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Resource recovery of engineering plastics from E-waste recycling

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Abstract
E-waste contains about 15-25% plastics which can be profitably reclaimed for reuse by component manufacturers, or subjected to pyrolysis to obtain liquid fuel. The recovery process described herein follows separation of plastics from metals and glass, followed by cleaning and extrusion into multiple thin strands which are cut into small granules of 2-3mm size, fit for further use to manufacture household and other plastic components.

Keywords: Plastics in E-waste, potential to pollute, pyrolysis, granular form for reuse

Introduction
Electrical and in particular electronic waste (termed as E-waste) is fast becoming to be a major pollutant due to rapid growth in the use of electronics in recent years for household, entertainment and communication purposes. The principal components of E-waste are ferrous and non-ferrous metals, plastics and glass. Plastics constitute 15 to 25% of the waste depending upon the end-of-life products. The use of plastics in electrical and electronic equipment is a necessity due to their inherent advantages as engineering materials. However, presence of plastics in E-waste is highly objectionable as they are non-bio-degradable and are likely to contain brominated flame retardants, thus endangering both the humans and the environment.

The nature of plastic in E-waste
Land filling and incineration, the two methods commonly used for waste disposal, are undesirable for E-waste for fear of I) losing valuable metals and II) pollution. The importance of reclamation of plastics from end-of-life electronic and electrical gadgets is universally noted, as the conventional methods of waste disposal such as land filling, sea dumping, incineration etc., are undesirable due to their potential of causing damage to the environment. Plastics find application in electrical and electronic gadgets because of their thermal and electrical insulating ability, light weight, durability, attractiveness, freedom of design, reusability and cost.

Engineering thermoplastics are mostly used for the purpose, as they can be repeatedly melted and remoulded. Some commonly used plastics in electronic equipment include Acrylonitrile Butadiene Styrene (ABS), Anti-microbial Acrylonitrile Styrene Acrylester (ASA), Polyamide (PA), Polycarbonate (PC), Phenolharz, Polymethyl Methacrylate Plexiglass (PMMA), Poly Phenylene Ether (PPE), Poly Phenylene Oxide (PPO), Styrene Ethylene Butadiene Styrene (SEBS). Since plastics are inflammable the electronic gadjets contain brominated flame retardants (BFRs) such as Deca-Brominated DiPhenyl Ether (BDE), Tetra-Bromobisphenol (TBBPA). Plastics found in E-waste are thus valuable materials, and wisdom is to recover them for recycling or for other processes such as melting and remoulding to get components like plates, battery boxes, compact disk trays or to use as ingredient in hot mix asphalt concrete.

The main challenge lies in dealing with the plastics in E-waste that are left behind after the recovery of metals and glass. Land filling is not advisable as plastics are not bio-degradable and therefore contaminate the soil and with time the water bodies and possibly atmosphere. Incineration of plastics in E-waste is highly hostile to the environment. For example, burning of waste containing PVC or wire insulation emit polychlorinated dibenzo–p-dioxins (PCDD), and polychlorinated dibenzo-p-furans (PCDF). PCDD and PCDF are persistent organic pollutants (POP) hazardous to human health. Burning of PVC insulated copper wires leads to higher emissions of PCDD and PCDF as copper acts as catalyst in the incineration process. Another persistent toxic by-product of incineration is polybrominated diphenyl ethers (PBDE), especially the Penta-BDE, Octa-BDE and Deca-BDE. Brominated compounds are used in printed circuit boards, computer casing, cables and connectors. PBDEs cause liver damage, impaired brain development and damage tissues. In a few cases, it is advised to separate the plastics in those containing BFRs, from those that are BFR – free. The non BFR fraction is used for recovery and reuse, while the only option for BFR fraction is "controlled" landfill.

Attempts to utilise E-waste plastics include I) Pyrolysis (both catalytic and non- catalytic) to obtain liquid fuel and II) mixing upto 6-8% in concrete5. The Creasolv process3 is reported to be cost effective and commercially viable option to deal with BFR contaminated plastics. The process consists of separation of plastics in E-waste from metals and glass, followed by dissolution using a proprietary solvent to remove other contaminants such as wood and fibres. The polymer-free BFRs is then precipitated out from the solution for reuse. William and Williams7 studied pyrolysis of PCBs in a fixed bed reactor at 800 0C and reported an average mass balance of 69% residue, 23% oil and the rest gas. Mustofa and Zainuri Fuad4 reported pyrolysis of waste plastics at 900 0C; the resulted vapour was condensed using a cross flowcondenser to give liquid fuel with a calorific value of ~47,000 KJ/Kg. Desai et.al2 studied pyrolysis of PE, PP, HDPE, LDPE at temperatures ranging from 300 to 500 0C and condensed the gases to liquid fuel. They reported an yield of 7Kg of raw fuel from 7.5Kg of plastic waste. The plastic waste constituted plastic bags, saline bottles and regular household plastic items. Damal et.al.1 studied the use of plastic E-waste in concrete to report that the compressive strength of concrete was optimal when it was substituted with 7.5% E-waste. The criteria for recovery and recycling /reuse of plastics from E-waste depends on value-to-recovery-cost ratio or in determining whether the potential value of the recovered plastic is more than the cost of reprocessing and remarketing it.

The recovery process at E-Parisaraa Pvt. Ltd.

Below is described the process (Figure 1) of recovery of plastics from E-waste followed at M/s E-Parisaraa, Bangalore, India. The plant capacity is 30 T/day of E-waste and constitutes computer equipment 75%, telecommunication equipment 13%, electrical and medical equipment each 4%, rest miscellaneous.

Plastics are segregated manually at the dismantling stage into ABS, HIPS (High Density Poly Styrenes), PP and others as mixed plastics. When manual separation is not possible, such as from thick wires and cables the components are mechanically slit and subjected to shredding. The metal and plastics are then conveyed to a vibrating separator when the lighter particles of polymers are sucked and collected using a cyclone separator. It is noted here that Yadav and Upadhyay6 modified a mixer-grinder to separate plastics from E-waste. In the present process plastics after separation from metals are shredded into small pieces, cleaned, color dyed and subjected sequentially to centrifugal drying and solar drying. They are then extruded at thermal re-flow temperatures (200-222 0C) into long multiple strands and quenched using water. They are then cut into granules (2-3mm) to be sold to plastic raw material dealers. Normally these granules are mixed with virgin plastics to manufacture items such as buttons, buckets, plates, cups etc.

As part of research program to convert plastic waste into liquid fuel preliminary experiments have been carried out at M/s E Parisaraa subjecting PP and PE waste to vacuum pyrolysis. Figure 2 presents the Differential Scanning Colorimetry (DSC) and Thermogravimetric Analysis (TGA) of the sample. It is noted from the data that vacuum pyrolysis is a viable process to obtain high grade liquid fuel. Further experiments are in progress to establish the optimal operating conditions.

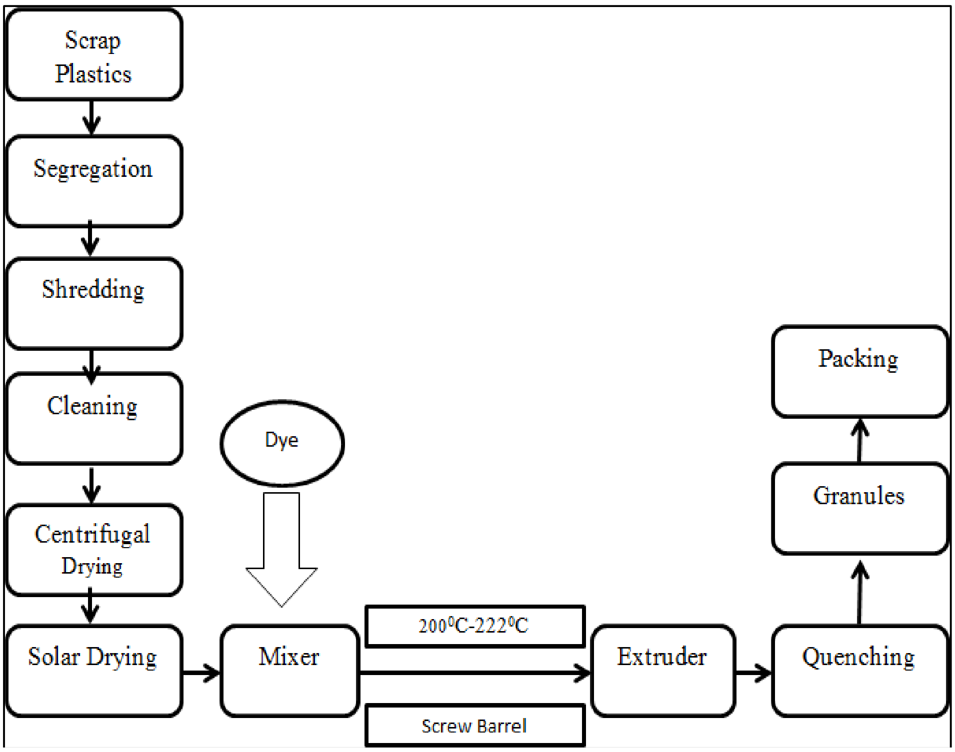
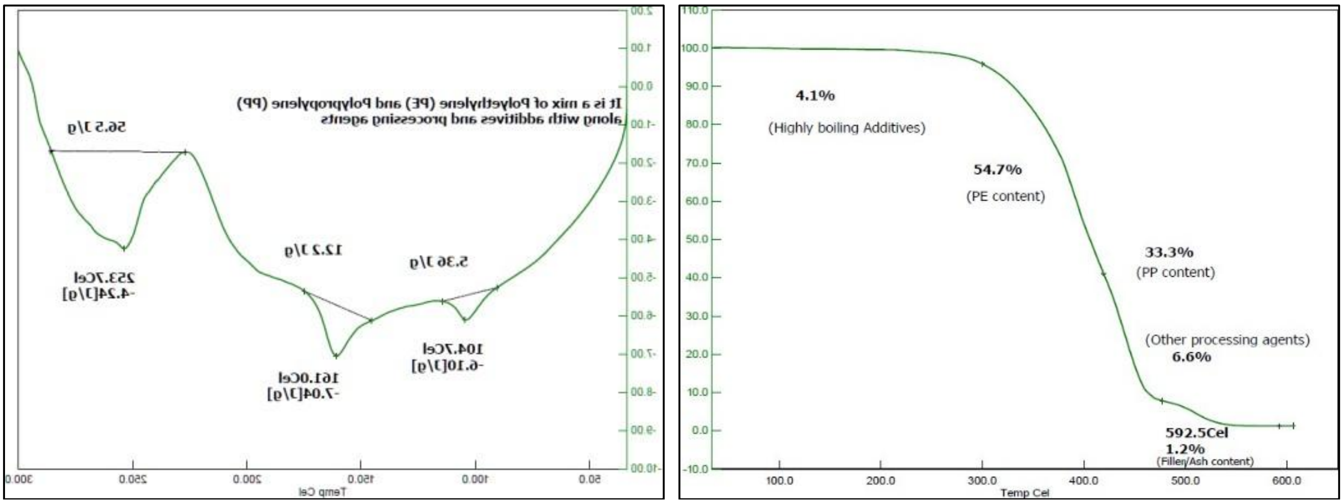


Fig 1: Plastic Recycling Flow Chart



DSC of Sample TGA of Sample

Fig 2: Differential Scanning Colorimetry (DSC) and Thermogravimetric Analysis (TGA) of the sample

Conclusion

E-waste is a rich source of metals, plastics and glass necessitating their separation for further processing into usable products. The nature and composition of plastics prohibits their disposal through land filling or incineration. In land filling, they pollute land and water bodies, while in incineration; they emit hazardous dioxins, furans and polycyclic aromatic hydrocarbons. Viable methods of disposal include pyrolysis to liquid fuel, segregation followed by purification and recasting into usable products, mixing with concrete for road-laying etc. the process described in the paper is a commercially viable process wherein plastics are separated from glass and metal, followed by shredding, cleaning and extruding into strands which are cut into granules to be sold to component manufacturers.

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