Metal related materials have been a key element in furthering the progress of mankind that they are at the core of today's life and continue to be enablers of future wealth creation. Metal related materials have vital role, as they can be efficiently and infinitely recycled, which makes them the basis for sustainable products and service.

- DIT New Delhi Report
CHAPTER - 1

INTRODUCTION

"Unless we know the value of minerals, know-how to utilize them, promote to the welfare of the country, we should let them lie in the ground.". Further, "it is wrong to indulge in giant excavations and exporting large tonnage of raw ore. A tower of income will grow only when raw materials are progressively transformed in to finished products, value added products and then utilized. Mineral identification and locations has to be given enough attention and to the associated technologies of mining, transport, recycling and substitution of primary resources by secondary resources".

- Nobel laureate Sir C. V. Raman

For centuries, metals are extracted from the naturally occurring minerals. The minerals which form primary resources for metals and many non metals are finite and non-renewable in nature. Therefore, the optimum and economical use, and conservation of these primary natural resources through substitution and recycling for sustainable development are matter of greater concern.

The global economic growth of the last century accompanied by exponential growth in population and consumption of natural resources viz., fossil fuels, water, and minerals are unfortunately unsustainable. Now, we are almost in the second decade of the 21st century, and have already noticed the consequences of supply gaps of various resources. The demand and supply of mineral resources are affected by the factors such as;

- Per capita consumption of mineral commodities
- The standard of living.

The market for mineral commodities expands considerably with the invention of new materials and applications. The best example for this is seen in the application of Strontium (an alkaline earth metal) which was not widely used until 1960, now it is widely used as most cost effective means of
preventing radiation escaping from the colour monitors of computer and television (Kesler 2009).

1.1 Status of mineral supply in 21st century

Humanity faces immense hurdles as it struggles to define the path toward sustainability which demands attention and understanding the very concept of sustainability itself (Linkages of Sustainability).

The life of metalliferrous mineral resources are calculated based on a modest consumption growth of 2% per annum, indicates (Fig1. 4) despite huge reserves, iron ore would last for only 50 years and Copper may last for another 25 years (Mohan Yellishetty et al 2010). Iron being the mother of all other industries, will there be any other cheaper metal substituting iron? Mineral scarcity may affect our entire industrial civilisation (Ugo Bardi, 2009).

According to US Geological Survey (USGS), global annual primary production of a large number of metalliferrous minerals go into various products and compounds, part of them being steel, alloys and metal products (http://www. The oil drum.com). in United States, each year, copper recovered through recycling per annum is equivalent to the primary production. Excluding the production of wire, more than three-fourths of the amount used for products like brass mills, ingot makers, foundries, powder plants and other industries comes from recycled scrap. That means, recycling is an alternate option to meet the demand and supply, in turn mineral conservation practice during 21st century.

Time is running out, one has to seriously address the issue of mineral scarcity. Without timely implementation of mitigation strategies, the world will soon run out of all kinds of affordable mass products and services. During the next few decades, one will certainly encounter serious problems of mining of many important ore minerals at the desired extraction rates.
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Years left at sustained 2% annual primary production growth, based on reserves

Fig. 1.1 Life of the natural mineral resource. (http://www.theoildrum.com)

Among them, Zinc, Tin, Indium, Cadmium, Zirconium, Tungsten, Copper, Manganese, Nickel, Cobalt and Molybdenum and precious metals such as gold, silver and Platinum-group metals, which are extensively used in the production of electronic equipments.

In India, even after six decades of independence, huge quantities of minerals continue to be exported from our country in raw state without any processing whatsoever and import finished goods. Unfortunately, much attention has not been given to resource utilization and conservation, which is far more important than resource exploration and exploitation.

If one keeps following the ruling paradigm of sustained global economic growth, we will soon run out of cheap and plentiful ore minerals of most types and their extraction rates will no longer follow demand. The looming metal crisis is being caused primarily by unfolding energy crisis. Conventional easing strategies are, recycling and substitution. The precautionary principle urges us to take immediate action to prevent or at least postpone future shortages. As soon as possible, we should impose a co-coordinated policy of management with all seriousness, not only to address mineral shortages, but also other interrelated resource constraints such as energy, man power, water etc (Radhakrishna 1996).
1.2 The National Mineral Policy of India- 2008

The National Mineral Policy of India, 2008 stresses the following

- Mining is high risk venture
- Mining is a closely related to the forest and environment.
- There is need for zero mining waste by employing latest technologies to extract minerals and metals from the ores.
- Research and development in minerals, alternate methods/sources for extraction of metals should be developed.
- Flora, fauna and biodiversity and the invaluable forest wealth to be safe guarded while minerals are used.

It is unfortunate, both private sector and Government Organisations have focussed their attention on large scale exploitation of high value metallic minerals with export potential without bothering about our National Mineral Policy-2008. Considering these problems of mineral resources, E-waste processing in developing nations has only recently emerged as an important issue, thus relevant research remains scarce. However, the issue of assessing and managing the environmental impacts of electronics has a history of research and implementation, especially from 1990’s. Terming this field as “Green electronics”, major areas of research on such activity, includes recovery of metals from EOL-PCs (Eric Williams 2005). Therefore, there is an urgent need for chemists, geochemists, geologists, environmentalists to focus their attention and find out alternate methods of obtaining metals and metal related materials. One such attempt is to recover metals from End of Life Personal Computers which form nearly 75% of the total E-waste generated.

Literature survey conducted during the present study has revealed that, the only data available for the characterisation (for P-3 model EOL-PC), thus far is from Handy Harman (Handy Harman Electronics Materials Co. Ltd,
Introduction

1996) which has determined the elemental composition of EOL-PC with 14 inch monitor weighing about 70 lbs.

In the present study an attempt has been made to recover the metals and non-metals from EOL-PCs to fulfil the one of the objectives of National Mineral Policy (2008) - “Research and development in minerals, alternate methods/sources for extraction of metals should be developed”.

This technology of recovering metals from EOL-PC is now popularly known as Urban Mining/Surface mining which is cost effective, free from pollution, generates employment and helps conserve natural resources. This technology is also known as Metals without mining or Green Mining.

1.3 Present Study:

To address the issues of National Mineral Policy of India, to facilitate and ensure sustainable development of mineral resources in harmony with environment, i.e. “commitment to human development within the ecological limits of the biosphere, in the present study an attempt is made to use End of Life Personal Computers (EOL-PC) (Fig.1.2) as secondary resource and substitute for the primary natural resources for the recovery of metals, that

- does not involve risk of deep mining operations,

- No blasting in the mining area

- No need of mineral beneficiation, roasting, calcination, no need to use fluxes.

- Metals almost available in their pure state, no need of further refining

- Help conserve natural resources, like water, coal/coke, non-renewable sources like ores.

- No emission of Green House Gases

- Flora, fauna, biodiversity and the invaluable forest wealth will be safe guarded while minerals are conserved.

- Provide employment opportunity to the locals.

Ph. D. Thesis: Recovery of Metals from EOL-PC
Introduction

In short, we have to behave sustainably which is defined as-“meeting the needs of the present generations without compromising the ability of future generations to meet their own needs”

So far, there is no comprehensive study reported to highlight the advantages of eco friendly, scientific methods adopted by the formal sector for the recovery of metals from EOL-PCs over unscientific, highly polluting methods adopted by the backyard practitioners. With this aim of characterization carried out of EOL-PCs, for major recyclable metals including the precious metals along with non metals, by following pollution free, eco-friendly manual dismantling and selective segregation and quantification use standard analytical procedure.

1.4 Aim

The main aim of the present study is to develop a scientific method of recovery of metals from the End of Life (EOL) Personal Computers as substitute for natural resources to conserve the primary mineral resources for sustainable development.

1.5 Objectives

- To understand the resource potential of EOL-PCs
- To understand the recovery process adopted by the backyard practitioners, occupational health hazard and the impact on the environment.
- Physico-chemical characteristics of EOL-PC for optimization of recovery processes of various metals and non metals including hazardous materials.
- To develop suitable economically, environment friendly in-house recovery processes/methods.
- To asses the recovery efficiency of the process developed and compare with that of backyard practitioners.
- To understand the impact of recovery process developed in the present study on ecology and environment.
1.6 Scope of the study

The present study mainly involves recovery of metals from EOL-PC (P3 model) and therefore, the research work is carried out to cover-

- Evolution of personal computers
- Impact of miniaturisation due to technological advancement
- Inventory of generation EOL-PC (P3 Model) from available data and survey conducted in Bangalore city as secondary resource for characterisation of EOL-PC.
- Prospects and problems of backyard practices- occupational health hazard and impact on the environment due to unscientific methods adopted for resource recovery.
- Characterisation of EOL-PC for optimum recycling efficiency.
- Physico-chemical principles involved in identifying and recovery of metals like Al, Fe, Cu, Ag, Au, recovery & recycling of plastics and leaded glass.
- Estimation of natural resource conservation and mineral substitution by recovering resources from EOL-PC

1.7 Materials and Methodology

1.7.1 Materials

A heterogeneous mixture of End of Life Personal Computers (PC)-P-III model (Desk top computers) of different brands, different date of production with 14 inch monitor and Dot-matrix printer have been used. A PC consists of Central Processing Unit (CPU) Monitor-(Cathode Ray Tube) keyboard, mouse with card.

1.7.2 Methodology

To achieve the aim and objectives of the present study, following methodology has been adopted…

- Literature survey and data collection from various sources.
Introduction

- Inventory of EOL-PC generation in Bangalore city through field survey and questionnaire.
- Physical characterization of EOL-PC and Dot-matrix by adopting dismantling and conventional physical measurements using a calibrated digital balance.
- Chemical characterization of EOL-PCs for various elements using ICP-MS and "fire assay".
- Recovery of base metals such as Aluminium, Iron (Steel) and Copper physical processes and extraction of precious metals such as Gold, Silver by chemical processes.
- Field study: visit to Jindal Steel Works,(JSW) Torangallu, Bellary Dist. Karnataka State, Hutti Gold Mines- only leading Gold producer of India and also to Indian Aluminium Factory,(HIDALCO) located at Belgaum.
- Field study to assess the benefits of recycling of plastics recovered from EOL-PC.
- Special visit to UMICORE Precious Metal Refinery, Belgium, to study the recovery of precious metals from EOL-PC.
- Recovery, characterisation, and recycling of various plastics and glass by physical process.
- Evaluation of recycling efficiency of the EOL-PC in terms of socio-economic and environmental impacts based on experimental data generated and field study.