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EFFECTIVITY STUDY OF WASTE PERSONAL COMPUTER THROUGH MANUAL DISMANTLING AND HYDROMETALLURGICAL PROCESS USING LEACHING PROCESS

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ABSTRACT

Lately, the dumping of electrical and electronic at the market caused by the old electric and electronic goods has become outdated and often thrown away without any awareness of the dangers or about the precious material at goods. Generally the life of electrical and electronic waste (e-waste) just ended in landfills only. These items can be categorized as a valuable commodity and also a dangerous thing if we do not take steps that we should do about this stuff. Valuable materials contained in these products can be recycled, such as copper, aluminum, gold, steel, plastic and many more. However, the dangerous elements contained in the e-waste are chromium, beryllium, lead, mercury and so on. This study is focusing on the investigation of recycling potential of e-waste through manual dismantling process and leaching test. The methods that can be used for leaching are internal chamber and hydrometallurgical methods. These methods are used to obtain a solution containing precious and hazardous metals from the PCB. The leaching test was conducted with constant stirring speed, constant water-sample ratio and variable method. The liquid residue was analyzed by Atomic Absorption Spectroscopy (AAS). It was found that total time required to dismantle all parts in the waste motor is about 10 minutes and the part that required longest dismantling time was front cover. The metal elements that were observed are Zn, Cu, Mn, Pb and Cr. It was found that the pH of the solution increased with the increasing leaching time.

Keywords: e-waste, hydrometallurgical, high pressure, dissolution, leaching, PCB.

INTRODUCTION

At present day, waste disposal increasingly to be at a critical level, there are also disposal of electronic goods or formerly known as 'e-waste'. However, awareness of waste electrical and electronic goods is less. Health problems will arise if awareness of waste electrical and electronic products is still in a low level. This is because the water contained in the bowels of the earth results from the leaching of these mechanisms may cause harmful toxic pollution such as cadmium, chromium, lead, mercury, beryllium, and more. [1] Not only health problems and even shortages of raw materials will also arise, because a lack of desire to recycle electronics. There are some items that can be recycled are available in electronic products including brass, copper, aluminum and so on. Therefore, technology in handling electronics waste 'e-waste', management and recycling is very important in order to reduce the environmental impact brought by the 'e-waste'. In electrical and electronic goods there are an assortment of valuable content which if not recycled or restoration done on the waste products would be detrimental to a party.

There are several important components in the computer including the motherboard, hard disk, casing, power supply, heat sink, ram, disk drives, USB, graphic card, and the card and others. Among these components are recyclable and non-recyclable. Among the components that can be recycled is like casing, motherboard, heat sink and others. For example, PCB better known as the motherboard (printed circuit board) can also be recycled because there is precious metal on the PCB. There are two types of PCB, which is single layer and double layer type. Single layer PCB which is always used by most personal computer or laptop, while the two-layer PCB type is have been used by most mobile phones and smartphones [2].

Hydrometallurgical technology also is a traditionally method for the recovery of precious metal contained in PCB. There is a major step in the process is a hydrometallurgical acid leaching process in which solid materials will be immersed into a solution of acid. Then the mixture goes through several procedures including dirt precipitation, solvent extraction and ion-exchanger to isolate and focus only on the important metals only. Before the samples of metallic materials were leaching, the metal material to go through some tests first. The experiment was such tests XRD (X-ray diffraction) or EDS (Energy Dispersive X-Ray Spectroscopy). Test XRD (X-ray diffraction) is a test to determine the composition of a substance contained in the solid material. While test EDS (Energy Dispersive X-Ray Spectroscopy) to determine the elements contained in a solid material [3]. The high pressure chamber is a tool used to perform experiments in which leaching process is one process of extracting valuable materials from PCB or electronic components. According to DOE Malaysia, the main technology employed to recover e-wastes in terms of precious metals in Malaysia is still limited to wet chemical processes and electrolysis. There are still very limited literatures on the e-waste management, handling and recovery process of hazardous materials in Malaysian e-waste industry. In our previous study, the re-utilization of industrial waste had been investigated [4-6]. Thus, the current study is to investigate the recycling process of E-waste through the manual dismantling process and hydrometallurgical process. The E-waste that been used is waste dc motor due to the massive amount of it in the E-waste industry in Malaysia.

EXPERIMENTAL PROCEDURES

Figure-1 shows the personal computer used in the study. It is a common personal computer that can be easily found at the e-waste landfill area or electronic shops. The motor was manually dismantled and the time required to dismantle all parts was measured. The dismantled parts were then categorized into ferrous, non-ferrous and plastic parts, and composition of each types of part was measured. Then, in order to investigate the leaching behavior of ferrous parts, the ferrous parts were collected from several numbers of motor and the leaching test of the ferrous parts was conducted. The leaching test of the ferrous parts was carried out according to Figure-2. The parameters of the leaching test are shown in Table-1. The ratio between samples and leachant is 1:10. 100g samples were inserted into glass beaker and then the leachant which is rain water was softly poured into the beaker. After that, the water in the vessel was mixed at rotational speed of 100 rpm. The test was conducted in ambient air and temperature and also with temperature 60°c. 50 ml liquid samples were collected every 1, 3, 6, 12, 24 and 48 hours by syringe and filtered by filter paper. The liquid residue was then analyzed by Atomic Absorption Spectroscopy (AAS). The samples before the leaching test were characterized by Scanning Electron Microscope (SEM) and the chemical composition was measured by Energy Dispersive X-Ray Spectroscopy (EDX) that equipped in the SEM.

Figure-1. Waste CPU unit.

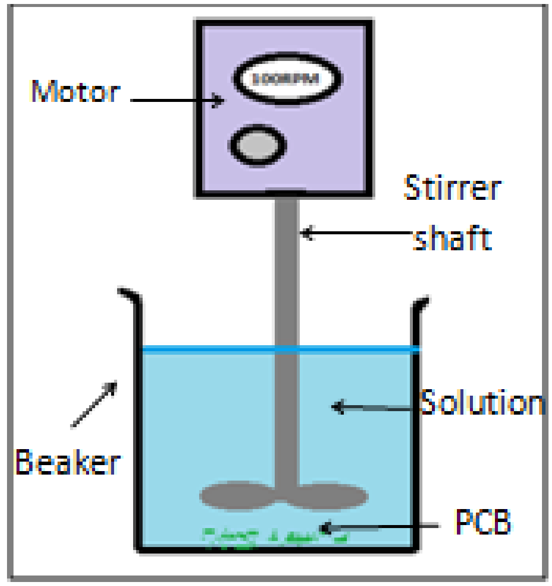

Figure-2. Schematic of leaching concept.

Table-1. The parameters of leaching test.

Rotation speed:	**100 and 300 rpm**
Amount of water:	1000 ml
Amount of sample:	100 g
Temperature:	Ambient and 60°c
Types of water:	Rain Water
Leaching time:	1, 3, 6, 24 and 48 hours
pH:	6

RESULT AND DISCUSSIONS

The dismantling process of personal computer was conducted manually using player and screw driver. The sequences of dismantling processes are as follows: Housing→wire and connector→ hard drive→ power supply→ lan card→cooling processor→processor→ motherboard→ hard disk/floppy disk→front cover. Time required for each processes is shown in Table-2. The total time required to dismantle all components is about 549 seconds or 10 minutes. The process that required longest time is the process to separate the front cover. If this process can be simplified, the overall dismantling time can be reduced and it can ease the recycling process of personal computer. There are three types of parts consisted in the motor; a) ferrous, b) non-ferrous and c) plastic parts, as shown in Figure-3. The weight contributions of each type of parts are 58.3%, 38.8% and 2.9% respectively.

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Table-2. Time required for the dismantling process.

Work procedure	Time
Dismantle housing	4 sec
Dismantle Wire and connector	2 min 4 sec
Dismantle drive	18 sec
Dismantle power supply	30 sec
Dismantle Lan Card	10 sec
Dismantle Cooling Processor	37 sec
Dismantle processor	50 sec
Dismantle motherboard	1 min 3 sec
Dismantle hard disk/ floppy disk	2 min
Dismantle front cover	2 min18 sec
Total	9 min9 sec

Characterization of PCB

Table-3 shows the material composition in that have in the PCB. A typical PCB composition is 30% plastics, 30% refractory oxides and 40% metals. The most abundant metal is copper with a concentration between 10% and 30%. Metal compositions in PCBs are deference according to the manufacturer and the year of its manufacturing and technology [7].

Table-3. Material composition [7].

Element	Composition
Cu	10-26.8 (%)
Pb	0.99-4.19 (%)
Zn	0.16-2.17 (%)
Au	80-1,000
Au	110-3,301
Pt	.6-30 (g/t)
Pd	10-29 (g/t)

Leaching behavior of PCB

Figure-3(a) shows the change in pH during the leaching test. The initial pH was 6 and it increased as the leaching started and continuously increased up to 6.8 at the end of the leaching test. The standard of pH for river that was based on Interim National Water Quality Standards (INWQS) is also shown in the figure [8]. The final pH was within the permissible range of pH set in INWQS Class 1. Class 1 is considered as the “best” with no requirement of treatment and suitable for the conservation of natural environment. However, in the case leaching method, the final pH was in range of class I as shown in Figure-3(b). The magnetic stirrer method show the higher pH value compared that other method. Looking on the trends of pH changes for both cases, it is expected that by prolonging the leaching time, the final pH would be in the range of class I. Since this work is more on the fundamental study of the dissolution behavior of each main element in the PCB, more study is required to validate this expectation in the coming works.

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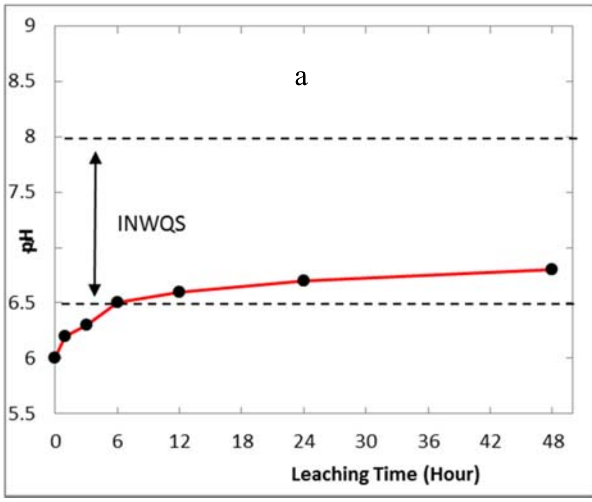

Figure-3 (a).

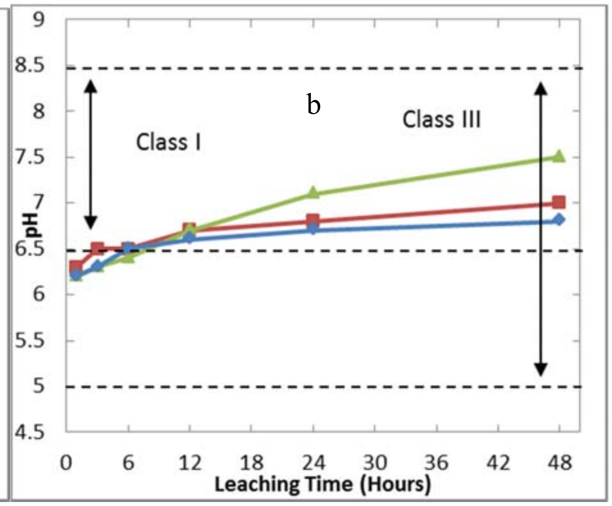

Figure- 3(b).

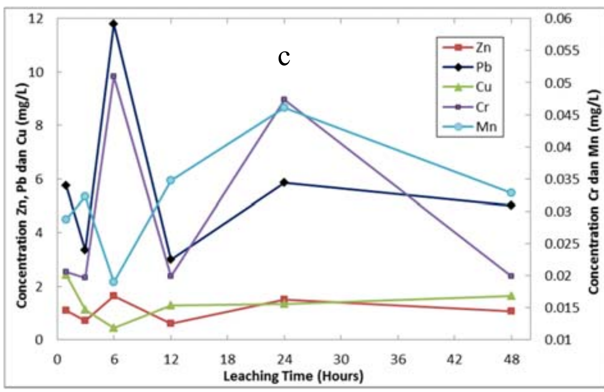

Figure-3(c).

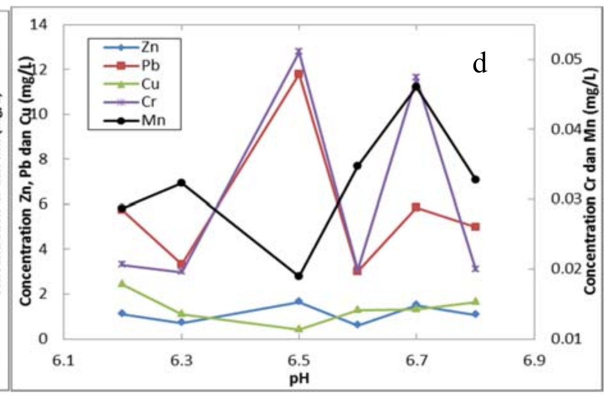

Figure-3(d).

Figure-3. pH changes and dissolution behavior of main elements during the leaching test.

Figure-3(c) shows the dissolved concentration of main elements inside PCB during the leaching test. Pb shows the highest dissolved concentration during the initial stage of leaching. However, it gradually decreased afterward and almost no dissolution of Pb was observed after 6 hours leaching. The dissolution of Pb was little bit high in the early stage of leaching before decreased and almost unchanged afterward. The dissolved concentration was higher than permissible level class IIA of INWQS and all pollutions of EQS as shown in Table-4. The concentrations for Mn and cr were very low throughout overall leaching test.

Figure-3(d) shows the behavior of dissolved concentration of each element with changes in pH of the leachant. Pband Cr concentration increased as the pH increased and almost not dissolved after pH exceeded 6.5. Mn also increased and almost unchanged after pH more than 6.7. On the other hand, concentration of Zn and Cu almost unchanged with the increasing pH. It can be concluded that there is a high potential of recycling of PCB by utilizing the leaching test and internal chamber leaching method. However, more effort has to be putted on reducing the dismantling time of the PCB and on managing the dissolved Pb during the recycling process.

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Table-4. Malaysian interim national water quality standard (INWQS) and Japanese environmental quality standard (EQS).

Parameters	Malaysian INWQS [9]						Japanese EQS [5]		
	Classes								
	I	IIA	IIB	III	IV	V	Soil pollution	Marine pollution	Water pollution
CrIII [mg/l]	-	-	-	0.01	-	-	-	2	-
Pb [mg/l]	NL*1	0.05	-	-	5	-	0.01	0.1	0.01
Fe [mg/l]	NL	-	-	-	-	-	-	-	-
Mg [mg/l]	NL	-	-	-	-	-	-	-	-

CONCLUSIONS

Fundamental study of waste Personal Computer was carried out to investigate the dismantling processes and dissolution behavior of the waste. It was found that the longest dismantling time was contributed by the dismantling of front cover. More efficient recycling technique can be achieved by reducing the dismantling time especially when it involved huge amount of waste motor. Dissolution of each main element in the waste motor was observed and it has affected to the increase of pH. The increase of pH has then led to the reduction of Fe and Pb concentration. Dissolved concentration of Pb must be controlled to ensure that it does not exceed the permissible amount set under INWQS.

From the leaching experiments were performed using several methods including internal chamber method, overhead leaching method and magnetic stirrer, there are a few things that can make a comparison between the three methods. The different pH show that the magnetic stirrer is the higher pH value compared than other. However the all three method can be used for the leaching process.

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