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Recycling of waste electrical cables

Abstract

Cables, that are the indispensable parts of electrical and electronic industry, consist of plastics, aluminum, and copper. Cables are usually recycled once the electronic apparatus complete their useful lives. The old fashioned way of recovery process is to burn the plastic that covers the wire, and then recover the copper and aluminum. But this technique is extremely harmful to the environment since it releases toxic gases. Waste cables are very important source of raw material in terms of their non-ferrous metal content and it is an obligatory measure to recover these metallic contents both for economical and ecological reasons. The recovery of these metals decreases the danger of global warming. Metals can be infinitely recycled without compensating form their initial quality. Moreover, the recycling procedures generally consume much less energy than primary production methods and its CO_2 emissions are decreased. The aim of this research is to recover copper from waste electrical cables by the application of physical and chemical separation techniques. Waste cables are shredded first to decrease their size and the metallic parts are separated from plastics physically by using gravity and electrostatic separation techniques. Then copper was recovered from metallic part by smelting and refining. As a result of this experimental study, 97.2% of copper in waste cables is recovered and refined copper with 99.6 %Cu content is produced.

Keywords: cables, copper, plastics, recycling

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Introduction

Today, recycling and recovery of valuable metals from all sorts of waste are the most commonly discussed and heavily researched fields. One of the main reasons of this is both the global warming and ever increasing amounts of waste and scrap material. Severe regulations and legislations are passed in developed countries' parliaments in order to recycle the produced goods when their economic lives are over. A steady decrease is observed in our natural resources due to changes in our habits of consumption, in parallel to the increasing world population. Therefore, recycling of valuable waste by decreasing the amount of material consumed constitutes an important agenda.[1] Changes in the habits of consumption cause the formation of various sorts of waste material. One of those various waste materials is "electronic equipment waste", briefly addressed as e-waste. Due to the unprecedented development of today's technologies, electronic equipments which have faster, more efficient, more stylish, and more economical marketing trends will be either incapable of working in one or six-year-period or repairing them will be more costly than their new ones. Thus, the electronic equipment once bought with a high price, will be either given away to the scrap dealers or thrown out to the garbage unconsciously, as the developing technology is presented more economically. That is how the problem of modern age, e-waste, was born.[2] It is obvious that our natural resources are limited and will be shortly exhausted unless properly used. Developed countries which realized that the resources were being jeopardized by the energy crisis, conducted research and developed methods for collecting and recycling wastes, in order to prevent the extravagance and conserve the natural resources. With this in mind, the member countries of the European Economic Community regulated that the recycling of electronic equipments' wastes an imperative action. By the same token, the infrastructure work is being conducted in Turkey and some important arrangements are being accomplished.[3] In a general sense, recycling concept is actually transforming the waste to secondary raw material by some physical and chemical processes and re-joining to the production process.[4] Waste cable recycling is widely utilized both in Turkey and in the world. Waste cables are important source raw material in terms of their non-ferrous metal content. In Germany alone, about 150.000tons of waste cable is generated annually. Cables that materialize as a result of repairs, telephone line cables, or cables that are produced defectively are some them. Numerous varieties exist in isolation materials, other than the copper, aluminum, lead, and steel; namely, PE and rubber coatings, various kinds PVC's, woven plastics, etc.[1] Environment and Forestry Ministry of Turkey published a legislation regarding the collecting, recycling, and proper disposal of e-wastes. As of 1 July 2012, producers will be responsible for financing the e-wastes that would materialize as a result of utilization of every product that is marketed.[5] According to these legislations, the most appropriate processes must be developed and the best separation methods must be utilized for the recycling of e-wastes.

There are several processes to recover metal and plastics from electronic wastes.[6–11] After liberation of the materials in the disassembled WEEE through comminuting, the separation of them can then be performed by mechanical/physical methods. The differences on the physical characteristics of materials in non-homogeneous compounds, such as magnetism, electric conductivity and density, etc., are the bases of the mechanical/physical separation of them. Mechanical/physical separation processes include electronic magnetic separation, electronic-conductivity-based separation, density-based separation and so forth. All of them have application instances in the WEEE recycling field. Magnetic separation is widely used for the recovery of ferromagnetic metals from non-ferrous metals and other nonmagnetic wastes. Over the past decade, the advances in the design and operation of high-intensity magnetic separators also make it possible to separate copper alloys from the waste matrix.[12] Electric conductivity-based separation is used to separate materials of different electric conductivity (or resistivity). There are three typical electric conductivity-based separation techniques: (1) Eddy current separation, (2) Corona electrostatic separation, and (3) Triboelectric separation.[13–16] After separation of metallic parts, there are some chemical treatment processes. Most of the scrap copper is re-melted and re-cast without chemical treatment.[17] The remainder, however, requires refining to be used again.

Within the framework of this work, copper recovery is targeted from the used electric cables that are considered as e-wastes, and copper wire was separated as a valuable metal from the plastic parts by utilizing mineral processing techniques. This study shed some lights for the determination of processes that could be utilized by the manufacturers for the recycling of e-wastes. Moreover, this study, which may be considered as a first step for recycling e-wastes that will increase enormously in the near future, is one of the important fields of work of mineral processing engineering.

Material & method

The aim of this research is to recover copper from waste electrical cables by the application of physical and chemical separation techniques. Waste cables are shredded first to decrease their size and the metallic parts are separated from plastics physically by using gravity and electrostatic separation techniques. Copper was also recovered from metallic part by smelting and refining. In the experiments about 13kg waste electrical cables in different shapes, diameters and length are used. Copper cable diameters vary between 0.5-2.5cm in the form of wire and rod covered with plate. In the experiments a mixture of energy, telephone, Lan&Data, single line PVC, coaxial, underground energy, and household appliance cables are used. In the experiments physical separation methods are utilized to recover copper from used cables. For this purpose in order of size reduction, Mozley table and electrostatic separation tests are applied. During the tests screening and chemical analyses are made. After separating plastic and copper, melting of copper is done by pooling for the production of pure copper. A flow sheet of experimental procedure is seen in Figure 1.

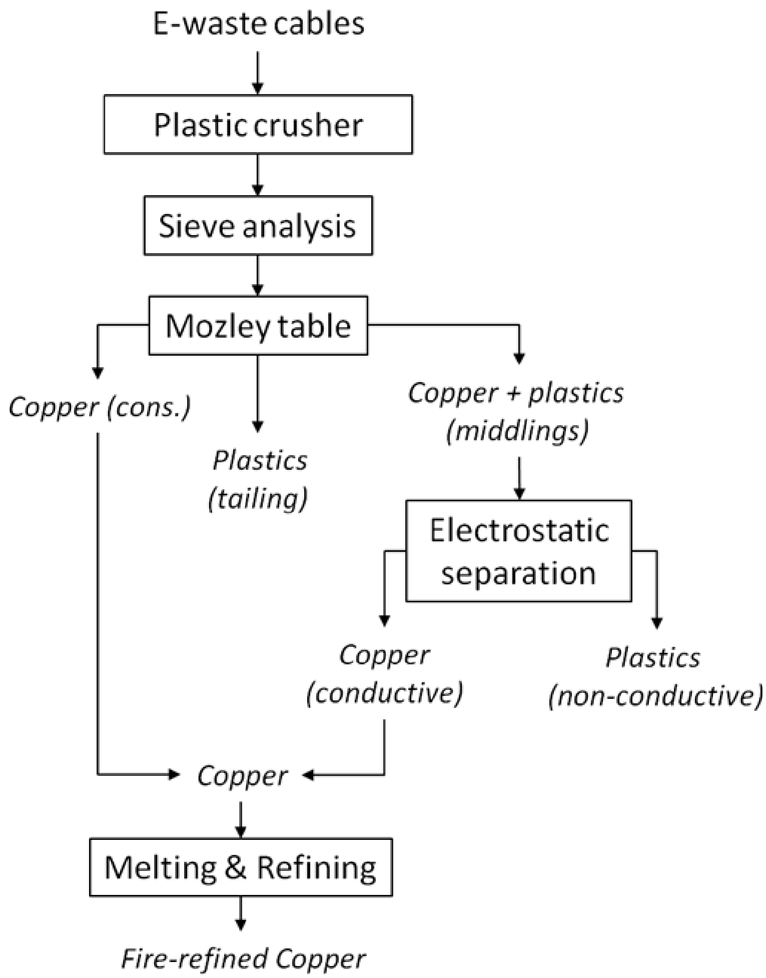
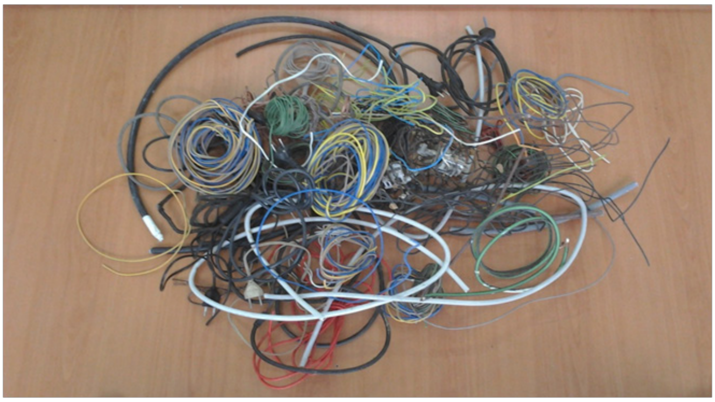


Figure 1 A flow sheet of experimental procedure.

Results and discussion

Size reduction tests

Size reduction is applied in order to liberate the conductive copper part from plastics in waste cables. Before feeding the material to plastic shredder, plug, key, etc. parts are removed by cutting. Since plastic and copper in the shredded material are not distributed homogenously (Figure 2), well controlled sampling is performed before screening and chemical analysis. About 1 kg shredded sample is subjected to screening test and sieving results are given in Table 1. Copper analysis in each size range is also done and listed in Table 1. As it can be seen from the table, 85 % of copper was accumulated in the size range of over 0.5mm.


(A)


(B)

Figure 2 Original (A) and shredded waste cables (B) subjected to the experimental study.

Table 1 Particle Size Distribution and Copper Analysis Results

Particle Size Range (mm)	Amount (%)	Undersize (%)	Oversize (%)	Content (Cu %)	Distribution (Cu %)
-4+2	31.71	100.00	31.70	37.16	18.28
-2+1	47.77	68.29	79.48	76.23	56.49
-1+0.5	10.24	20.52	89.72	72.82	11.57
-0.5+0.3	4.39	10.28	94.11	86.70	5.90
-0.3+0.212	3.98	5.89	98.08	88.98	5.49
-0.212+0.15	1.40	1.92	99.48	82.22	1.78
-0.15+0.106	0.33	0.52	99.81	58.01	0.29
-0.106+0.075	0.13	0.20	99.93	64.14	0.13
-0.075+0.053	0.07	0.07	100.00	67.45	0.07
Total	100			64.46	100.00

Mozley table tests

Since there is a big difference in the densities of copper and plastics (the density of pure copper is 8.9g/cm^3 and the density of plastics 1.5g/cm^3), Mozley table is used for separation. 500g material is fed in each test by changing vibration and feed water velocity in order to find the best separation condition. According to the preliminary tests results, vibration is kept constant and water velocity is changed during the tests. Three products are taken and the results are shown in (Table 2) (Figure 3). According to the shape factor, having some leaf type copper particles and fine copper wires, some copper is lost in the middling's which then fed to the electrostatic separator (Figure 4). As it can be seen from Table 2, %59.4 of the sample with 98,5% Cu is produced as a concentrate with 95.5% efficiency. This shows that Mozley table is very effective on separating copper and plastics in waste cables. 30.4% of the feed with 0.66% Cu content is disposed. Middling's with 25.01% Cu content is sent to the electrostatic separation as mentioned.

Table 2 Mozley table test results

Products	Amount (%)	Content (%Cu)	Efficiency (%)
Concentrate (Copper)	59.4	98.5	95.5
Middling's (Copper+ Plastics)	10.2	25.01	4.2
Tailing (Plastics)	30.4	0.66	0.3
Total	100.0	61.25	100.0

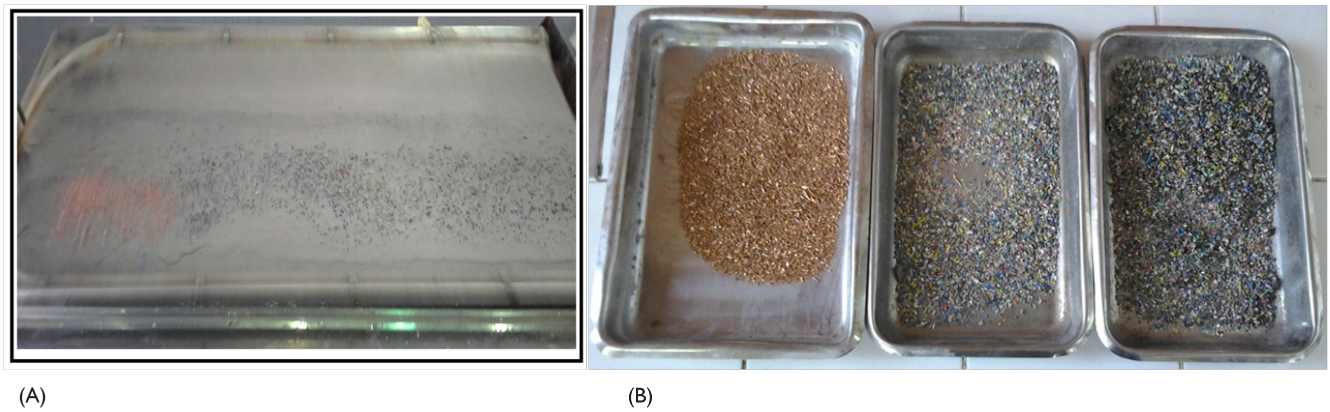


Figure 3 Mozley table (A) separation f copper and plastics, (B) products (copper-middlings-tailing).

Figure 4 Heavy – fine (rod type) – leaf type copper particles.

Electrostatic separation tests

Electrostatic separation tests are applied to the middling's of Mozley table in four steps. Experimental parameters current and splitter angle are chosen as 10Kv-87°, 12 Kv-90°, 13Kv-92°, 13Kv-92°. In order to find optimum separation conditions. Results found at those conditions are given in Table 3. Combined results of Mozley table and electrostatic tests are also shown in Table 4. According to that table, a concentrate with 96.6% Cu content is produced with 97.2% efficiency. As it can be seen from the results during the electrostatic separation tests some copper loss is observed in the tailing (non conductive part). Leaf type particles due to the shape factor and heavy particles due to their weights, as shown in Figure 4, are ended up in tailing. In general plastic particles are acted as conductive particles due to being loaded with electrical charge and appeared in the concentrate.

Table 3 Electrostatic separation test results

Products	Amount (%)	Content (% Cu)	Efficiency (%)
Concentrate (Copper)	22	47.26	41.60
Tailing (Plastics)	78	18.74	58.40
Total	100	25.01	100.00

Table 4 Combined results of Mozley table and electrostatic tests

Products	Amount (%)	Content (% Cu)	Efficiency (%)
Concentrate (Copper)	61.6	96.6	97.2
Tailing (Plastics)	38.4	4.4	2.8
Total	100.0	61.25	100.0

Smelting and refining experiments

The copper from the above processes is then smelted and refined. In order to produce pure copper from Mozley table copper concentrate with high copper content, direct smelting tests are done and pooling is applied to be sure that remaining impurities are removed. Total amount of 3500g shredded sample is subjected to the Mozley table tests in order to have enough samples for smelting. 2150g sample is smelted in induction furnace by pooling. As a result of this, refined copper (99.6 %Cu) is produced and is shown in Figure 5.

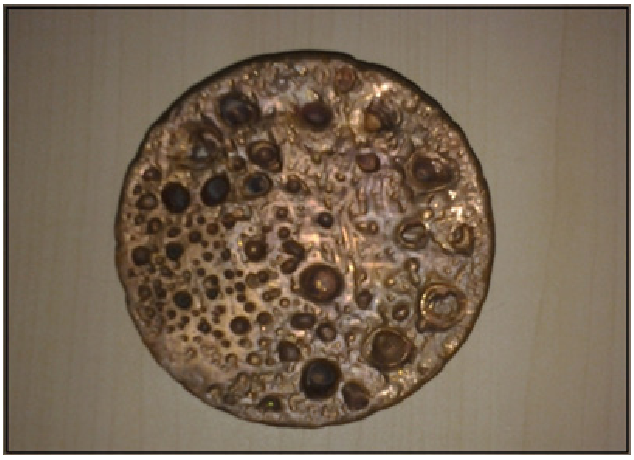


Figure 5 Refined copper produced as a result of this experimental study.

Conclusion

Waste cables are very important source of raw material in terms of their non-ferrous metal content. Therefore it is necessary to recover these metallic contents both for economical and ecological reasons. Waste cables containing different types are shredded first to decrease their size and the metallic parts are separated from plastics physically by using gravity (Mozley table) and electrostatic separation techniques. Then copper was also recovered from metallic part by smelting and refining. As a result of this experimental study, 97.2% of copper in waste cables is recovered and refined copper with 99.6 %Cu content is produced. Although this experimental flow sheet applied for the recovery of copper from waste cables is found very successful, by sorting results would be even better. In industrial scale shaking tables and air tables can be used. Coaxial cables may be separated before shredding to have better results. In conclusion, this experimental study showed that copper and plastics can be separated effectively from waste cables very efficiently.

Acknowledgements

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Conflicts of interest

Authors declare that there is no conflict of interest.

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