Evaluation Of End-Of-Life Treatment Alternatives for Electronic Waste by Means of Material Characterization of Mobile Phones

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Abstract

Recycling is an alternative to decrease the amount of electronic scraps produced from the final life cycle of electronic appliances, such as mobile phones. This work analyses different mobile phones regarding polymers in mobile phone housings and metals, i.e., Cu, Au, Ag and Sn in the printed circuit boards (PCBs). The preliminary results indicate significant differences in metal concentrations in PCBs. Housings are composed mainly of polycarbonate (PC) and polycarbonate blends (PC/ABS).

Keywords: Environmental Impact, products life cycle assessment, electronic scraps, materials characterization, recycling

1. INTRODUCTON

With R-$ 63,2 Billion in total revenue, US-$ 4,7 Billion in export volume, a workforce of 121.000 in 2003, and an expected revenue growth of 13% in 2004 [1], the development, production and sale of Electric and Electronic Equipment (EEE) in Brazil has developed into one of the key (export) industries. At the same time, current management practices and the increasing standard of living in Brasil and other industrialized countries cause a steady increase of resource consumption. As a result the ecological limits might be exceeded and resources might be exploited [2]. A higher standard of living must not be achieved by proportional growth in resource consumption because of ecological limits. Resource and energy consumption have to be reduced to reach and maintain a high standard of living for everyone. Increasing the use-productivity of resources enables a higher global standard of living for more people with lower resource consumption. The ecological impact of EEE, when not treated with care after its use phase, and the economic loss involved by ignoring the potentials of a cycle economy for EEE are immense. In Europe alone, 8 Mio. tons of EEE are being disposed every year. As an example, the number of obsolete cellular phones worldwide is already estimated to be above 500 Mio. and increasing rapidly. Land filled or incinerated cellular telephones create the potential for release of heavy metals or halocarbon materials from batteries, printed circuit boards, liquid crystal displays, plastic housings or wiring [3].

Cycle economy in the areas of packaging materials, end-of-life vehicles, and EEE - to name only the most recent - has already evolved into an integral part of society and legislation in Australia, the European Union (EU), the United States (US) or Asian countries such as Korea and Japan. Also, it has added and will continue to add to the formation of new business opportunities in recycling, reuse or remanufacturing creating new qualified employment and reducing the cost of materials employed in the production process. Material or thermal recycling of EEE reduces the overall need for exploration of virgin materials, such as steel or aluminium, fuels, precious materials such as gold or silver as well as toxic materials, e.g. cadmium, mercury, lead or bismuth required for the production of most electric elements on printed circuit boards. Besides recycling, the reuse and remanufacturing of products or components can be an even more ecologic and economic option for a cycle economy, when offer and demand for used EEE correspond to each other. EEE such as brand name computers, cellular phones, toner cartridges or single use

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1 **RESULTS AND DISCUSSION**

Grouping systematic

Generally, "Candy Bar" cell phones consist of a front and back base, where most of the components are placed, as printed circuit boards (PCB), display (LDC), microphone and speakers, which are of interest for remanufacturing and reuse. In the modem models, the components are placed in the upper part of the PCB, but in the older models, the components are connected to the PCB through friction between the interfaces of the components.

Modem equipment PCB contain most of the precious metals, that as opposed to older models, have less.

cameras are already successfully being remanufactured [4].

Today, adequate take back or treatment systems for EEE are not in place in Brazil. EU members states like Sweden or the Netherlands implemented take back obligations including EEE. Germany laid the basis for a sustainable cycle economy in 1996 with the "Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal" [5]. A EU-wide standardization regarding the treatment of EEE, i.e. the directive for "Waste of Electric and Electronic Equipment" (WEEE), was published in 2003 and shall be implemented into national law by 2004 in most EU member states [6]. In Germany, by the end of 2005, Original Equipment Manufacturers (OEMs), importers and first marketers will be required to take back obsolete EEE and treat them professionally, i.e. appropriate reuse, recycling or disposal, according to the WEEE. In Brasil, a rather short declaration on how EEE (technological waste) shall be treated in the future was published in 1998, without specifying in detail or making suggestion of how implementation will take place [7].

According to Anatel (2004) the quantity of mobile phones grows from 667 in 1990 to more than 50 Mio. in 2004 (Figure 1).

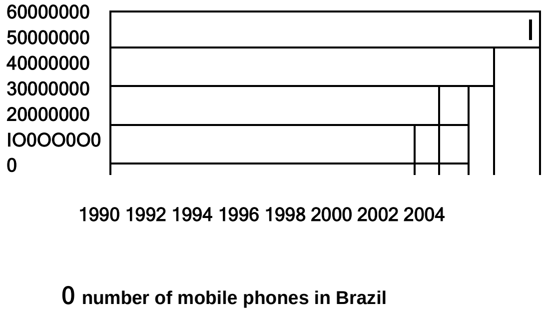

Figure 1: Mobile phones in Brasil (ANATEL, 2004) [8]

Therefore, to know the material cellulars are made of is fundamental to help in the decision process in order to carry out recycling and to determine environmental and economical earnings. Thus, the objective of this work is to pre evaluate equipment of mobile cellular phones by means of characterizing the material involved in the main components, keeping in mind its recycling.

2. METHODS AND MATERIAL

In the mid-nineties the precious metals content of a standard PC printed circuit board was large enough to allow very profitable electronics scrap recycling. Depending on the type of board, platinum, palladium, gold and silver could be extracted in high quantity to make even small-scale computer circuit board recycling lucrative. Yet, PC industry manufacturing changes over the last decade have gradually reduced the use of precious metals in printed circuit boards. In many cases, the computer industry has reduced use of precious metals by over 90%. Today, product recovery alternatives such as the reuse of components and the remanufacturing of products have developed into profitable niche markets.
Products used in electronics containing gold are bonding wire, electroplating salts, sputtering targets, solder alloys, or thick film pastes, and are used for electrical contacts and connectors, soldered joints, solderable surface coatings for PCBs and leads, bonding wires, or hybrid circuits. The economical and ecological feasibility of refining gold from metals obtained from printed circuit boards (PCBs) depends primarily on the refining method applied and the quantity of gold in the metal. This paper presents the material analysis conducted for different generations of mobile phones, to determine their characteristic material compositions, as they might have an influence on the decision on whether or not separate treatment of PCBs obtained from different mobile phones and other electronic waste are economically justifiable or not. The results can be applied to support the decision on treatment alternatives, i.e., the determination of when material recycling becomes economically advantageous compared to remanufacturing.

Collection

The used equipment in this work were obtained from different cell phone retail stores in the city of São Carlos in the Brazilian state of São Paulo. 12 apparatus of different brands and models were used, all of them originating from six manufacturers. The equipment that was evaluated differs in generation and technology.

Evaluation of Product Variation

The mobile phone market has a large variety of models, taking into account characteristics with different types of software and configurations. There are 1800 variations in the market. Nevertheless, even when reducing the brands and models, the range of variations is still significant, 600. Therefore, the cell phones are grouped according to their more relevant characteristics, based on analysis and component disassembly of different brands. Figure 2 shows grouping systematics of the apparatus, according to "Candy Bar" and "Flip" types.

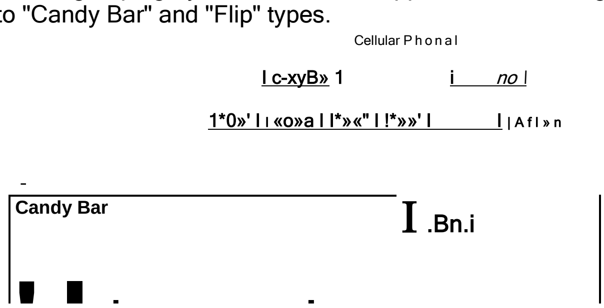

Figure 2: Types of cell phones and product structure [9].

All equipment was manually disassembled to obtain separatedly the electronic boards, parts and housings. All stages in process (A-E) are exemplified in the model used, according to Figure 3.

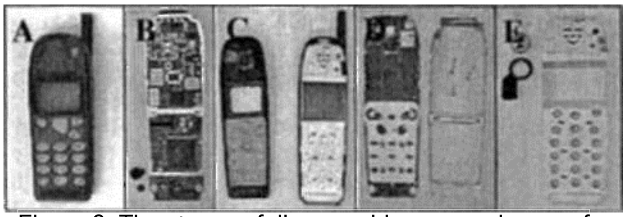

Figure 3: The stages of disassembly process in one of the models used.

Extraction process

The electronic boards were cut in pieces that varied from 0.5 to 1.0 cm. The material cut was submitted to an extraction process in a hydrochloric acid and nitric acid. The mixture 3:1 of hydrochloric acid and nitric acid, called aqua regia, was used to dissolve the metals [11,12] acid mixture for 24 hours. After this period, sample dilutions were carried out to determine contents of metals by ICP-OES. For determinations, an optic emission spectrometer by plasma induced (Varian, Vista) was used.

Thus, a second characteristic used to group the equipment is age.

The cell phones that present flip have a complex structure because they are formed by four compartments, an upper and lower one for LCD and two more for PCB and other components, making dismounting and reassembly difficult when trying to remanufacture the equipment.

Cell phones of a same brand usually present a similar structure, generally with standard components (speakers, microphones and LCDs).

Content determination of Cu. Sn. Au and Aq.

In Table I the values obtained for Cu, Sn, Au and Ag originating from electronic board extractions are shown. Values are expressed in % (m/m).

samples

Sample	Element			
	Cu	Sn	Au	Ag
1	16.28	1.67	< 0.0018*	0.025
2	15.96	1.50	< 0.0018*	0.034
3	40.61	5.33	0.0067	0.045
4	31.88	4.82	0.0028	0.058
5	14.92	4.03	< 0.0018*	0.063
6	13.61	5.17	< 0.0018*	0.041
7	13.13	4.31	0.0047	0.040
8	34.17	2.58	0.0029	0.033
9	27.2	4.05	0.0034	0.058
10	23.03	3.56	0.0088	0.087
11	24.00	1.56	0.0018	0.026
12	27.34	3.82	< 0.0018*	0.055

(*) the sign "<" shows a lesser value than the limit of instrumental

Table I. Result of chemical analysis for evaluated

Identification of polymers of the **framework** of equipment.

The identification of polymers of the housings was done by data obtained through FT-IR. These results are shown in Table II.

Table II. Results of FT-IR for evaluated samples.

Sample	Polymer2
1	PC/ABS Blend PC/ABS Blend PC/ABS Blend PC
2	PC/ABS Blend PC/ABS Blend PC/ABS Blend PC/ABS
3	Blend PC
4	PS/PPO Blend PC/ABS Blend PC

5 4. **CONCLUSIONS**

6 The results which are presented indicate that the
7 equipment have differentiated characteristics in relation
8 to its conception. This is due to different projects that
9 each manufacturer has, as well as technological development over the years. ICP-OES data show small
1 variations in the concentration of the elements evaluated. FT-IR data show that housings are basically
0 made of polycarbonate (PC) and polycarbonate
1

acrylonitrile-butadiene-styrene (PC/ABS) blends. World-wide trends of product administration of life cycle represent, at the same time, challenges and opportunities. Besides environmental aspects, life cycle economy also contains economical aspects, with post-use administration representing a new business opportunity. Within this context, recycling of materials used in the manufacturing of mobile phones appears to be a feasible alternative, environmentally as well as economically. Complementary studies ought to be achieved in order to verify the possibility for the recycling of the main components that constitute mobile phone equipment.

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2(PC) polycarbonate; (ABS) acrylonitrile-butadiene-styrene; (PS) polystyrene; (PPO) polyphenylene oxide. The spectra were obtained in an infrared spectrometer with transformed Fourier - FT-IR (Magna 550, Nicolet).

5. ACKNOWLEDGMENT

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