WASTE TABLETS CHARACTERIZATION AIMING RECYCLING

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Abstract: The constant increase of waste of electrical and electronic equipment (WEEE) generation is caused, mainly, as a function of technological advancement. Tablets are taking place in market of laptops and smartphones because of its characteristic of integrating the two products having access to the internet and communication and a screen that allows a reading in adequate size and good resolution for other purposes, these products are in market since 2010 and each year they becomes more acquired. Over time these devices became obsolete and are discarded becoming WEEE after being exhausted repair attempts or even possess outdated technologies. This paper aims was to perform waste tablets characterization in order to determine their recycling potential. Methodology includes a survey of tablets sold in Brazil in order to identify the potential variety of waste tablets and manual dismantling of waste tablets to physical characterization. Results suggest that a recycling route only for tablets can be benefited due to higher metal concentration in relation of total weight than other similar WEEE such as PC and laptops.

Keywords: Recycling; tablet; characterization; metal recovery.

Introduction

Electrical and electronic equipment (EEE) indicate increasing consumption, and given the technological advances, many of these materials end up in landfills or center collections becoming waste of electrical and electronic equipment (WEEE), since they cannot compete with new products or reveal some defect in a short period. Thus, this can create a problem with products discarded without proper processing, although there is a growing number of government agencies promoting and encouraging the proper disposal of WEEE (PERKINS et al., 2014).

United Nations University reported in 2014 that were generated 41.8 million tons of WEEE on a global scale, with 3 million tons only for small equipment of information technology (laptops, tablets and smartphones), and the projection for 2018 was also made pointing out that this would generate 50 million tons (BALDÉ et al., 2015). A survey conducted by Panambunan-Ferse & Breiter show that about 60% of people keep end-of-life mobile phones in their homes, in this way the generation values may be even greater since those products are not being counted, and this attitude may be related to other EEE, such as tablets (PANAMBUNAN-FERSE & BREITER, 2013).

Because of the immense amount that has been accumulated, it has become a prominent environmental problem, but also can be a source of valuable materials, such as precious and base metals (ZENG et al., 2012; PETTER et al., 2015).

Brazilian policy on solid waste, launched in 2010, obliged that WEEE must have a reverse logistic, and in 2012 the Brazilian Industrial Development Agency create 4 categories (Green, Blue, Brown and White Lines) (MAZON et al., 2012; ABDI, 2012). Currently, WEEE from the Green Line, such as tablets, laptops, smartphones, personal computers (PC), computer accessories, has considerably increased its waste volume (ABINEE, 2014). Table 1 shows the increase in the consumption of some equipment over the years in Brazil.

Table 1 – Sells of personal computers, laptops and tablets in thousand units by year since 2011.

Year	Personal computers	Laptops	Tablets
2011	7.500	8.354	1.144
2012	6.582	8.932	3.267
2013	5.740	8.205	8.386
2014	3.974	6.361	9.623

Source: ABINEE (2014) and IDC (2015).

It can be seen in Table 1 steady growth in the tablets market and decrease in the personal computers and laptops market, which is probably due to the society who is looking for portable with internet access, besides the factor of screen size may also influence, as a larger screen compared to a smartphone are easy to read. According to Cucchiella et al. (2015), notebooks seem to gradually lose market shares in favour of tablets although the structure and function are different.

The word tablets and your description become world famous with release the iPad in 2010 by Apple Inc. Company (LUT, 2014). Currently the tablets can be differentiated by their operating system the leading are iOS by Apple, Windows, Android, Linux and Firefox OS. Companies use these operating systems in many tablets that are updated constantly.

Tablets are disputing the market with laptops and smartphones and gradually this will cause them to have a greater presence in WEEE soon (PINGEL et al., 2012). There are no studies reported in the literature on the average useful life time of tablets, but taking laptops as comparison purposes, they have about 5 years of useful life time to be discarded and an analogy could be made for tablets (WANG et al., 2009; BALDÉ et al., 2015).

The purpose of this paper is to determine the recycling potential of waste tablets through physical characterization, which is an initial study aiming materials recovery.

Material and methods

Waste tablets

Waste tablets and their screen, battery and charger used in this research were characterized in the Brazilian company "*Doctor Tablet Assistência Técnica*", with staff who perform maintenance on this type of equipment. PCB from waste tablets were obtained by e-commerce.

This was necessary because tablets are not currently found together with WEEE since they entered the market in 2010 and the disposal of this type of equipment is still recent. It were used different models/brands of 14 full waste tablets, 10 broken tablets screens, 17 printed circuit boards (PCB), 15 charges and 15 batteries from tablets.

Survey of tablets sold in Brazil

The survey of tablets sold in Brazil was performed looking for each brand and model released in Brazil, since 2008, through consulting in websites of manufactures and stores, in order to identify the potential variety of waste tablets. The results survey are presented graphically.

Physical characterization

Physical characterization of waste tablets was performed by dismantling, weighing of components and classifying according to the material.

It was used 5 categories:

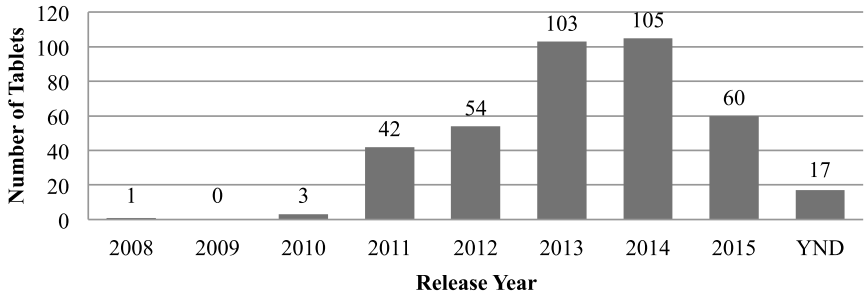
- Full waste tablets, which includes: frame, screen, battery, PCB, wires and metal shields;
- Printed circuit boards from waste tablets;
- Broken tablets screens from different sizes (7.1" up to 9");
- Chargers and cables from different tablets models;
- Battery from waste tablets.

Results and discussion

Survey of tablets sold in Brazil

The Figure 1 shows number of models of tablets released since 2008 of 30 brands found in Brazilian market.

Figure 1 - Number of tablets models *versus* release year.



Legend: YND – Year not defined.

As can be seen in Figure 1, since the release of the tablets models: iPad 1st, Galaxy Tab and Streak 5, in 2010, is noticeable the increased of models number in the following years. N810 launched by Nokia in 2008 can also be considered as a tablet, but the tablets market boom started from 2010.

It is also seen that, in 2015, it was observed a decrease of the models number, most likely caused by the economic crisis in Brazil and consequent market decline. Even with possibility of sales decrease, based on existing models number, and tablets that have entered the market that eventually become waste, generation represented by waste tablets is significant.

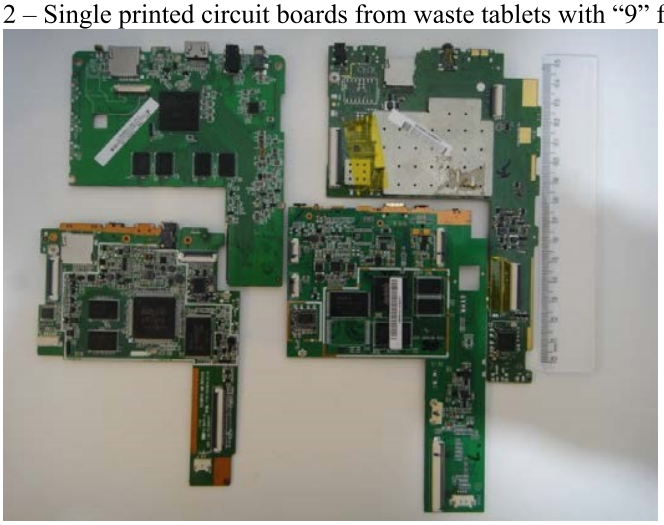
The decrease in 2015 may be also because the stabilization in the manufacture technologic, this can reduce the production of products that had low sales, also maintain and innovate models that were accepts by the costumers.

Comparing with recycling of smartphones or laptops, it is know that these have potential for recycling due to metals of commercial interest in their PCB, which will be probably applied to tablets.

Physical characterization

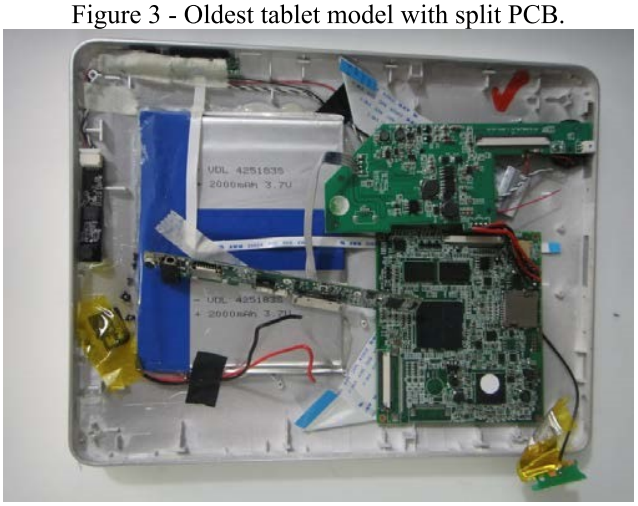
In the disassembling of waste tablets it was observed that the PCB shape differs according to manufacturer, but many of them have a "9" format (about 64% of full tablets and 94% of the PCB) as shown in Figure 2.

Figure 2 – Single printed circuit boards from waste tablets with "9" format.



Single board shape is currently the most widely used in tablets market, however, older models use separate plates, probably for the basic functions, as an example showed in Figure 3, which has 4 separate plates. The size of these boards fills around 33 to 50% of the space tablets; the only exception is the iPad with PCB filling only 14% of the total space.

Figure 3 - Oldest tablet model with split PCB.



During the disassemble was noticeable that some tablets had more complex PCBs them others and a lot of the brands share similar construction and design technics making the easy to compare. Most of the tablets analyzed had a plastic cover, as shown in Figure 3, and few were made of aluminum, because the plastic cover is cheaper.

Additionally, it was reported that the most technical problems of waste tablets were caused by mechanical accidents, such as screen broken, and the second more common was problems battery.

Weight results of the full waste tablets, broken tablets screen, PCB, charges and batteries are presented, respectively, in Tables 2, 3, 4, 5 and 6.

Table 2 - Weight of full waste tablets.

Full Waste Tablet	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Weight (g)	707	461	323	361	344	327	311	560	488	345	480	492	351	319
Average (g)	419.21													

Table 3 - Weight of broken tablets screens.

Screen	1	2	3	4	5	6	7	8	9	10
Weight (g)	222	60	113	105	116	118	113	93	120	121
Average (g)	118.1									

Table 4 - Weight of PCB from waste tablets.

PCB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Weight (g)	24	21	26	22	45	23	31	32	31	29	37	33	31	41	33	35	38
Average (g)	31.29																

Table 5 - Weight of charger/cables from waste tablets.

Charger	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weight (g)	68	58	55	65	62	71	188	94	92	70	47	65	62	88	73
Average (g)	76.37														

Table 6 – Weight of batteries from waste tablets.

Battery	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weight (g)	41	46	55	40	51	70	78	85	45	44	47	41	52	50	46
Average (g)	52.7														

According to Table 2, it was observed that the average tablet weight is 419.21g. Similar with reported by Cucchiella et al. (2015) that estimated tablet weight in 0.5 kg.

Table 3 presents average weight of tablets screen of 118.1 g which represents 28 wt.% of total tablet weight while PCB taking close to 7.5 wt.% (Table 4). Some brands such as Apple have different technology in the screen and their screens weigh about half the average value of the combined weight of all brands.

Bachér et al. (2015) studied weight distribution in small and large mobile phones reporting that screen (display) represents 21wt.% while the PCB 5wt.% in large phones.

Although weight distribution results are similar, metal content in PCB vary depending on device. Printed circuit boards from mobile phones presents higher concentration of copper and lower concentration of precious metals than printed circuit boards from personal computers (YAMANE et al., 2011).

Ilyas et al. (2009) affirmed that PCB may contain 0.3-0.4% of those precious metals and in case of tablets is represented around 0.09-0.12g of metals like gold silver and platinum.

In Table 5 is notable that the weight of chargers is change in order of the manufacture and model. The heaviest charger is from company Motorola it have a larger power supply compare with others changers this type of charger is more robust also keep the power supply far from the wall outlet, his long cable prevent damage to the charging cable, this damage can be seen in Figure 4.

Figure 4 – Damage charging cable

The damage cause by misapplication while the equipment is charging may damage the cable and cause a short circuit across it damaging the battery or even the device. Some brands manufacture the charger in 2 pieces, the power supply and the cable. In case of the cable appears damaged it can be easy replace by a new one.

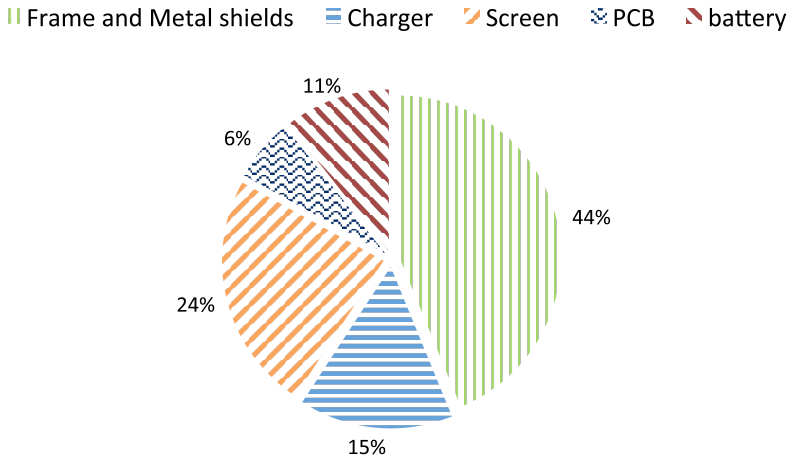
Table 6 shows that the weight of the battery is about 12.5wt.% of the total tablet, even that this value is not high it must be considered that this component is one of the most harmful to the environment since is contains some metals such as lithium, zinc, mercury, lead and others, those metals can contaminate soil, explode or set fire to the collection if the batteries are discarded improperly (TERAZONO et al., 2015).

The lithium ion batteries are commonly use where in those mobiles devices and according to Baldé et al. (2015) about 15% of the total e-waste are well treated with good standards of treatment removing the batteries from the rest of the waste (BALDÉ et al., 2015). The lithium contained in those batteries can pass through stages and be recycled (HANISCH, et al., 2015).

The chargers sometimes can be reuse in other devices, since it's not always damage this may reduce the unnecessary purchase and decrease the amount of waste generated.

A gravimetric composition of tablets can be made with the average value of the Tables 2 to 6, and can be seen in Figure 5.

Figure 5 – Gravimetric composition of tablets.



The gravimetric composition of tablets shows that the 65% of the tablet are easy to be recycled. In all dismantled tablets, PCB and metal shields can be easily removed which facilitates recycling processes. Other easily removed is the cover aluminum that appear in some models.

The content in valuable materials is higher in tablets than laptops (for a given weight), due to a more compact design, being one of the hardest problems to solve when they have to be recycled (CUCCHIELLA et al., 2015).

Sarath et al. (2015) shows the trends in mobile phone waste management and most of the articles focus their efforts on material recovery. This trends should be also be followed by tablets, since their wastes have materials that are easily recycled and analogies can be made in the recycling steps.

According to the characteristics of each type of printed circuit board, the recovery of precious metals may be the main goal of the recycling process of printed circuit boards. Hence, these printed circuit boards would not be mixed prior treatment.

Conclusions

As the waste tablets are a recent type of WEEE, just a few papers cite specific data about tablets such as composition, generated volume and market values. Main goal of this paper is to increase discussion about waste tablets, in especial, about recycling potential, since waste tablets generation will probably increase over the years, as show in survey market, even with models number decrease. It is well know that characterization is first step to determine a recycling route.

Characterization results suggest that a recycling route for tablets can be benefited due to higher metal concentration in relation of total weight than other similar WEEE such as PC and laptops.

Another area pointed by this paper that can be explored is the recycling of screen, since they make up about 28wt.% of a tablet and are the most fragile part to mechanical impact.

Acknowledgments

The authors wish to thank the Fundação de Amparo à Pesquisa e Inovação do Espírito Santo (FAPES), Espírito Santo, Brazil for research financial (Process n°68781369/14) and the company "*Doctor Tablet Assistência Técnica*" for technical support.

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