

**INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH  
TECHNOLOGY****EXTRACTION OF MATERIALS FROM E-WASTE****Aljo Anand<sup>\*1</sup>, Seju Thomas<sup>2</sup> & Deeksha Aggarwal<sup>3</sup>**<sup>\*1,2&3</sup>Department of Chemistry, Christ University, Bengaluru, Karnataka, India - 560029<sup>2</sup>Dharamaram College, Bengaluru - 560029

DOI: 10.5281/zenodo.829776

**ABSTRACT**

Electronic waste (E-waste) is the term used to describe old, end-of-life or discarded applications. It includes computers, consumer electronics, batteries etc. which have been disposed of by their original users. It is one of the fastest – growing pollution problems worldwide given the presence of a variety of toxic substances (heavy and toxic metals like Cd, Pb, Ni, Li,.....) which can contaminate the environment and threaten human health, if disposal protocols are not meticulously followed. The current study presents an overview of toxic substances present in e-waste, which can be extracted using standard methods. These extractions can be done in laboratories and also in common household equipped with certain safety measures. E-waste solutions were analyzed for presence of various metals qualitatively and those present were estimated quantitatively. From the eight Ni-Cd batteries containing a total of 11.342 g of source material from which 5.986 g of Graphite and 2.109 g of Cadmium were obtained. Eight AA alkaline batteries contain 16.325 g of source material which yielded 6.859 g of graphite, 5.439 g of Manganese and 2.380g of Nickel. From six Lithium Laptop batteries yielded a source of 15.714 g out of which 2.989 g of Lithium were extracted. These salts or compounds extracted can be recycled and purified. It also can be used as a substituent or potential replacement in the laboratories.

**KEYWORDS:** e-waste, pollution, cadmium, lithium, nickel, salts and batteries.**I. INTRODUCTION**

Electronic waste, commonly known as e-waste, waste electrical and electronic equipment or end-of-life electronics, denotes electronic and electrical equipment, including all components, sub-assemblies, and consumables, deemed obsolete or unwanted by a user. However, the word can be misleading because it characterizes used electronics categorically as waste, although the flows include some equipment that will be reused via secondary markets. Functionality of information and communication technology (ICT) is growing rapidly, and from a sustainability viewpoint, there are clearly social benefits to ICT's technological evolution that contribute to its continuity. As technology advances, people purchase increasingly more electronic devices (such as computers, entertainment electronics, mobile phones and others) even though they are not essential. Meanwhile, the significant increase in e-waste has not corresponded to growth in the processes related to collection, recycle and reuse of these electronic devices, which has led to the difficulties in disposing this waste off and we are losing upon many resources of ours which are found in nature.

Electrical and electronic equipment contain various fractions of valuable materials. Most of the valuable substances are found in printed circuit boards, which occur in relevant quantities mainly in the categories Office, Information and Communication Equipment as well as Entertainment and Consumer Electronics. Besides well-known precious metals such as gold, silver, platinum and palladium also scarce materials like indium and gallium start to play an important role, due to their application in new technologies (e.g. flat screens, photovoltaics) <sup>[1]</sup>

**The standard composition of E-Waste**

E-waste is dangerous to deposit into Solid Waste landfills because of the heavy metals contained in them. All the circuitry uses trace amounts of these materials that may not be hazardous on an individual basis, but we are landfilling tons and tons of these materials together. Like other Hazardous materials going into these landfills, the cumulative effect will be dangerous. Solid Waste Landfills are built to handle banana peels, and other non-toxic materials; not this toxic-soup. We will have to deal with these materials at some point. Either we deal with



them now to divert a usable resource into a recovery market that exists and can be economically rewarding. Or, we dispose of them in the landfills and will have to deal with the breakdown of liners and barriers, one day, and increase filtration needs of water, and possible other contaminants to our natural resources [2]. In the electronics recycling process, valuable materials can be recovered from the electronics that can be used to be made into new products. As a result, we reduce pollution and save energy by extracting fewer raw materials from the earth. Many electronic waste recycling facilities actually just send the electronics they collect overseas, where people pick through massive landfills of electronic waste to collect the metals and profitable materials that are found in electronics. In the process, they come in contact with all of the dangerous chemicals also found in electronic waste. Hence it's high time that the country comes up with its own solution for E-waste disposal and aware the public also about it.

There are various ways of extraction of heavy metals from E-waste by applying basic chemistry. For this the E-waste should be segregated from the rest of the waste and has to be recycled to obtain the composition of the E-waste, such extraction of heavy metals from the waste collected from the cities also called as city mining. City mining will just not help to reduce the waste but also but also will reduce the stress on the natural mines and will also help in the following ways-

Conserves natural resources. Recycling recovers valuable materials from old electronics that can be used to make new products. As a result, we save energy, reduce pollution, reduce greenhouse gas emissions, and save resources by extracting fewer raw materials from the earth. Protects your surroundings. Safe recycling of outdated electronics promotes sound management of toxic chemicals such as lead and mercury. Helps others. Donating your used electronics benefits your community by passing on ready-to-use or refurbished equipment to those who need it. Create Jobs. E-waste recycling creates jobs for professional recyclers and refurbishes and creates new markets for the valuable components that are dismantled. Saves landfill space. E-waste is a growing waste stream. By recycling these items, landfill space is conserved. The materials which are extracted after the recycling of E-waste have very high value. It has a great value at the commercial level. Metals like lead, cadmium, nickel, aluminium etc. have a great importance which is elaborated in the paragraph following [3].

### **Cadmium**

**Batteries-** Ni-Cd batteries :In 2009, 86% of cadmium was used in batteries, predominantly in rechargeable nickel-cadmium batteries. Nickel-cadmium cells have a nominal cell potential of 1.2 V. The cell consists of a positive nickel hydroxide electrode and a negative cadmium electrode plate separated by an alkaline electrolyte (potassium hydroxide). The European Union set the allowed use of cadmium in electronics in 2004 to limits of 0.01%, with several exceptions, but reduced the allowed content of cadmium in batteries to 0.002%.

**Electroplating-** A photograph and representative spectrum of photoluminescence from colloidal Cd-Se quantum dot. Cadmium electroplating, consuming 6% of the global production, can be found in the aircraft industry due to the ability to resist corrosion when applied to steel components. This coating is passivated by the usage of chromate salts. A limitation of cadmium plating is hydrogen embrittlement of high-strength steels caused by the electroplating process. Therefore, steel parts heat-treated to tensile strength above 1300 MPa (200 ksi) should be coated by an alternative method (such as special low-embrittlement cadmium electroplating processes or physical vapor deposition). In addition, titanium embrittlement caused by cadmium-plated tool residues resulted in banishment of these tools (along with routine tool testing programs to detect any cadmium contamination) from the A-12/SR-71 and U-2 programs, and subsequent aircraft programs using titanium.

**Nuclear fission-** Cadmium is used as a barrier to control neutrons in nuclear fission. The pressurized water reactor designed by Westinghouse Electric Company uses an alloy consisting of 80% silver, 15% indium, and 5% cadmium.

**Laboratory uses-** Violet light from a helium cadmium metal vapor laser. The highly monochromatic color arises from the 441.563 nm transition line of cadmium. Helium-cadmium lasers are a common source of blue-ultraviolet laser light. They operate at either 325 or 422 nm and are used in fluorescence microscopes and various laboratory experiments. Cadmium selenide quantum dots emit bright luminescence under UV excitation (He-Cd laser, for example). The color of this luminescence can be green, yellow or red depending on the particle size. Colloidal solutions of those particles are used for imaging of biological tissues and solutions with a fluorescence microscope. Cadmium is a component of some compound semiconductors, such as cadmium sulfide, cadmium selenide, and cadmium telluride, which can be used for light detection or solar cells. HgCdTe is sensitive to

infrared light and therefore may be utilized as an infrared detector or switch for example in remote control devices.

### Nickel

Nickel-containing materials play a major role in our everyday lives – food preparation equipment, mobile phones, medical equipment, transport, buildings, power generation – the list is almost endless. They are selected because - compared with other materials - they offer better corrosion resistance, better toughness, better strength at high and low temperatures, and a range of special magnetic and electronic properties. Pots and Pans are alloys of iron, nickel and chromium, of which stainless steels (frequently 8-12% nickel) are the largest volume. Nickel based alloys - like stainless steel but with higher nickel contents - are used for more demanding applications such as gas turbines and some chemical plants. In addition, iron and nickel alloys are used in electronics and specialist engineering, while copper-nickel alloys are used for coinage and marine engineering. There are about 3000 nickel-containing alloys in everyday use. About 90% of all new nickel sold each year goes into alloys, two-thirds going into stainless steel.

Nickel metal is used to provide hard-wearing decorative and engineering coatings as 'nickel-plating' or 'electroless nickel coating' or 'electroforming'. When used with a top layer of chromium, it is popularly known as 'chrome-plating'. When done in combination with silicon carbide it is known as composite plating. Nickel is a key part of several rechargeable battery systems used in electronics, power tools, transport and emergency power supply. Most important today are nickel-metal hydride (NiMH). Nickel is a key ingredient in many catalysts used to make chemical reactions more efficient. Nickel use is growing at about 4% each year while use of nickel-containing stainless steel is growing at about 6%. The fastest growth today is seen in the newly and rapidly industrializing countries, especially in Asia. Nickel-containing materials are needed to modernize infrastructure, for industry and to meet the material aspirations of their populations. Toyota Prius. Much more about all these applications of nickel can be found in Nickel Use in Society and the Material Selection and Use areas of the web site. A list of some of the major nickel alloy and nickel stainless steel producers in the world is available here. Most nickel-containing products have long useful lives. Average life is probably 25-35 years, with many applications lasting much longer. Nickel containing products frequently can provide optimum solutions to practical challenges at a lower total cost and with more efficient use of resources, including energy. At the end of their useful life, nickel-containing products can be collected and recycled for future use and re-use. Nickel is one of the most recycled materials globally. It is collected and recycled, mostly in the form of alloys. About half of the nickel content of a stainless steel product today will have come from recycled sources. For more information on nickel recycling go to Recycling. Scrap Nickel is of considerable economic and strategic importance to many countries, as can be appreciated from the wide diversity of end-use industries which it serves. It is traded on the London Metal Exchange. The International Nickel Study Group, based in Lisbon, Portugal, is an inter-governmental body which publishes monthly statistics on nickel supply and demand, and acts as a forum for the exchange of information and views on nickel trends. Nickel and nickel compounds can in certain circumstances be associated with toxicity, carcinogenicity and with dermal sensitization. Most of the practical risks associated with nickel hazards are seen in certain complex processes used in nickel production and refining. The risks are well known and are managed and controlled by specific workplace regulation. In the nickel industry's view, significant risks are not normally associated with the use of nickel, nickel-containing alloys or nickel-containing products, with the exception of the use of nickel and some nickel alloys in jewelry. Nickel use makes a very high practical contribution to improvements of health, safety and protection of the environment. Society will lose a lot more than it will gain if it adopts an excessively precautionary approach to the assessment and management of the risks associated with nickel.

### Graphite

Along with these heavy metals few non-metals like graphite are also obtained in considerable quantity which also has great importance in the industry. Steelmaking- Natural graphite in this end use mostly goes into carbon raising in molten steel, although it can be used to lubricate the dies used to extrude hot steel. Supplying carbon raisers is very competitive, therefore subject to cut-throat pricing from alternatives such as synthetic graphite powder, petroleum coke, and other forms of carbon. A carbon raiser is added to increase the carbon content of the steel to the specified level. An estimate based on USGS US graphite consumption statistics indicates that 10,500 tons were used in this fashion in 2005.

**Expanded graphite**

Expanded graphite is made by immersing natural flake graphite in a bath of chromic acid, then concentrated sulfuric acid, which forces the crystal lattice planes apart, thus expanding the graphite. The expanded graphite can be used to make graphite foil or used directly as "hot top" compound to insulate molten metal in a ladle or red-hot steel ingots and decrease heat loss, or as firestops fitted around a fire door or in sheet metal collars surrounding plastic pipe (during a fire, the graphite expands and chars to resist fire penetration and spread), or to make high-performance gasket material for high-temperature use. After being made into graphite foil, the foil is machined and assembled into the bipolar plates in fuel cells. The foil is made into heat sinks for laptop computers which keeps them cool while saving weight, and is made into a foil laminate that can be used in valve packings or made into gaskets. Old-style packings are now a minor member of this grouping: fine flake graphite in oils or greases for uses requiring heat resistance. A GAN estimate of current US natural graphite consumption in this end use is 7,500 tons.

**Intercalated graphite**

Structure of CaC<sub>6</sub>. Graphite forms intercalation compounds with some metals and small molecules. In these compounds, the host molecule or atom gets "sandwiched" between the graphite layers, resulting in compounds with variable stoichiometry. A prominent example of an intercalation compound is potassium graphite, denoted by the formula KC<sub>8</sub>. Graphite intercalation compounds are superconductors. The highest transition temperature (by June 2009) T<sub>c</sub> = 11.5 K is achieved in CaC<sub>6</sub> and it further increases under applied pressure (15.1 K at 8 GPa).

**Brake linings**

Natural amorphous and fine flake graphite are used in brake linings or brake shoes for heavier (nonautomotive) vehicles, and became important with the need to substitute for asbestos. This use has been important for quite some time, but non-asbestos organic (NAO) compositions are beginning to cost graphite market share. A brake-lining industry shake-out with some plant closings has not helped either, nor has an indifferent automotive market. According to the USGS, US natural graphite consumption in brake linings was 6,510 tons in 2005.

Extraction of these heavy metals from E-waste, if is done at a university level also, this can be a source of income and few salts containing cadmium, mercury, lead etc. can also be obtained for the student to work in the laboratory. While extracting these metals, precaution has to be taken as the metals are dangerous and toxic in nature, if precautions are not taken it can be fatal also.

Mahadeo M Ttlu while working on their research "Alkalimetric Method For The Estimation Of Cadmium And Zinc. In Cadmium-Copper And Zinc-Copper Alloys," studied the various method for the estimation of cadmium and zinc using potassium iodide and sodium thiosulphate as reagents Sodium hydrogen carbonate, used as the precipitant in the above method, keeps copper(II) in solution, allowing complete separation of cadmium and zinc from copper-containing mixtures<sup>[4]</sup>.

Ramachandra Reddy et al in their study on "Chloride leaching and solvent extraction of cadmium, cobalt and nickel from spent nickel-cadmium batteries" talked about the studies conducted on the leaching and solvent extraction separation of metals from chloride leach liquor of spent nickel-cadmium batteries diluted in kerosene as the extractants. Dissolution of these metals increased with increase in acid concentration and time but decreased with the solids-to-liquid ratio. Complete dissolution of Cd, Co and Ni was achieved with 1.5 M HCl at 85 °C for 8 h and a solids-to-liquid ratio of 4. Treatment of leach liquor for the separation of metals showed that increase of extractant and chloride ion concentration increased the percentage extraction of cadmium. Moreover, it enabled a clear separation of Cd from Co and Ni. Extraction of cobalt involves a cation-exchange mechanism with the formation of a 1:2 metal-to-ligand complex in the organic phase. Based on the distribution data, extractant concentration and equilibrium pH of the aqueous phase, a possible separation process was proposed for the recovery of cadmium, cobalt and nickel with >99% efficiency<sup>[5]</sup>.

Tanaka M. and T. Niinomi conducted studies on extraction of copper in their paper "Extraction of copper (II) with capric acid dissolved in benzene". The Extraction of copper (II) with capric acid dissolved in benzene was theoretically treated. The extracted species had the dimeric structure of composition (CuR<sub>2</sub>HR)<sub>2</sub> down to 10–5 M of copper. In the presence of acetate buffer, acetate incorporates in the extracted species and the ultimate composition approached to (CuRAcHR)<sub>2</sub> at acetic acid concentrations higher than about 0.5 M<sup>[6]</sup>.

[Anand \* *et al.*, 6(7): July, 2017]ICT<sup>™</sup> Value: 3.00

Thakare Y S et al in their study on “Highly selective liquid-liquid extraction of cadmium (II) with hexaacetato calyx (6) arene” talks about cadmium (II) which had been extracted with 10 ml of 0.0001 M acetyl derivative of calyx (6) arene at pH 8.0 by equilibrating for 5 min. Cadmium (II) was stripped quantitatively with 0.5 N hydrochloric acid and determined photometrically by complexation with 4-(2-pyridylazo) resorcinol at 495 nm. The method afforded the binary separation of cadmium from associate elements and was further extended to analyze the synthetic mixtures. The nature of extracted species was determined from the log plots. The result showed the formation of an ion pair complex  $[Cd(HR)_2]_{org}$  in the organic phase. The temperature dependence of the extraction equilibrium was examined by the temperature variation method. The value of  $\Delta H^0 = +160485.48 \text{ J mole}^{-1}$  indicated that the extraction reaction was endothermic. The metal loading capacity of the reagent was found to be 150 ppm. The proposed method was applicable to the analysis of real samples and the results obtained were found to be reproducible and accurate<sup>[7]</sup>.

The study on “Hydrometallurgical processing of manganese ores: A review” done by A. Baba Alafara et al talks about how hydrometallurgy is considered to be the most suitable extractive technique for the extraction and purification of manganese as compared to all other techniques including bio metallurgy and pyro metallurgical processes. In the hydrometallurgical processing of manganese ore the leach liquors often contain divalent ions such as iron, manganese, copper, nickel, cobalt and zinc along with other impurities which make manganese very difficult to separate. The processes employed for solution concentration and purification in the hydrometallurgical processing of manganese include precipitation, cementation, solvent extraction and ion exchange. Solvent extraction also proves more efficient and it plays vital roles in the purification and separation of the manganese as compared to all other techniques. A detailed review of the various steps involved in the hydrometallurgical manganese processing, concentration and purification processes and newer processes of extraction of manganese from ores and waste materials were discussed<sup>[8]</sup>.

Kuman Manis Jha et al. in their study “Review on solvent extraction of cadmium from various solutions” says about how cadmium had a wide application in the manufacturing of alloys, batteries, pigments and metal plating. The solid and liquid waste was generated during the production and at the end of service life. The recovery and recycling of cadmium from these waste materials was necessary to gain the metal values and protect the environment from hazard. In hydrometallurgical processes, solvent extraction was an important process for the recovery of non-ferrous metals from different aqueous leach liquor and waste effluent/solutions. Different process parameters, viz. pH, organic-to-aqueous ratio, kinetics of extraction and stripping to establish the conditions required for the extraction of cadmium and formation of a complex in the organic phase from different solutions, have been reported. The studies show the possibility of extraction and separation of cadmium from different solutions containing other metallic ions using anionic, cationic, solvating or mixed extractants. However, further attempts are also being made to develop selective organic extractants to recover cadmium efficiently on a commercial scale. The findings of these studies are also reported.

M. R. Ullah and M. EnamulHaque in their study “Spectrophotometric Determination Of Toxic Elements (Cadmium) In Aqueous Media” talks about the presence of Trace amount of toxic element (Cadmium) which was determined by spectrophotometer method using 1, 2-dihydroxy anthraquinone-3-sulphonic acid, sodium salt. (Alizarin red S) as a new spectrophotometer reagent. Alizarin red S reacts in slightly acidic solution (0.005 M H<sub>2</sub>SO<sub>4</sub>) with cadmium to give a deep greenish yellow chelate which had an absorption maximum at 422 nm. The reaction was instantaneous and absorbance remains stable for over 24hrs. The average molar absorption coefficient and sandell’s sensitivity were found to be 2.24 × 10<sup>3</sup> L mol<sup>-1</sup> cm<sup>-1</sup> and 20 ng cm<sup>-2</sup> of Cd respectively. The method was successfully used in the determination of cadmium in Several Standard Reference Materials (alloys, steels and water) as well as in some environmental waters (In land and surface), biological samples (human blood and urine), soil samples and complex synthetic mixtures. The method had high precision and accuracy. (S = 0.01 for 0.5 g mL<sup>-1</sup>)<sup>[9]</sup>.

## II. EXPERIMENTAL SECTION

### Method

#### *For the extraction of Manganese*

The batteries of the varying compositions are carefully opened. The inner contents are dissolved in aquaregia (HNO<sub>3</sub> + 3HCl) and is kept undisturbed for few minutes in a fume chamber until it stops fuming and all the contents are completely dissolved except the graphite content and the other undissolved constituents. The concoction after the complete dissolution is taken and poured into a 50ml burette which is previously fitted with

a piece of non-adsorbent cotton and then lined with a layer of amberlite so as to filter off the undissolved graphite effectively. The remaining filtrate is treated with a few drops of 3mol/L HCl. H<sub>2</sub>S gas is passed in acidic medium. To the solution, NH<sub>4</sub>Cl and NH<sub>4</sub>OH is added. H<sub>2</sub>S is passed in basic medium. A pink precipitate is obtained. This is then treated with 0.5mol/L HCl. In the absence of precipitate, the solution is treated with 6mol/L NaOH and 3% H<sub>2</sub>O<sub>2</sub>. The solution shows the presence of a brown precipitate. This is then treated with NaBiO<sub>3</sub> and HNO<sub>3</sub>. A violet coloration is observed and this shows the presence of MnO.

#### ***For the extraction of Lithium***

The Li ion containing batteries are carefully opened and the polymers contained inside are separated from the metal containing thin sheets. The metal sheets are then dipped into a beaker containing 100% ethyl alcohol. It is left undisturbed for a while. Li precipitates out into the ethyl alcohol as its respective hydride. The precipitate containing solution is then poured into distilled water. Here the Li hydride precipitates out in its oxide form. The solution containing the Li is then filtered using filter paper and the residue containing the lithium is dried and stored for further use.

#### ***For the extraction of Nickel***

The batteries of the varying compositions are carefully opened. The inner contents are dissolved in aquaregia (HNO<sub>3</sub> + 3HCl) and is kept undisturbed for few minutes in a fume chamber until it stops fuming and all the contents are completely dissolved except the graphite content and the other undissolved constituents. The concoction after the complete dissolution is taken and poured into a 50ml burette which is previously fitted with a piece of non-adsorbent cotton and then lined with a layer of amberlite so as to filter off the undissolved graphite effectively. The remaining filtrate is treated with a few drops of 3mol/L HCl. H<sub>2</sub>S gas is passed in acidic medium. To the solution, NH<sub>4</sub>Cl and NH<sub>4</sub>OH is added. H<sub>2</sub>S is passed in basic medium. A black precipitate is obtained. This is then treated with 0.5mol/L HCl. The black precipitate is then treated with conc. HNO<sub>3</sub>. Ni<sup>2+</sup> is then obtained.

#### ***For the extraction of Cadmium***

The batteries of the varying compositions are carefully opened. The inner contents are dissolved in aquaregia (HNO<sub>3</sub> + 3HCl) and is kept undisturbed for few minutes in a fume chamber until it stops fuming and all the contents are completely dissolved except the graphite content and the other undissolved constituents. The concoction after the complete dissolution is taken and poured into a 50ml burette which is previously fitted with a piece of non-adsorbent cotton and then lined with a layer of amberlite so as to filter off the undissolved graphite effectively. The remaining filtrate is treated with a few drops of 3mol/L HCl. H<sub>2</sub>S gas is passed in acidic medium. A yellow precipitate is present as Cadmium in its sulphide form.

### **III. RESULTS AND DISCUSSION**

The qualitative analysis of these above said metal ions like Cadmium, Manganese, Nickel and Lithium were obtained through the various process mentioned above. The obtained cadmium salts are slightly yellowish because of it being in aqua regia. When its precipitated out it's a colourless salt. Then the Manganese salt is slightly muddy brownish coloured. While the nickel obtained from the battery also was slightly brown with a tinge of golden yellow sparkle. The lithium obtained here is greyish black in colour indicating that the formed lithium salt is in the form of hydride. The graphite was eventually qualitatively separated and seen as dark black in colour.

The quantification of these batteries were done and the eventual salt that was extracted was also quantified to know the amount of each salt present in various composition. A total of eight Ni-Cd batteries yielded a sum of 11.342 g out of which 5.986 g of graphite was obtained and 2.109 g of Cadmium salt (Figure-3) was obtained as in table-1. A total of eight AA batteries yielded 16.325 g out of which 6.859 g of graphite (Figure-1) was obtained, 5.439 g of Manganese (Figure – 2) was obtained and a total of 2.380 g of nickel was obtained as shown in table-2. In the Laptop Lithium batteries a total of 6 batteries were taken and this yielded around 15.714 g out of which 2.987 g of lithium (Figure-4) could be extracted as shown in table-3.

Ni-Cd batteries usually have a metal case with a sealing plate equipped with a self-sealing safety valve. The positive and negative electrode plates, isolated from each other by the separator, are rolled in a spiral shape inside the case. This is known as the jelly-roll design and allows a Ni-Cd cell to deliver a much higher maximum current than an equivalent size alkaline cell. Alkaline cells have a bobbin construction where the cell casing is filled with electrolyte and contains a graphite rod which acts as the positive electrode. As a relatively small area

of the electrode is in contact with the electrolyte (as opposed to the jelly-roll design), the internal resistance for an equivalent sized alkaline cell is higher which limits the maximum current that can be delivered.

Nickel-Cadmium batteries contain the chemicals Nickel (Ni) and Cadmium (Cd), in various forms and compositions. The positive electrode is made of Nickel hydroxide (Ni (OH)<sub>2</sub>) and the negative electrode is composed of Cadmium hydroxide (Cd (OH)<sub>2</sub>), with the electrolyte itself being Potassium hydroxide (KOH). The low content of Cd and Ni in the battery is due to the fact that the electrolyte part i.e. KOH composition is higher in the cell as compared to the other two elements in their hydroxide forms namely Ni and Cd. The electrolyte is filled to almost 2/3<sup>rd</sup> of the battery and thus the battery was almost 90% KOH only. This explains the low Cd content in the Ni-Cd battery.

In case of Li ion battery, the three primary functional components of a lithium-ion battery are the positive and negative electrodes and electrolyte. Generally, the negative electrode of a conventional lithium-ion cell is made from carbon. The positive electrode is a metal oxide, and the electrolyte is a lithium salt in an organic solvent. The electrochemical roles of the electrodes reverse between anode and cathode, depending on the direction of current flow through the cell. The most commercially popular negative electrode is graphite. The positive electrode is generally one of three materials: a layered oxide (such as lithium cobalt oxide), a polyanion (such as lithium iron phosphate) or a spinel (such as lithium manganese oxide).

The electrolyte is typically a mixture of organic carbonates such as ethylene carbonate or diethyl carbonate containing complexes of lithium ions. Graphite is a major compound which is used as an electrode in the Ni-Cd batteries and the Ni hydride batteries. Graphite is used as an electrode in most of the batteries and this is no exception.

Alkaline batteries (IEC code: L) are a type of primary battery dependent upon the reaction between zinc and manganese(IV) oxide (Zn/MnO<sub>2</sub>). A rechargeable alkaline battery allows the use of specially designed cells. The negative electrode is zinc and the positive electrode manganese (IV) oxide. The alkaline electrolyte of potassium hydroxide is not part of the reaction, only the zinc and manganese (IV) oxide are consumed during discharge. The alkaline electrolyte of potassium hydroxide remains, as there are equal amounts of OH<sup>-</sup> consumed and produced. This is understandable as the manganese contained in the cell is present only in the positive electrode part and during electric discharge the oxides are rather consumed leading to the small amount of Mn yield at the end as the battery is also a 'used' battery. This explains the low Mn yield.

#### IV. CONCLUSION

Thus the extraction of e-waste using batteries was done and the quantitative and qualitative analysis also yielded a handful of salts. The extraction of Cadmium and Graphite from Ni-Cd batteries, Manganese, Nickel and Graphite from AA batteries and Lithium from Laptop batteries were done. This can be used a minor source for these and other salts. The amount of e-waste can thus be reduced. It not only reduces the amount of waste but also gives us a clear and quantified amount of salt from a very less number of batteries. Instead of throwing away these batteries and in turn polluting the environment we can effectively use them to obtain these salts and these salts can be used for a variety of purposes majorly for use in Laboratory. These salts can be further purified if necessary and also can be used for various other purposes.

Table : 1 : Quantification weights of Ni-Cd Batteries

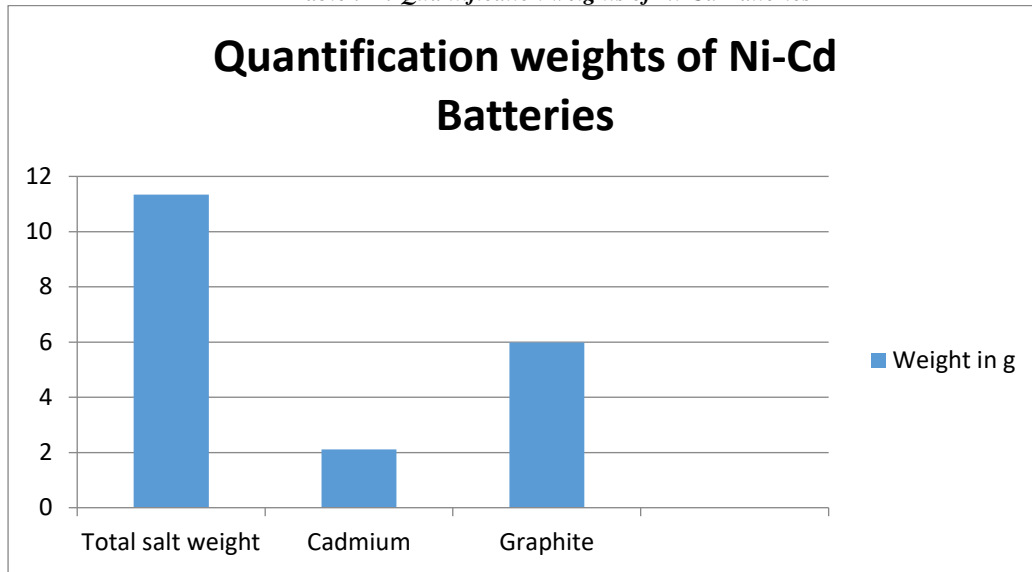


Table : 2: Quantification weight of AA batteries

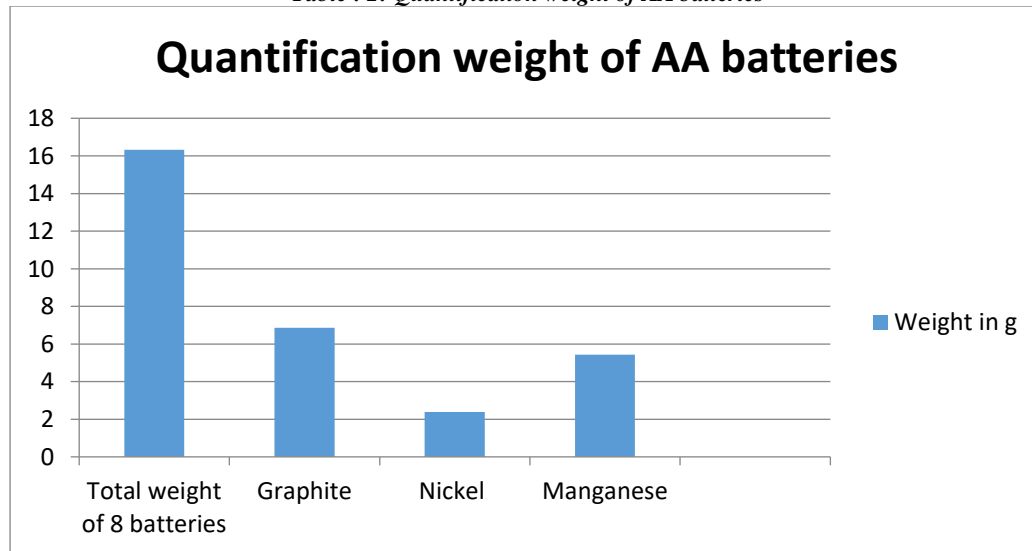




Table : 3 : Quantification of Laptop Lithium Battery

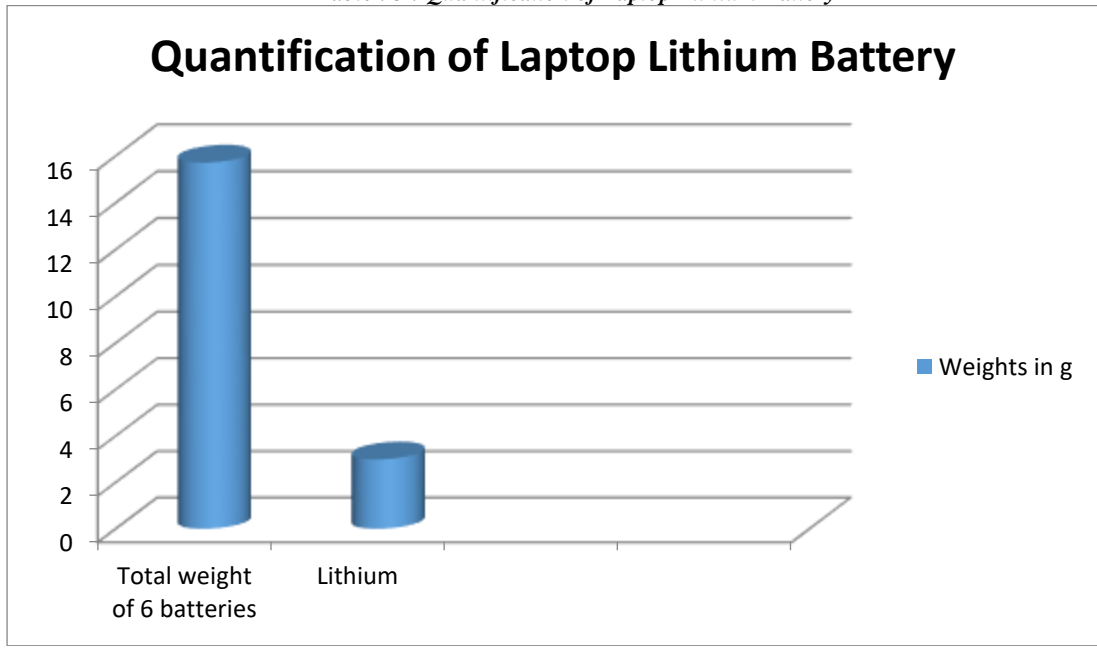


Figure : 1 : Graphite Powder



Figure : 2 : Manganese Salt



*Figure : 3 : Cadmium Salt*



*Figure : 4 : Lithium Salt*

## V. ACKNOWLEDGEMENT

AA and ST would like to thank Dr. James Arulraj, Dr. Sreeja P B and Dr Prasad Pujar of Department of Chemistry, Christ University, Bengaluru for their valuable help and guiding us throughout the work. I would also like to thank my friends Surjalal Singh, Alida Baby, Rakshitha G and Harshitha S for their support and help during the work.

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**CITE AN ARTICLE**

**Anand, Aljo , Seju Thomas, and Deeksha Aggarwal. "EXTRACTION OF MATERIALS FROM E-WASTE." *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY* 6.7 (2017): 574-84. Web. 15 July 2017.**