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Printed circuit boards: its characteristics and its potential for recycling

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ABSTRACT

The changes happened in recent decades have allowed technological advances invade our daily lives and significantly increase the consumption of Electrical and Electronic Equipment (EEE). With the life cycle reduced increasingly the related products have been calling attention to an environmental problem, characterized by increasing the volume of such waste, intensified by improper discard. This paper has for aim to study the components of the printed circuit board (PCB) considering the heavy metals that compose it, its damages to the environment and man. The PCIs have an average of seventeen metals, highlighting the precious metals that can be used recycling methods. Among the forms of recycling the mechanical process is form less aggressive to the environment and to humans by producing less pollutant wastes. Environmental perspective recycling of printed circuit boards is an important option to reduce the extraction of natural resources, but the informal recycling carried out by associations of collectors, often do not have any kind of assistance or supervision.

Keywords:, equipments electronics, métaux lourds, computers

INTRODUCTION

The changes happened in recent decades have allowed technological advances invaded our daily lives and significantly increase the consumption of Electrical and Electronic Equipment (EEE). The EEE have a diversity, from large appliances to small information and communication technology equipment (ABINEE, 2015).

To Lima and Maia (2015), successive capitalism technological revolutions resulted in exploitation of natural resources on a large scale since the logic of the market economy leads to parasitism in the economy and the depletion of natural resources on the inability ecosystems to assimilate the impacts of economic expansion.

The Brazilian Association of Technical Standards (ABNT) defines EEE:

> Equipment and parts whose appropriate functioning is dependent on electric currents or electromagnetic fields, as well as equipment for the generation, transmission, processing and measurement of such currents and fields and may be of domestic, industrial, commercial and services use. (ABNT, 2013, p. 3).

The life cycle increasingly shorter products related to information and communication technology has been drawing attention to an environmental problem, characterized by a significant increase in the volume of such waste, intensified by improper discard when terminating the useful life of the equipment. GERBASE (2012) defines electronic wastes (WEEE), as electronics waste which consists of appliances, computers, radios, televisions, cell phones and other goods that are damaged, obsolete or broken.

In Brazil, Law 12.305 of 2 August 2010 establishing the National Policy on Solid Wastes (PNRS), deals with the principles, objectives and instruments as well as the guidelines for management and solid wastes management, involving and assigning responsibilities to all the productive chain and the public authorities (BRAZIL, 2010).

The PNRS art. 33, section VI, which deals specifically with electronic products and components, has the obligation to logistic reserve system implementation by return of products after use by consumers independently of the public service of urban cleaning and management of solid wastes, for manufacturers, importers, distributors and traders (BRAZIL, 2010). It is important to mention that electronics products are considered consumer goods, property you bought them. Thus, the disposal of wastes after consumption depends on the action of the possessor of good.

Many challenges can be minimized when considering the implementation of reverse logistic from a broader view of the participation of various social actors. The PNRS exactly proposes that way to recognize the shared responsibility for the product life cycle, which makes it important the fact that the solutions arising from cooperative systems, involving, in addition to companies and cooperatives, the government and trade (DEMAJOROVIC, J.; LIMA, M. 2013).

According to Lima and Maia (2015), Law 12.305 / 2010 defends reverse logistics, through an integrated solid wastes management can minimize the environmental impacts generated by the contradictions that exist in the capitalist mode of production as the decrease in life cycle products, especially electronics, and improper discard of these. Despite being referred to as shared responsibility, (MOREIRA, 2011) highlights the importance of defining who is the "polluter-that-must-pay".

As Brandão and Oliveira (2012), the principle of polluter payer has fundamental application on shared responsibility, considering that polluters should bear with costs of prevention, repair and prosecution of environmental damages, which now fall on society in general.

The rules NBR / ABNT 16156/2013 establishes the requirements for environmental protection and control of security risks and health in the job reverse manufacturing activity of electronic wastes (ABNT, 2013).

The state of Pernambuco was the forerunner in the regulation of tax incentives for the management of technological wastes. Law 15,084 of September 2013, regulates the mandatory implementation of WEEE collection posts (batteries and small size electronics) from commercial establishments in the state, under penalty of application fines (PERNAMBUCO, 2013).

The emergence of new technologies has added most often a high impactful value, this is caused by the increasing consumption of electronic equipments and waste generation, stimulated by obsolescence, the life cycle programmed of products that are potentially toxic and polluting, can prove as a socio-environmental problem and compromise the quality of the environment and human health. Santos (2015) defines obsolescence as a widely used strategy by the industries, so there is a decrease in the life cycle of products, with the intention to be replaced by more technologically advanced product, be increasing factor in the consumption of electronic equipments and generation of WEEE.

This paper has for aim to study the components of the printed circuit board lifted into account the heavy metals that compose it, its damages to the environment and man.

The theoretical framework was developed through literature review, a survey of secondary data by reading dissertations, scientific articles, books, laws, documents about the content involving electronic wastes and pollution caused by heavy metals.

REVIEW

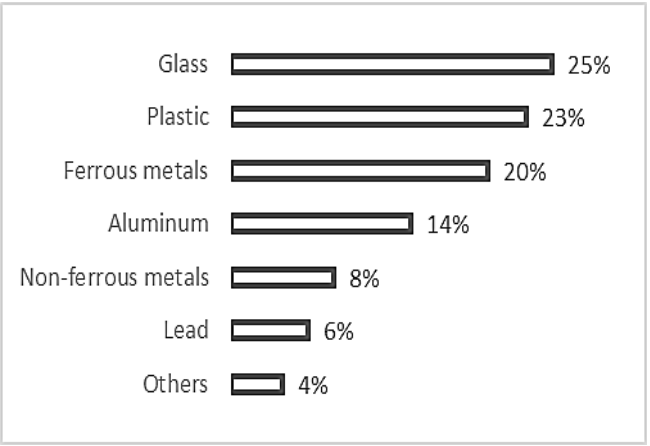
1. Electronics Wastes

WEEE have a varied composition may contain more than a thousand different substances, including hazardous and non-hazardous elements. Overall, they have in their constitution: iron, nonferrous metals, plastics, glass, printed circuit boards, ceramics, rubbers, etc. (PORTO DIGITAL, 2011).

Particularly the computers, this research object, contains substances in its physical structure (Figure 1) that take a long time to decompose, such as plastic, glass, heavy metals that are extremely harmful to human health and the environment. Improper disposal of wastes causes beyond the contamination of soil, water pollution and air.

Water pollution occurs by natural phenomena such as leaching, percolation, entrainment, etc. (SANTOS, 2015). In soil, physical properties may accelerate or make these slower processes, but do not prevent the infection from occurring. In the air pollution, there is waste gases and particles emitted into the atmosphere from the various segments man performs some activity that can be characterized by production wastes (SANTOS, 2015).

Figure 1 - Main items in the composition of a desktop computer of approximately 27kg Source: VIRGENS (2009).



According Rocha et al. (2015), demographic growth and consumption patterns have contributed in increasing the volume of waste generated, which implies challenges for proper management. Environmental vision has been attributed great importance in the generation of WEEE to computers by the speed spread of nd the speed with which they become obsolete. Between 2009 and 2013, about 71.0 million computers (desktop and notebook) were sold, representing an average growth rate of around 4.9 per year (ABINEE, 2014). Consequently this increase was batting on disposal of such equipment, which can be done in the environment or not, depending on the administration and management of same.

According to PNRS and its National Policy on Solid Wastes, Law 12,305 / 10, the requirements of environmentally appropriated destination and shared responsibility of WEEE are points to guide the generators and indicate them of the importance of good management. However, the need to find a suitable area has been one of several current problems.

Various techniques have been used for the treatment of electronic scraps in order to reduce the bulk of the wastes. Researches are also being developed with a view to final disposal in a manner that minimizes the provision of the constituent metals by chemical leaching process or by microbiological action (SANTOS, 2010).

All pollution brings an environmental cost to society, thus bringing the need for investment in technology, remedial action and / or other mechanisms (LIMA, MAIA, 2015).

Law No. 6.938 / 1981, which provides about the National Environmental Policy provides the polluter-pays principle in its art. 4th item VII aims:

> The imposition, the polluter and the predator, the obligation to recover and / or indemnify the caused damage and the user, the contribution by the use of environmental resources for economic purposes (BRAZIL, 1981).

2. Characterization of Circuit Boards

The printed circuit boards (PCBs) constitute an essential and typical component for almost all electronic products (BARROS, 2012). The base of the PCB is called laminate, formed of layers of plastics and fibrous materials which may have different compositions, for example: phenolite, fiberglass, polyester fiber and film, among other polymers. The laminate is covered with a thin film of metallic substances (copper, silver, gold or nickel) on which electronic components are mounted. The connections between the components occur on the side coated with copper via conductor paths (GERBASE 2012).

The PCBs have an average of seventeen metals (GONÇALVES, 2015), in these are present, precious metals which are used recycling methods. Silver and gold, for example are those with the greatest recyclability index, 98% and 99% respectively, which underscores the importance of the process of recycling of computers for the recovery of high-value economic elements (XAVIER, 2014).

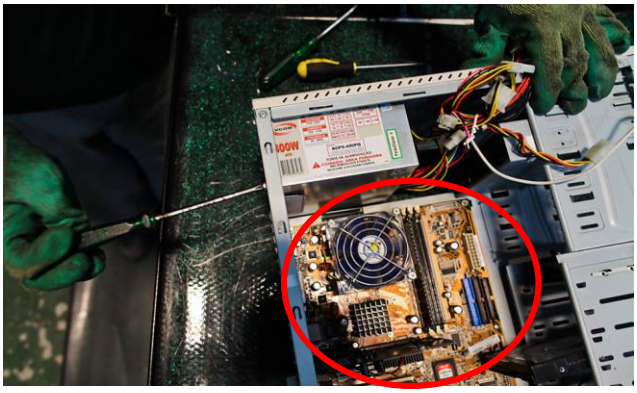
Besides heavy metals, in the PCB composition there is a large amount of brominated compounds are used as flame retardants for fire prevention, amount of bromine presented by these components ranges from 5 to 15%. The retardant materials flame are precursors of dibenzo-p-dioxins polybrominated and dibenzofurans, are classified as persistent organic pollutants (SANTOS, 2010).

The incineration flame retardant compounds, plastic and resins without any prior treatment, can form byproducts such as dioxins, furans and polybrominated organic pollutants and polycyclic aromatic hydrocarbons. Thus, accumulate environmental damage related to WEEE (HUANG, GUO & XU, 2009 apud SANTOS, 2010).

PCB's recycling processes can be: mechanical, chemical or thermal. The main processes are mechanical (sanction, classification and separation), pyrometallurgical, hydrometallurgical, electrometallurgical and biometallúrgical (GERBASE, 2012). First, the mechanical process is most widely used in Brazil at low cost, it can be considered a pretreatment in order to separate previously metals, polymeric materials and ceramic (Table 1). This form of recycling is less aggressive to the environment and humans to produce less polluting wastes. Even with these technologies well-established in the recycling of relatively pure metals, recycling of metals from WEEE is difficult, due to its complexity, composition and presence of toxic materials, complicates the process (SANTOS, 2015).

The environmental problems caused of mining activity are numerous, especially those related to the extraction of precious metals, which are taken from mines where the amount is low (UNEB 2009 apud XAVIER, 2013)

Figure 2 – Stage table-computer disassembly for recycling of printed circuit board (PCB). Source: SANTOS (2010).



A simple comparison is possible to observe the gains from recycling, 1 kg of aluminum by recycling, it is used 1/10 of the energy needed for primary production of that metal, in addition to preventing the generation of wastes as bauxite, CO_2 emission and SO_2 emissions (UNEP & UNU, 2009 apud XAVIER, 2014).

Broadly, the concentration of contaminants in WEEE depends on some factors such as: type of waste, manufacturing date, amount of processed wastes and the chosen method for the recovery of metals (SANTOS, 2015). The major heavy metals which make up the PCB computers are mercury, lead, cadmium and arsenic that are highly toxic (GERBASE, 2012). Heavy metals related to WEEE are fat soluble and are concentrated in the bones, blood and tissues of organisms, causing numerous diseases (AQUINO, 2015).

In contact with the environment heavy metals are potentially impactful. According ABDI (2013), WEEE same landfilled, the simple touch of heavy metals in the water causes immediate contamination, penetrating the soil, this material may contaminate groundwater or accumulate in living organisms, with negative consequences to the environment as a whole.

Table 1 - Mechanical separation processes based on the electrical characteristics of materials. Source: (Cui and Forssberg, 2003).

Process	Separation criteria	Separation principles
Separation by swirling current (Eddy's currents)	Electrical conductivity and density	Repulsion forces exerted on the electrically conductive particles due to interaction between the alternative magnetic field and Eddy's currents induced by the magnetic field (Lorentz force)
Corona electrostatic	Electrical conductivity	The corona charge and discharge differentiated

separation type		entail differents particle loadings and this in action of different forces (particularly, strength image)
Triboelectric separation	Dielectric constant	The tribe loads with different charges (+ or -) of the components cause force directions differents.

Human health when not have due care in the discard and especially the handling is quite fragile. Normally, no use of Personal Protective Equipment (PPE), adequate training and inadequate technologies are the great villains. A work developed by Trombini (2013) with artisans of WEEE particularly use PCBs, shows the ignorance of the risks they are exposed to neglect it with the handling with the recommendations for use of PPE. The research shows that only 4% claim to adopt some measure of protection as wearing gloves, masks and / or goggles during work handling of WEEE (TROMBINI, 2013).

Direct contact with heavy metals during the WEEE dismantling step results in skin absorption and possible contamination bioaccumulation in the body. When burned, it causes the release of toxic materials in the atmosphere and in this case, contamination occurs by inhalation of toxic agents (Xavier, 2014).

Discarded in the trash, WEEE cause different impacts to ecosystems and human health (SANTOS, 2015). When the poisoning is caused by toxic agents the body can be subjected to treatment for detoxification, much of the metal contamination cannot be removed, causing immediate damage or long-term. Thus, the use of protective equipment can minimize or eliminate the impacts of destination (reuse, recycling, etc.) or final discard (landfill and incineration), post-consumer equipment (XAVIER, 2014).

The large increase in the amount of substances that are constantly being released into the environment, causing a change in the environmental balance and as a consequence of this fact and the matter and energy conservation principle is the accumulation of matter or energy in systems, generating a contamination extending in time and space (SISINNO, 2013).

According Santos (2015) heavy metals dependent on certain conditions to have mobility, bioavailability and toxicity, such conditions refers to hydrogenionic potential (pH) of the water and soil, redox potential, matrix components and organic matter. For Barrocas (2013) some metals are classified even as global pollutants (p. Eg. Lead, mercury) because of its ubiquitous presence in the biosphere, even away from any natural sources or anthropogenic.

The extraction of metals from electronic wastes equipment can be a big deal in Brazil due to increasing consumption of EEA, however, the cost of extraction still favors that the materials extracted from nature and recycling is less important for the industry Brazilian.

Recycling is an important option especially in environmental perspective, to reduce the extraction of natural resources, but the informal recycling carried out by associations of collectors, often do not have any kind of assistance or supervision. And ignorance of the danger in handling of WEEE waste pickers are exposed of various health damage. Through the survey of secondary data, you can analyze the composition of the wastes and noted that the heavy metals are the most harmful for its

perpetuation in the life cycle in the body contaminated due to its bioaccumulative effect.

The printed circuit boards are always target the interests of associations of collectors and recyclers for it is a material is practically in almost all electronic equipment and contain precious metals. But it takes attention when the form of recycling is the same technology that may perchance generate large environmental liabilities.

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