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Separating Inorganic from the Non-metal Fraction of the Processed Waste PCBS Using Heavy Liquid Separation

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Abstract
Electronic waste is one of the most investigated waste streams around the world due to the presence of valuable metals and hazardous chemicals. Printed circuit boards (PCB) represent a significant amount of this stream which consists of metals such as copper, silver, gold and palladium, and a non-metal fraction (NMF). The NMF represents approximately 70% by mass of the total PCB consisting of fibreglass or cellulose as reinforcing materials and epoxy, phenolic or polyester as resins. This paper presents results of the test work on the separation of inorganic and organics from the non-metal matrix using heavy liquid separation. A liquid medium of varying specific gravity was used to separate different streams from the NMF based on the density variations, and then analysed for metal content, loss on ignition and calorific value. Results showed that most of the inorganic materials reported to the density range of 1.8-2.4 g/cm3 with a low calorific value of <9 GJ/t and a mass yield of 30-40% of total NMF. The fraction with density <1.8 g/cm3 consisting mostly the organic materials had a high calorific value of >20 GJ/t and a mass yield of 60-70% of the total NMF. It also showed that the heavy metals like copper and iron were concentrated in the heaviest density fraction (>2.4 SG). An optical microscope or scanning electron microscope analysis and mechanical strength tests would be required to further test the quality and respective applications of separated products, which will be considered in the follow up research.

Keywords
E-waste; Printed circuit boards; Non-metal fraction; Fibreglass; Calorific value; Loss on ignition

Introduction:
Electronic waste is one of the fastest growing waste streams in the world. He estimated growth rate of e-waste is reported to be 3-10% [1-4]. He United Nations University (2017) reported that the total e- waste generated in 2016 was 45 million tones and expected to reach 52 million tons by 2021. He presence of various valuable metals such as copper, silver, gold, palladium, iron, and aluminium provides an economic incentive for recycling, whereas the hazardous metals such as lead and arsenic and flame retardant bearing chemicals require pre-treatment before proper disposal [5,6]. He most common types of PCBs are flame retardant 2 (FR-2) and flame retardant 4 (FR-4) which uses cellulose reinforcement with phenolic resins, and fibreglass reinforced with epoxy resin respectively [7]. FR-2 boards are mostly used in low-end electronics such as television and radios, whereas FR-4 is widely used in high-end electronics such as desktops, laptops, and cell phones [7,8]. With an approximate value of 40% of the total e-waste and 6% fraction by weight, waste printed circuit boards (PCBs) are one of the significant fractions of the e-waste stream [9,10]. Kumar et al. showed that the concentration of copper, silver, gold, and palladium in e-waste is 5 to 250% higher than average mining operations which provide major economic benefits for recycling [11]. He average metal content in PCBs is approximately 30-35% and rest of the material is referred to as non-metal [12-14]. He metals in PCBs are extracted for their value and the remaining non-metal fraction (NMF) containing the resins, including reinforcing materials, and residue metal are open sent to landfills

Material and Methods
A representative sample of NMF was received from the Ronin8 Technologies Limited pilot plant located in Richmond, British Columbia representing an actual NMF generated at an industrial scale. He plant processed mixture of FR-2 and FR-4 PCBs obtained from computers, printers, and televisions using gravity separation (wet concentration table) to separate metals from non-metals. A representative sample of 25 kg NMF was collected using cone and quarter method from a 750 kg bulk bag lot and was oven dried at 600°C for 96 hours to remove any residual moisture.

Equipment and test procedures
Particle size distribution analysis and sample preparation: Approximately 300 grams of sample were obtained from the dried sample for particle size distribution using dry screening method for 20 minutes. He size distribution was plotted, and 80% and 50%cumulative passing size were determined.
Results and Discussion
He particle size distribution of the received NMF sample was determined using screening. He distribution is shown in Figure 2. He 80% passing size (P80) and 50% passing size (P50) of the sample was estimated to be 819 μm and 498 μm respectively.

Conclusion
He non-metal fraction of the printed circuit boards contain a significant quantity of resins and fibreglass that was separated by using heavy organic liquids. A clear separation of organics from inorganic was obtained at a density of 1.8 g/cm3. His separation could enhance the energy value and reduced the metal content of the concentrated organic fraction (SG <1.8). He lower specific gravity fraction (<1.8) showed an energy content of approximately 21 GJ/t, which is higher than the calorific value of lignite coal and dried wood and can likely be used for energy recovery. However, the by-products of the energy recovery process/incineration, such as the flue gas and fly ash, should be evaluated for chemical and metal

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contamination. He heaviest density fraction showed an elevated metal content which can be used for further enhancing the overall metal recovery.

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