for Environmental Strategies. The Ökopol review elaborates upon the limitations of the QWERTY study, including the fact that the QWERTY study examines only Swedish practices and conditions, rather than a more complete set of possible waste management scenarios. This critique also questions the lack of transparency regarding the cost data used in the QWERTY study (proprietary data for specific Swedish firms), as well as some of the economic calculations and data inputs.

4.8 Recommendations on Section 4

1. The General Facility Guidelines of Section 4.1 should be implemented by all pre-processing, smelting, refining and other processing facilities that are involved in any aspect of mobile phone material recovery and recycling.

2. If shredding is utilized, mobile phone batteries should be removed prior to shredding. Batteries should also be removed prior to any smelting or refining. Mobile phone batteries should be sent to an authorized battery recycler.

3. Where mobile phones or their components are shredded or heated, appropriate measures to protect workers, the general public and the environment from dusts and emissions are especially important. Such measures include adaptations in equipment design or operational practices, air flow controls, personal protective equipment for workers, pollution control equipment or a combination of these measures.

4. Companies capable of pre-processing, smelting, refining or performing other steps in mobile phone material recovery and recycling should identify themselves to their competent authorities. Competent authorities should inspect and verify that these companies are practicing environmentally sound management consistent with this guideline.

5. Mobile phone collectors and pre-processors should perform due diligence to assure that subsequent handlers and processors operate consistent with this guideline.

6. To assist Parties and others in performing inspections and due diligence audits based on this guideline, a new MPPI project should be initiated to create an audit checklist or similar tools.

7. Further eco-efficiency analyses should be performed to greater inform decision making by parties and other interested persons regarding optimal approaches for material recovery and recycling of end-of-life mobile phones. Recovery of some materials from waste and scrap, such as metals and especially precious metals, has been shown to provide significant savings in energy use and prevention of other adverse environmental consequences, compared to production of the same materials from ores and natural resources. Further eco-efficiency analyses should be performed to show how such savings can best be achieved through selection

[20] Qwerty and Eco-Efficiency analysis on cellular phone treatment in Sweden" September 2004, Knut Sander, Ökopol GmbH, Institute for Environmental Strategies, Nernstweg 32-34, D-22765 Hamburg, Germany

of recovery processes and prevention of losses of material in recovery from end-of-life mobile phones.

8. Because conformance with this guideline may mean an increase in recycling costs, Parties, industry and other interested persons should collaborate to ensure that there is adequate financing for mobile phone material recovery and recycling.

9. The material recovery and recycling phase of end-of-life mobile phones should be taken into account by manufacturers during product design, by considering the issues of increased recyclability, reduction in toxicity. (See the report of Project Group 4.1 for greater detail.)

10. Mobile phone manufacturers should collaborate to address the recyclability of plastics in mobile phones. Specifically, consideration should be given to greater consistency in material selection during the design stage for all mobile phones, which would allow plastics recyclers to eliminate sorting steps necessary to achieve compatibility of plastics types.

5. MATERIAL RECOVERY AND RECYCLING CAPACITY

The technology needed to recycle end-of-life mobile phones is specialised. There are a relative small number of smelters and refiners, both large and small, in the world that have specialised material handling equipment and pollution control systems that are appropriate for metal recovery from the handset (minus the battery). The building of new smelters and refiners would necessitate a great amount of investment. Furthermore, the annual recycling of mobile phones is estimated to provide not more than 65,000 tonnes worldwide, which raises the question of the relevance of the building of such facilities in most countries. Mobile phones are one type, among others, of electronic wastes and the quantity of all such electronic wastes may justify the building of additional smelting and refining capacity. However, we do not see such a need, in view of existing capacity.

Pre-processing capacity may be constructed where it does not exist, depending on the collection of mobile phones and domestic demand for such capacity. As with smelting and refining facilities, other end-of-life electronics may add to local demand for such processing capacity.

Because of the unlikely creation of pre-processing and smelting/refining facilities in every country, it will be necessary, in order to achieve environmentally sound management, that mobile phones, whether whole or pre-processed, that are intended for material recovery and recycling be exported by many countries to other countries where such facilities exist. Thus, regardless of whether or not mobile phones were to be considered hazardous waste, this transboundary movement is in conformity with the Basel Convention's Framework Document on the Preparation of Technical Guidelines for Environmentally Sound Management[21], which includes the following principles:

21 Basel Convention Website, Guidance Document for the Preparation of Technical Guidelines for the Environmental Sound Management of Wastes Subject to Basel Convention, www.basel.int/meetings/sbc/workdoc/framewk.htm.
See also Basel Convention Website, Basel Convention Technical Guidelines, www.basel.int/meetings/sbc/workdoc/old%20docs/guidelns.htm

- The **Self-sufficiency Principle** by which countries should ensure that the disposal of the waste generated within their territory is undertaken there by means which are compatible with environmentally sound management, ***recognizing that economically sound management of some wastes outside of national territories may also be environmentally sound***;

- The **Proximity Principle** by which the disposal of hazardous wastes must take place as close as possible to their point of generation, ***recognizing that economically and environmentally sound management of some wastes will be achieved at specialized facilities located at greater distances from the point of generation***;

- The **Least Transboundary Movement Principle** by which transboundary movements of hazardous wastes should be reduced to a minimum ***consistent with efficient and environmentally sound management***;

These principles recognize that transboundary movements may be made when economically sound, efficient, and environmentally sound material recovery and recycling takes place in other national territories, without regard to distance.

The guidance document recognizes as well "that the application and formulation of these principles will vary from country to country. It is also recognized that cost and economic efficiency are considerations in developing a waste management strategy".

5.1 Recommendations on Section 5

1. It is of utmost importance that in every country a sufficient infrastructure is put in place to collect end-of-life mobile phones and direct them to appropriate material recovery and recycling channels, taking into account the Guideline on Collection of Used and End-of-life Mobile Phones, developed by the MPPI Project Group 2.1.

6. PROPOSAL FOR ENVIRONMENTALLY SOUND MANAGEMENT (ESM) OF END-OF-LIFE MOBILE PHONES (MPs) IN THE RECYCLING PHASE TO DESIGNATED GOVERNMENTAL AUTHORITIES

In order to develop the ESM of end-of-life MPs by material recovery and recycling facilities, these need to operate within a regulated framework that establishes a balance between the necessity of ESM and economic efficiency. Parties should elaborate and implement policies and/or programs that ensure that competitive pressures do not encourage cost savings to the detriment of environmental and health protection. However, domestic policies and/or programs should not generate unnecessary economic burden to material recovery and recycling facilities.

Taking into account the size of the enterprise, the type and amount of waste, the nature of the operation, the regulatory infrastructure, Parties should:

1. develop appropriate governmental level legal requirements such as authorisations, licences, permits, or standards. The legal requirements should address facility operation, workers' health and safety, control of emission to air, land, water and waste management. The license

or permit should describe and authorise specific facility capacities, processes and potential exposures;

2. require that facilities operate according to best available technologies while taking into consideration the technical, operational and economic feasibility of doing so;
3. encourage information exchange between used MPs managers and authorities in order to optimise recovery operations;
4. move toward internalisation of environmental and human health costs in waste management;
5. encourage the development and implementation of an environmental liability regime for the material recovery and recycling facilities to prevent environmental damage;
6. require that facilities take appropriate measures to ensure workers' health and safety ;
7. recommend that material recovery and recycling facilities develop adequate monitoring, recording and reporting programmes;
8. encourage material recovery and recycling facilities to set up adequate employee training programs;
9. require that material recovery and recycling facilities have an adequate emergency plan;
10. require that material recovery and recycling facilities establish an appropriate plan for closure and after-care, ensuring the financial means for such closure.

6.1 Enhancement of use of international management systems (ISO 14000/EMAS)

In order to facilitate the integration of domestic environmental and health policies in the recovery facilities' management system, these should be certified by an independent ESM system, like ISO 14000 series, or by an equivalent system, such as the European Eco-Management Audit Scheme (EMAS).

With ISO 14000 series, an ESM system is defined as the part of the overall management system that includes: organisational structure; planning activities; responsibilities; practices; procedures; processes; and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.

ISO 14001 provides a management system framework and implementation guidance for addressing regulatory requirements and company policy. The structure of an ISO 14001 ESM system is based essentially on 5 stages: 1) environmental policy; 2) planning; 3) implementation and operation; 4) checking and corrective action; and, 5) management review.

While ISO 14000 series provides an efficient system for the management of facilities in an environmental perspective, it is important to note that the EMS system, under ISO, does not itself specify environmental performance criteria, such as limits upon exposure to substances of concern for environment or health. It only requires improvement and measurement of the system's capacity for higher performance and a commitment to achieve compliance with the applicable national regulatory framework. This stresses the necessity of a domestic regulatory framework that encourages ESM of recovery and recycling facilities since the international standards implemented by facilities base their environmental policies on the national regulatory requirements.

The Eco-Management and Audit Scheme (EMAS), like ISO 14000 series, is a management tool for companies and other organisations to improve their environmental performance[22]. EMAS, however, goes beyond the ISO 14001 requirements in topics such as external communication, audits, commitments and other requirements.

The scope of EMAS is also different from ISO 14000 series. Indeed whereas ISO 14001 is a worldwide standard, EMAS is a voluntary regulation that is applicable only to the organisations operating within the European Union and the European Economic Area (EEA). Parties contained in this area should encourage recovery facilities operating in their countries to use EMAS.

The implementation of ISO 14000 series or EMAS should generate both environmental and economic benefits to recovery and recycling facilities. First, it will improve the ability of the facility to comply with environmental legislation. Second, it will reduce the cost of facility operation through minimising use of materials, energy consumption, water consumption and other aspects. Third, reduced environmental risks can become financial benefits resulting from trust by shareholders, investors, insurance companies and financial institutions. Fourth, the ESM system will improve the efficiency of the activities of the recovery and recycling facilities. Fifth, the competitiveness of the facility will be maintained and/or increased by being able to respond to the growing demand of ESM requirements.

6.2 ESM system for pre-treatment facilities of end-of-life MPs:

The facilities integrated in the recycling chain of end-of-life MPs vary in their complexity. Shredding facilities and other pre-processing facilities are less sophisticated and generate less environmental and health risks than the copper smelting facilities. Their procedures for achieving certification/registration for international management systems such as ISO 14001 or EMAS should be simplified in comparison to copper smelting facilities. Indeed, regular audits may create a burden and impose heavy costs on pre-treatments facilities. These audits should thus be less complicated and may be carried out less frequently than at the copper smelting facilities, while being consistent with the need to maintain the ESM of waste.

6.3 Implementation of ESM regulatory framework for the recycling phase in developing countries and countries with economies in transition

Environmental policies tackling the issue of the material recovery and recycling phase of electronic wastes are still not much developed in most countries and specifically in developing countries and countries with economies in transition. These countries should be provided with the adequate capacity and the capability to implement such a regulatory framework. Article 16 of the Basel Convention requests the Secretariat of the Basel Convention (SBC) to compile specific information on sources of technical assistance, training, expertise and available technical and scientific know-how with a view to assisting requesting countries in many areas

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[22] Eco-Management and Audit Scheme (EMAS) Website, Executive Summary, www.europa.eu.int/comm/environment/emas/about/summary_en.htm

such as environmentally sound technologies related to waste or the strengthening of national institutions. The SBC provides assistance in the fields of law enforcement and capacity-building depending on each country's specific weaknesses and deficiencies that appear during the implementation of the national policies on hazardous wastes. The SBC could extend its role by including the topic of an ESM regulating framework in the material recovery and recycling phase of MPs in its program of work.

The implementation of ESM systems like ISO14000 could generate costs that could hardly be acceptable for facilities in developing countries and countries with economies in transition. In this context, the Regional and sub-regional centres of the Basel Convention could have an important role to play in order to encourage material recovery and recycling facilities to be certified by such management tools. The regional and sub-regional centres which provide training and technology transfer on the environmentally sound management of wastes are aimed primarily at strengthening the capacity of governments of the regions in complying with the technical requirements of the environmentally sound management of wastes. The centres of the Basel Convention have not yet tackled this issue of the ESM of used mobile phones including standards like ISO 14000 series. The centres could include this topic in their training and technology transfer. Pilot projects could be launched in specific Regional or sub-regional Centres chosen by the parties.

6.4 Recommendations on Section 6

1. Parties and signatories of the Basel Convention are encouraged to implement policies and/or programs which promote the environmentally and economically sound material recovery and recycling of end-of-life mobiles phones.

2. It is very important that end-of-life mobile phones be collected effectively (which is usually not the case today, even in industrialised countries), taking into consideration the Guideline on Collection of Used and End-of-Life Mobile Phones, developed by the MPPI Project Group 2.1. Environmentally sound material recovery and recycling of mobile phones requires setting up an effective recycling chain, comprising the steps of robust collection of used phones, testing/refurbishment/reuse if appropriate, preparing/dismantling of non-reusable phones or parts, and recycling of handsets and batteries.

3. Material recovery and recycling facilities should be certified through an independent environment management system, like ISO 14000 series and the European Eco-Management Audit Scheme (EMAS), or by an equivalent system. The procedures needed for pre-processing facilities to achieve certification/registration for international environmental sound management systems should be simplified.

4. Parties of the Basel Convention are encouraged to extend the role of the Regional Centers of the Basel Convention to develop training and technology transfer on environmentally sound material recovery and recycling of end-of-life mobile phones in order to help developing countries and countries with economies in transition implement regulatory frameworks for the environmentally sound management of end-of-life mobile phones.

Annex I

Summary of 2004 Swedish Eco-Efficiency Study

A recent study of recycling of end-of-life mobile phones (after removal of batteries) in Sweden in 2004 has concluded that their manual disassembly before metal recovery is not eco-efficient, because the added cost of such disassembly does not provide added environmental benefits.

This study, using an eco-efficiency approach, examines the environmental effectiveness of several waste management scenarios**,** ranging from disposal in a landfill to direct insertion into a metal smelter. The study considers the environmental losses of each scenario, e.g., landfill of mobile phones, and/or environmental gains, e.g., recovery of metals. In doing so, it takes into account the different environmental characteristics of the materials contained in mobile phones, and assigns an 'environmental weight' to each material, rather than just a physical weight. This approach, for example, places a high environmental value on the recovery of gold from waste, because it avoids the significant environmental damage of gold mining and production of gold from ore.[23] Thus, it views recovery of a small amount of gold from mobile phones as carrying greater environmental benefits than recovery of, for example, a larger amount of steel or plastic. After applying these 'environmental weights' the study then compares the overall environmental losses and gains of a waste management scenario with the economic costs and benefits of that scenario.

The following scenarios, based upon metal recovery processing data collected in Sweden, were investigated and compared:

> Baseline/Scenario 0: "MSW (100% landfill) = Disposal as Municipal Solid Waste"; Mobile phones are discarded by consumers as part of municipal solid waste stream, to landfill.
>
> Scenario 1: "No sorting route = Recycling in electronic waste stream, with shredding and material separation"; Mobile phones are recycled as part of general electronic waste (part of the IT and consumer electronics stream); all products are shredded and separated into four fractions – copper and precious metals, aluminum, iron and steel, and plastics – for separate recycling.
>
> Scenario 2: "Direct smelter route = Recycling with prior sorting from other electronic waste, and direct smelting without shredding and material separation"; Mobile phones are first sorted from other IT and consumer electronics, and then inserted directly (i.e. without prior shredding and material separation) into an integrated copper smelter for copper and precious metal recycling.

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[23] For details see: J. Huisman, The QWERTY/EE concept, Quantifying recyclability and eco-efficiency for end-of-life treatment of consumer electronic products, Ph.D. thesis, ISBN 90-5155-017-0, Delft university of Technology, May 2003, Delft, The Netherlands.

Scenario 3: "Disassembly route = Disassembly to remove circuit boards, with prior sorting from other electronics"; Mobile phones are manually disassembled to remove circuit boards for copper and precious metal recycling, and remainder of material is shredded and separated into aluminum, iron and steel, and plastics, for separate recycling processing.

Scenario 4: "Plastic recycling housing = Disassembly to remove plastic housing and circuit boards, with prior sorting from other electronics ;" Mobile phones are manually disassembled to remove plastic cases for plastics recycling, and circuit boards for copper and precious metal recycling. The remainder of material is shredded and separated into copper, aluminum, iron and steel, and plastics – for separate recycling processing.

The results of the analysis are shown in figure 2.

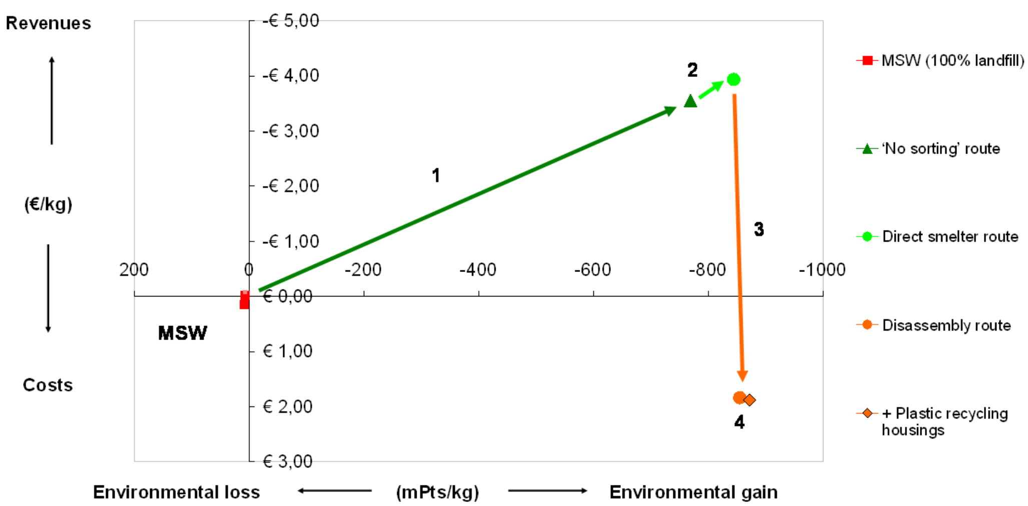

Figure 2: Eco-efficiency graph for four cellular phone recycling scenarios, 'average mix'.

The graphic can be interpreted as follows:

- Scenario 0: Disposal in municipal solid waste (MSW) landfill leads to some environmental loss, and relatively low costs.

- Scenarios 1 and 2 : Both recycling and metal recovery scenarios (shown on the green arrows) offer a significant economic gain from sale of recovered metals, and a significant environmental gain from avoided disposal and avoided new production from ores. The direct smelter route (scenario 2) is somewhat more favourable for mobile phones than shredding and separation (scenario 1), because net revenues are slightly higher (due to a better recovery of precious metals and less pre-processing costs) and the environmental gain is also higher (due to better recovery of materials with a high environmental weight). There are, of course, added costs to separate mobile phones (scenario 2) from other electronic waste (scenario 1), but the extra value recovered by this measure slightly outweighs the extra costs.

- Scenarios 3 and 4: Manual disassembly of mobile phones before metal recovery (shown on amber arrows) will achieve only a slightly better environmental gain, and its high costs completely outweigh the potential revenues from sale of recovered metals. The removal and recycling of plastic cases from mobile phones, which might facilitate their recycling as plastic, does not generate any significant revenue to offset the costs.

This study comes to the conclusion that, for mobile phones, the direct metal processing (scenario 2) is more eco-efficient than the other waste management scenarios that were examined.

Annex II

Glossary of Terms

Note: *These terms were developed for the purpose of the overall Guidance Document and individual project guidelines, and should not be considered as being legally binding, or that these terms have been agreed to internationally. Their purpose is to assist readers to better understand this Guideline and the overall Guidance Document. The processes of dismantling, refurbishment or reconditioning and repairing may entail the removal of batteries, electronic components, printed wiring boards or other items which should be managed in an environmentally sound manner and in accordance with the Basel Convention when destined for transboundary movement.*

Basel Convention: UNEP's Convention of March 22, 1989 on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, which came into force in 1992.

Components: parts or items removed from used mobile phones which may include batteries, electronic components, circuit boards, keyboards, displays, housing or other parts or items

DfE: Design for Environment; meaning a product has been designed to reduce environmental impact throughout its whole life cycle.

Dismantling: (manual) separation of components/constituents in a way, that recycling, refurbishment or reuse is possible.

Disposal: means any operations specified in Annex IV of the Basel Convention.

EMC: Electromagnetic compatibility (EMC) means the ability of equipment to function satisfactorily in its electromagnetic environment without either introducing intolerable electromagnetic disturbances to other equipment in that environment, or being adversely affected by the emission of other electrical equipment.

EMF: Electromagnetic Fields (EMF) are a combination of both electric and magnetic fields. EMF occurs naturally (light is a natural form of EMF) as well as a result of human invention. Nearly all electrical and electronic devices emit some type of EMF. Safety standards are applicable, but these may vary from country to country.

Eco-efficiency: producing economically valuable goods and services with less energy and fewer resources while reducing the environmental impact (less waste and less pollution) of their production. In other words eco-efficiency means producing more with less. It may include, for example, producing goods through recycling when that is more efficient, and more environmentally friendly, than production of the same goods with primary resources and methods.

End-of-life mobile phone: a mobile phone that is no longer suitable for use, and which is intended for disassembly and recovery of spare parts or is destined for material recovery and recycling or final disposal. It also includes off-specification mobile phones which have been sent for material recovery and recycling or final disposal

Environmentally Sound management: taking all practicable steps to ensure that used and/or end-of-life products, or wastes are managed in a manner which will protect human health and the environment.

Evaluation: the process by which collected used mobile phones are assessed to determine whether or not they are likely to be suitable for re-use. This assessment may include:
a) A visual check
b) A 'power-on' check
c) A check that the model is included / not included on a list of handsets provided by the refurbishment company.

Hydrometallurgical processing: processing of metals in cyanide, and/or strong acids such as aqua regia, nitric acid, sulphuric acid, and hydrochloric acid.

Incineration: a thermal treatment technology by which municipal wastes, industrial wastes, sludges or residues are burned or destroyed at temperatures ranging from 1000*C to more than 1200*C (high temperature incineration used mainly to incinerate hazardous wastes) in the presence of oxygen resulting from the rapid oxidation of substances. Most of them have an air pollution control equipment to ensure the emission levels meet the requirements prescribed by the regulatory authorities.

Integrated copper smelter: a facility, or related facilities in the same country under the same ownership and control, that melts metal concentrates and complex secondary materials that contain - among others - copper and precious metals, using controlled, multi-step processes to recycle and refine copper, precious metals and multiple other metals from managed product streams.

Labelling: the process by which individual or batches of mobile phones are marked to designate their status according to the guideline developed under the project 2.1.

Landfilling: the placement of waste in, or on top of ground containments, which is then generally covered with soil. Engineered landfills are disposal sites which are selected and designed to minimize the chance of release of hazardous substances into the environment.

Leachate: contaminated water or liquids resulting from the contact of rain, surface and ground waters with waste in a landfill.

Life cycle management: holistic way to consider the environmental issues associated with a substance, product or process from resource utilization, through manufacture, transportation, distribution, use, to waste management and disposal of residues from treatment or recycling operations.

Material Recovery: means relevant operations specified in Annex IVB of the Basel Convention.

Mechanical Separation: mechanical means to separate a mobile phone into various components or materials.

Mobile phone (sometimes called a cellular phone or cell phone): portable terminal equipment used for communication and connecting to a fixed telecommunications network via a radio interface (taken from International Telecommunication Union K.49 (00), 3.1). Modern mobile phones can receive, transmit and store: voice, data, and video.

Printed wiring board: also called a printed circuit board, consisting of integrated chips, resistors, capacitors and wires.

Pyrometallurgical processing: thermal processing of metals and ores, including roasting and smelting, remelting and refining.

RoHS: Directive of the European Parliament and the Council on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment.

RF: describes electromagnetic energy transmitted through radio and microwaves.

Recycling: means relevant operations specified in Annex IVB of the Basel Convention.

Refurbishment or Reconditioning: the process for creating a refurbished or reconditioned mobile phone.

Refurbished or reconditioned mobile phone: a mobile phone that has undergone refurbishment or reconditioning, returning it to a satisfactory working condition fully functional for its intended reuse and meeting applicable technical performance standards and regulatory requirements including the original product's rated operational characteristics. The intended reuse must include full telephony capability.

Repairing: a process of only fixing a specified fault or series of faults in a mobile phone.

Reuse: a process of using again a used mobile phone or a functional component from a used mobile phone, possibly after repair, refurbishment or upgrading.

SAR: stands for Specific Absorption Rate, which is the amount of Radio Frequency (RF) absorbed by the body. The unit of measurement is in Watts per Kilogram (W/Kg). SAR is determined, in laboratory conditions, at the highest certified power level of the mobile phone. When in use, the actual SAR can be well below this value due to automatic power control by the mobile phone. The SAR of each model of mobile phone is measured as part of the safety standard compliance process.

Segregation: sorting out mobile phones from other (electronic) wastes for possible reuse or for treatment in specific recycling processes.

Separation: removing certain components/constituents (e.g. batteries) or materials from a mobile phone by manual or mechanical means.

Transport of Dangerous Goods: UN Recommendations on the transport of dangerous goods which deals with classification, placarding, labeling, record keeping, etc. to protect public safety during transportation.

Treatment: means any activity after the end-of-life mobile phone has been handed over to a facility for disassembly, shredding, recovery, recycling or preparation for disposal.

Upgrading: the process by which used mobile phones are modified by the addition of the latest software or hardware.

Used Mobile Phone: a mobile phone, which its owner does not intend to use it any longer.

WEEE Directive: Directive of the European Parliament and the Council on Waste Electrical and Electronic Equipment.

Wastes: substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.