Electronic waste as coating for construction industry

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ABSTRACT: Electronic waste is a growing problem, as the production increases, also the waste grows. The e-waste is composed of hazardous materials and metals, as copper, iron, gold, aluminum, lead and others. A component that is massively present on electronic waste is the Printed Circuit Board (PCB), which is fundamental for any electronic device. Despite the danger that electronic waste brings with it, there is a large possibility of recycling, which could solve the problem of discard and creates a new raw material for another industry. Civil construction is an area that can incorporate several materials of another branch of industry, because of its multidisciplinarity. Knowing that PCB are present in large scale at the e-waste, this study has the main objective of evaluating the feasibility of use of printed circuit boards as raw material for coating in construction, which is a market that already uses coatings in board form, so, creating a product that uses recycled raw material and has a green design, can increase the market of coating and attract the public. As the main method for this study, as well as bibliographic research , it uses the dismantling of printed circuit boards and evaluation of materials associated with the board for its performance as a coating material in construction. At this stage, different recycled polymers are analyzed as a possibility for incorporation into the product. This material has the market needs, in association with recycling and innovating design, which is an alternative for e-waste, as well for construction industry.

Keywords *e-waste, recycling, coating, printed circuit board, sustainability*

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1. INTRODUCTION

The industrial activity ally with the lack of efficient waste management processes causes a discard without a proper use or disposition of these materials, which components are often harmful for the human and animal health, as well as can contaminate the ground, water courses and the water tables. (RIBEIRO & MORELLI, 2009)

This situation accurately applies to the technology industry, according to the exchange of electronic devices becomes frequent due to the modernization of techniques and science progress, the gadgets becomes obsolete more quickly, leading to an premature disposal, while the development of technologies and logistics do not follow this process for the proper handling of the e-waste (electronic waste).

According to Pereira et al. (2012), the competition between companies creates customizable products, heading the market to attend the specific needs of the costumer and modifying consume patterns. Thereafter, the companies see the need of adapting, which the main objective is the evolution of a productive chain and market innovation.

Thus the consumer trends and production, to innovate in the technology field and creates benefits to all kinds of knowledge areas, evokes the electronic waste generation, which, in turn, causes environment degradation.

Therefore, the waste in discussion becomes a responsibility not only of the area scholars, but of the society. That is, further than proper disposal, we have to create better ways for the e-waste to become a part of the new productive cycles.

Glufke (2008) defends that design can contribute not only for the cost-cutting, but also for the environmental damage reduction and for the creation of a sustainable environment by all aspects, and to achieve that, we must associate design to other knowledge areas.

In this way, this study has the main objective to use printed circuit boards (PCB), component present on the electronic waste, as raw material for coating in civil construction. For a better use of the boards, it was decided for the cut on a commercial pattern of tiles (ceramic, glass, etc.)

Printed circuit boards comes in a way that makes easy it use as coating, since there is various materials in board form in civil construction, as coating tiles for floor or wall. Besides, PCB exists in many colors and different hues, adding value to the design of the final product.

2. ELECTRONIC WASTE

2.1. Waste: General features

The waste of electro-electronic equipment is defined in different manners, so that there is not a standard definition. For Widmer et al. (2005), e-waste (electronic waste) is a term that encompasses distinct groups of electronic devices, as they no longer have value and/or useful to the consumer.

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A similar definition is found on ABNT NBR 16156:2013, in what refers to the waste of electro-electronics, defining it as pieces or parts that reach the end of its life cycle or its use were discontinued by the consumer.

Andrade (2002) points that there is a big diversity and quantity of metallic elements on electronic waste, which could make recycling difficult, beyond turning difficult also the proper final disposition, since metals represent a high level of contamination risk for whichever the environment that will receive it.

For Rodrigues (2007), the problem of the electronic waste of post consumption lies on the use of exhaustible natural resources and energy, totally lost when there is an early disposal of electronic devices, beyond the impact caused by toxic elements emission in practically all life cycle steps of these products.

According to Gonçalves et al. (2015), the collaboration between governments and private companies with research centers becomes fundamental to seek proper techniques of handling and management of e-waste, as well for access to information.

Yamane (2012) points out that the standard final destination given to the waste of electro-electronic equipment, landfill and incineration, is not the most appropriate for our reality, since that landfill can cause leaching of metals like cadmium, mercury and lead, which can contaminate soil and ground water. Already incineration releases toxic gases. Therefore, the recycling of this waste can contribute to natural resources maintenance and increases useful life of landfills.

Shinkuma & Huong (2009) say that the flow of e-waste on Asia has been cause serious problems, such as pollution and diseases, resulting of an inappropriate recycling of the waste. And defend that the waste generator must be responsible for it, until all its possibilities of reuse are exhausted. Shluep et al. (2009) points out that lack more improved Brazilian legislation regarding the recycling of e-waste.

Moreover, in Brazil, what is done with e-waste is the collecting, followed by dismantling and separation of the waste, then, printed circuit boards, where is the biggest concentration of value metals, are exported to countries that has recycling plants. Staying in Brazil only the waste that has lower value on market (YAMANE, 2012).

2.2. Printed circuit boards

Printed circuit boards (PCB) are essential parts for the operation of any electrical or electronic equipment thus are abundantly present in the same post-consumer waste. An ordinary circuit board is composed of epoxy resin, fiberglass and copper. The components connected to the card are usually made of metals such as aluminum, iron, gold, silver, among others. These components are integrated into the plate via a lead solder and tin. The presence of commercially valuable metals makes timely recycling of the PCB (Lee et al., 2004).

There are two types of circuit boards, the FR-2, which has a base in chipboard paper and phenolic resin, used in home appliances. The other type is the FR-4, which has laminated fiberglass, this is found on both sides, being used in the telecommunications, computer, industrial controls, etc. (ANDRADE, 2002)

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Andrade (2002) by physical-chemical analysis e by the procedure suggested in ABNT NBR 10004:2004, classifies printed circuit boards as a I Class waste (harmful). His study indicates this material has great potential for contamination of the soil by heavy metals, if the waste is disposed in uncontrolled landfills.

Sant'ana et al. (2013) points that concentration of valuable metals in printed circuit boards of smartphones are higher than the concentration of itself in mineral form, so, besides the environmental justification for the proper disposal of this waste, there is the financial angle, because the e-waste is an excellent metal source.

For Andrade (2002) and Lee et al. (2004), printed circuit boards compose a convenient raw material, by presenting precious metals (gold and silver) in small amounts, but that can be reutilized. Besides that, the boards are composed, in its big part of copper, which increases the economical side of recycling the material.

Yamane (2012) showed that it is possible to perform recovery of materials processes and recycling of printed circuit boards without the need for incineration. What increases the production process, giving new possibilities for materials that would otherwise be discarded.

To enable the use as coating for civil construction, the board's peripherals must be detached, preserving the value of it to return in to its respective productive cycles. The board, after the removal of most components, is convenient for use in architectural coating market, since is a field that already uses materials in board form.

2.3. Sustainable design possibilities of use in civil construction

According to Ribeiro et al. (2014), the design can contribute to the improvement of services, products and methods, focusing on a more conscious consumption. On account of being a multidisciplinary field of study, the Design walks alongside the much desired sustainable development, which in turn, influences consumption patterns whose origin permeates thoughts, desires, needs, in short, is surrounded by psychological factors. This pattern contributes to a much larger system, in size and complexity, in the economy. The policies of both power and production, give rise to what we call consumption.

Design is a difference in industrialized products since Industrial Revolution, being the main element and mean of dialog with the consumer printed on the final product, which will attract the user's senses. (MINUZZI, 2001)

Glufke (2008), points that design contributes to environmental impact and costs reduction, creating sustainable development when allied with another study areas.

Therefore, we must develop methods for reduce in civil construction of waste from other productive processes or from post-consume. Knowing that coating market can incorporate a large diversity of materials, for the purpose of creating a sustainable design, approaches the user/consumer of this concept.

For that, is also necessary the understanding of the logistical chain of the product and of the post consume waste that is intends to apply in this new concept and study the necessary changes to successfully achieve a viable product of the technological point of view and also economical.

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3. MATERIALS AND METHODS

For the proposition of this product, were analyzed the different types of printed circuit boards. To verify the variation in size of the plates due to the use, the device model and technological progress, it was decided for the court in standard size, in order to have a better use of them.

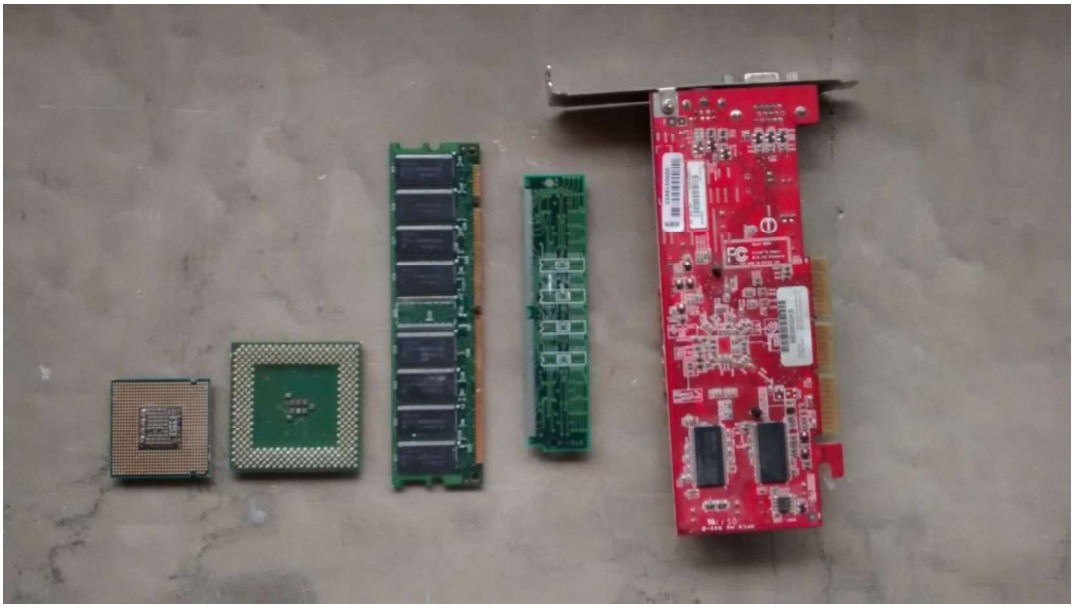

Figure 1 – Boards in different sizes. From left to right: processor, processor, RAM, RAM and video card.

Font: Elaborated by the authors, based on conducted research.

In the case of the boards design, there are also different hues of color shades, which can contribute for the aspect of the piece and attract the consumer with a differential not only by environmental issues, but also by its aesthetic characteristics.

For the definition of the cut for the boards, was taken as a reference a commercial pattern size used in glass and ceramic tiles. Bellow, an example of tiles in dimensions 2,5 x 2,5 cm.

Figure 2 –Recycled glass tile in dimensions 2,5x2,5cm.

Font: Elaborated by the authors, based on conducted research.

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To disassemble, it was conducted training with the project team "RENOVATECH", located in Colatina – ES, Brazil, which has the main objective the reconditioning of discarded desktops for donation to needy families in the region.

The dismantling has as objective the removal of metallic and plastic pieces attached to the board, which are part of the functioning of the system, but to stop working for their primary use, are discarded and composed by highly pollutant elements.

The printed circuit boards was dismounted with the help of simple tools like pliers, forceps and screwdriver and they were cut in mentioned dimensions with the help of a paper trimmer – 36 cm, Lassane brand.

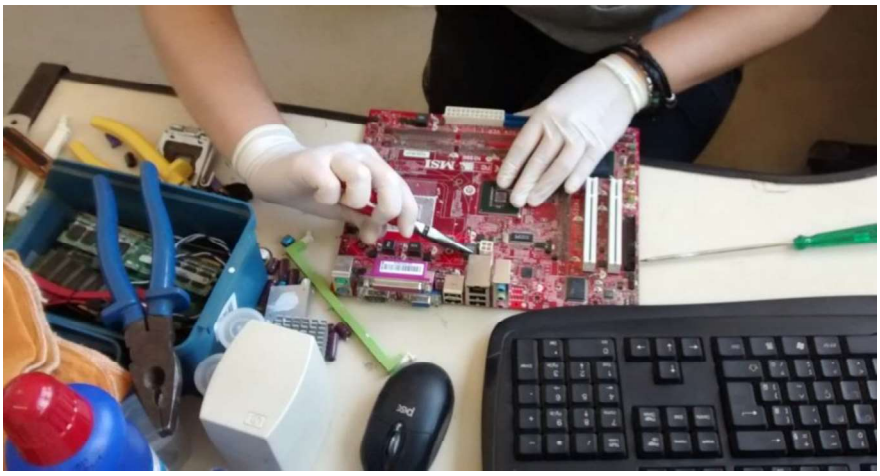

Figure 3 – Dismantling of a printed circuit board.

Font: Elaborated by the authors, based on conducted research.

The board pieces were organized so it can simulate the situation on a tile coating material. For the composition studies, was used the methodology of Ching (2013), taking up the principles of order: axis, symmetry, hierarchy and rhythm.

A coating plate, when applied to a surface is a plane.

A plane, in architecture, has the function of define the limits of a volume, being an art which includes almost exclusively the modeling of three-dimensional forms. So, the plane must be considered a fundamental element in the exercise of architecture (CHING, 2013).

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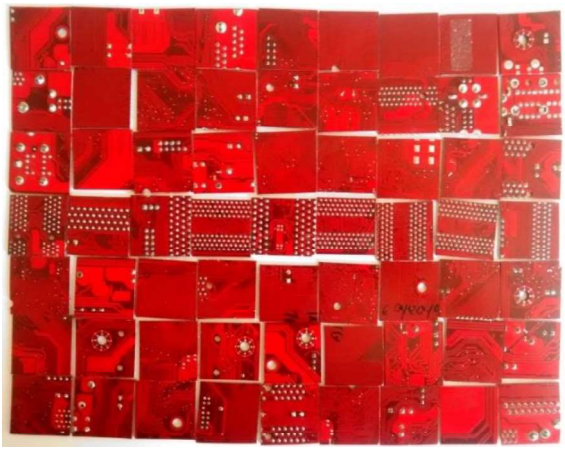

Figure 4 – Printed circuit board cut and organized according to the composition by rhythm.

Font: Elaborated by the authors, based on conducted research.

After disassembling step of the electronic components and subsequent cutting of the PCI's into smaller pieces, they were subjected to a coating procedure with polymeric materials from recyclable packaging. Despite the variety of polymers used for the manufacture of such packaging, this work was based on coating with polyethylene terephthalate - PET found mainly in disposable bottles. Clear bottles were used to maintain the visual appearance of the plaque.

To accomplishment the coating, a method were studied: the first occurred with the dip coating of parts in the molten PET in oven; while in the second the coating was performed out by means of a hydraulic press with heating, Model 4389, Carver, USA. After that, the plaque's polymeric coating was tested for the stability of the adhesive film.

The PET polymer was used for coating because this material is easily accessible and PET bottles are recyclable products, who's final destination is not efficient due to the amount that it is produced and discharged, increasing environmental contamination risk.

The PCB plaques have a very heterogeneous composition, which includes polymers, refractory oxides and several metals such as nickel, copper, iron and lead. (SAITO, 1994) and (HOFFMANN, 1992).

These metals in contact with the skin can cause allergic inflammation, becoming, therefore, necessary to coat the pieces with inert materials such as polymers.

After disassembling step of the electronic components and subsequent cutting of the PCB into smaller pieces, they were subjected to a coating procedure with polymeric materials from recyclable packaging. Despite the variety of polymers used for the manufacture of such packaging, this stage of the work was based on coating with polyethylene terephthalate - PET found mainly in disposable bottles. It was decided to use clear bottles to maintain the visual appearance of the plates.

A portion of colorless PET bottle has been removed to cover the PCB. Then the coating process was performed by compression with a hydraulic press heated, Carver, for 8 minutes at temperature of 230 °C and pressure of 10000 psi.

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Polyethylene terephthalate - PET was choose to coat the PCB because the bottles that contain this polymer are commonly discharged in the environment. By recycling this material, it is possible to decrease the value of the coating tiles and give a proper destination to the disposable bottles, reducing the risk of environmental contamination.

In addition, researches using recycled PET have been reported over the years and have shown that the mechanical and physicochemical properties are maintained in the tested analysis conditions. (CARASCHI, 2002), (CORDOBA, 2013) and (FREIRE, 1998).

Other recyclable polymeric materials will be tested and after the definition of the most appropriate to be associated to the board, the tests to attending the technical norms will be developed.

In relation with the final product, it must meet the criteria of ABNT NBR 13818:1997, which deals with test methods, ABNT NBR 13816:1997 and ABNT NBR 13817:1997, which treat on terminology and classification, respectively. Since the glass tiles and Polyethylene Terephthalate (PET) tiles also are tested in those parameters, the PCB tile covered in plastic polymer has to be valued by the same norms.

4. CONCLUSION AND DISCUSSION

Currently, observes a huge interest, such in the electronic waste as in insertion of different materials in civil construction, considering the scientific studies in these fields.

Also, it was also noted up a deficiency in coating materials research, especially with regard to the tiles of adherence issues.

For a coating material in these standard can be inserted in market, it is necessary the development of other studies of recyclable and translucent material, which can isolate the direct contact of the card to the user, making it inert and preserving the visual characteristics that refers to its origin. Besides that, it is also fundamental the valuation of the union material for the pieces as a unique board, just as in conventional tiles. In market, it is common that this union occurs by kraft paper on the exposed side of the tile or by nylon fabric on the back.

When assessing issues such as ease of dismantling and cutting of printed circuit boards and its position on e-waste, it is observed that they can become raw material for the coatings industry, considering that it is a segment that works extensively with materials in board form. The PCB is already shaped in board, facilitating its use as coating. Also, they can add value to architectural design, with their patterns of different colors and unique textures.

The developed material in this study aims to attend the needs of the market by associating recycling to an innovative design. So, it brings an alternative to the electronic waste by a new industry cycle in civil construction.

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