ENVIRONMENTAL ISSUES IN METAL EXTRACTION

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PREAMBLE

The non-ferrous metals industry is a key sector in the Indian economy as it meets the requirements of a wide range of key industries including engineering, electrical and electronics, infrastructure, automobile and automobile components, packaging etc. The Indian non-ferrous metals industry comprises of the primary and secondary downstream segments. Primary producers are those players who process the mined ore to obtain the primary metal. This metal is commercially available in the form of rods, ingots, cathodes, wires etc., Secondary producers are those players who manufacture value added products like foils, extrusions, dry batteries, castings etc., either by procuring the metal from the primary producers or from scrap.

The domestic industry is characterized by the presence of only a few players in the primary segment. However, in the secondary and downstream segments there are many players both in the organized and in the unorganized sectors. There are significant reserves of non-ferrous metal ores in India. India is rich in bauxite (aluminium ore) and has grades of zinc, lead and copper reserves. Copper, lead and zinc are also imported as scrap or concentrates to be processed by secondary/custom smelters.

The non-ferrous metals industry in India is growing strongly aided by the privatisation process started in early 2000. By 2020, it is expected that the industry, comprising aluminium, copper, lead and zinc sectors, will be completely privatised, and India will grow to become a global player in the non-ferrous metals industry.

Aluminium

India has nearly 10 per cent of the world's bauxite reserves and a growing aluminium sector that leverages this. Demand in the domestic market is expected to grow by 8-10 per cent in 2005-06. By 2020, India is expected to have an installed aluminium capacity of 1.7 to 2 million tones per annum. The primary market for aluminium in India is the power sector, which consumes about 35 per cent of the domestic production. This is in contrast to the global market, where the bulk of aluminium is consumed by the construction and packaging sectors. The ongoing reforms in the power sector as well as focus on improving power infrastructure is expected to further boost the aluminium sector in India.

Copper

Copper is a key sector impacting the Indian economy. Copper has a number of applications across several sectors such as telecom, power, construction, transportation, handicrafts, engineering, and consumer durables. The Indian industry has an installed capacity - about

477,500 tonnes per annum in 2003-04 - that is greater than the domestic market - about 290,000 tonnes - leading to a surplus situation. This is an advantage that can be leveraged for boosting exports, especially since the Asian region has a deficit of around 2.6 million tonnes. Nearly 40 per cent of copper production in India is currently exported.

The industry currently has three major players - Sterlite, Hindalco and Hindustan Copper Ltd. (HCL), which together account for nearly 80 per cent of the total copper production in the country. Other players include around 1000 small-scale industries (SSIs), which are primarily involved in converting scrap into ingots. While HCL is the only primary producer, which mines and refines copper, Hindalco and Sterlite are secondary producers, who process indigenous and/or imported copper concentrate to produce end products like copper bars, rods and wires.

The performance of the copper industry is highly dependent on the performance of and demand for products like power and telecommunication cables, transformers, generators, radiators and other ancillary components. Hence, its growth is closely linked to the country's economic and industrial growth. India has been growing at a steady and sustained compounded average growth rate of 5.6 per cent for the past 20 years. This is expected to improve further to a level of around 8 per cent in the future. The outlook for the copper industry in India is therefore positive.

Zinc

With the privatisation of the largest zinc producer, Hindustan Zinc Ltd, sold to the Sterlite group in April 2002, the Indian zinc industry is completely under the private sector and is in the midst of expansion. At present the smelting capacity for primary zinc in India is 260,000 tonnes per annum, as against a domestic demand of about 350,000 tonnes per annum. Over the next 5 to 6 years, demand is expected to grow at about 12 - 15 percent annually, as against a global average of 5 per cent. Domestic production capacity, however, is also expected to increase to attain self-sufficiency by 2010.

The main consumer for zinc in the domestic market is the steel industry - over 70 per cent of zinc is used for galvanising. Other sources of demand for zinc include die-casting, guard rails for highways and imported-substituted zinc alloys. The steel industry has bright prospects with demand drivers being the construction industry and exports. With continued infrastructure development such as roads, irrigation, construction, oil & gas, ports etc, there is a rising demand for steel, thus providing significant opportunities for zinc in India.

Lead

Lead is a very corrosion-resistant, dense, ductile, and malleable blue-gray metal that has been used for at least 5,000 years. Early uses of lead included building materials, pigments for glazing ceramics, and pipes for transporting water. Today's major use of lead is in lead-acid storage batteries. The electrical systems of vehicles, ships, and aircraft depend on such batteries for startup, and, in some cases, batteries provide the actual motive power. It is also for soundproofing in office buildings, schools, and hotels. It is widely used in hospitals to block X-ray and gamma radiation and is employed to shield against nuclear radiation both in permanent installations and when nuclear material is being transported.

DOMESTIC SCENARIO

- Lead production equalled approximately 82,000 tonnes in 2004, mostly from secondary sources.
- The main constraint in lead production in the country is the lack of lead ore reserves, which necessitates large-scale imports and recycling.
- Lead demand in India was estimated at 150,000 tonnes for 2004. Due to huge gap in demand-supply, India imported nearly about 50% of its domestic demand.
- The major suppliers for the imports were China, the Republic of Korea and Australia: 54%, 15% and 10% respectively.
- The domestic industry is characterized by the presence of only a few players in the primary segment. The primary lead industry in India is divided between the following main players: Binani Industries Limited and Sterlite Industries (India) Ltd. (Hndustan Zinc Ltd.). Due to increasing use of lead in domestic market both players are expanding their smelting capacities for lead.

WORLD SCENARIO

- USA, Japan, China, EU and India are the major consumers of Lead
- Supply is controlled by Australia and China.
- Lead in the global market is traded as soft lead, animated lead, lead alloys and copper-base scrap.

However, each of the above industry creates significant amount of environmental pollution through emission in air and water as well as pollution caused by solid wastes. Since technologies for metal extraction is constantly improving, newer clean technologies are likely to improve the environmental performance of these industries.

ENVIRONMENTAL ISSUES IN NON-FERROUS PROCESSING

As a part of the materials cycle, ores and fossil fuels are extracted from the earth, processed, and converted into metals, chemicals, and other processed materials. Wastes are generated by the mining, mineral processing, metallurgical and chemical industries at an estimated annual rate of over 2 billion tons. The accumulated solid wastes at both active and inactive mining sites approach 30 billion tons. These wastes include gases, dusts, sludge or solutions, ashes, and a variety of solid materials such as overburden, waste rocks, tailings, and slag that must be disposed of at low cost with a minimum of environmental degradation. A large volume of the wastes is normally disposed of at locations close to either the mining sites or processing plants. A significant amount of tailings is disposed of in impoundments, which range in size from a few acres to large ponds covering thousands of acres. Mining also leads to significant pollution of water resources around the mines and beneficiation plant sites. Man-made tailing ponds and dams are amongst the largest structures constructed by man. They may contain as much as

100 million tons of slurries. There are about 3500 such dams. The main effects of mining and beneficiation on the surrounding water bodies are listed below:

- Suspended solids and sediment from runoff and processing operations,
- Acids from various processes,
- Acid mine drainage (AMD) during and after operation,
- Heavy metals leached from waste and tailings,
- Sulphate, thiosulphate, polythionate etc. from acid drainage,
- Mercury from processes or from ores,
- Arsenic from oxidised mine waters,
- Cyanide from leaching processes and
- Oil and fuels from ancillary operations.

Even though the waste disposal issues from mining and mineral processing are not dealt with stringency in today's context, the situation is changing fast and precautions must be taken to both minimise and control waste disposal. Hence, the mineral or metal constituents in wastes, whether of little or no economic value, must be amended for their environmental impact [1,2].

In the non-ferrous processing sector, major environmental issues includes: fluoride emissions, use of spent pot-lining (SPL) from the aluminium electrolytic pots, sulphur dioxide pollution, waste water processing from sulphide smelting and recovery of lead from battery scrap. Drastic modification of the Hall Heroult technology through the substitution of carbon electrodes and adaptation of multi-polar cells would bring in significant improvement in the environment performance of the aluminium production process. These would result in achieving a high productivity, no generation of spent pot linings, reduction in carbon monoxide and green house gases emission such as fluorocarbons and CO_2. In the lead production area, the QSL process has emerged as a serious challenger to the old pollution prone blast furnace process. This high intensity single step process has the potential to be adapted for producing even copper and nickel. In copper area, the Isasmelt process has been established as a high intensity process with good environmental performance. M/s Sterlite Copper is operating a Isasmelt reactor which is doing very well for the last few years.

MAJOR ENVIRONMENTAL PROBLEMS IN ALUMINIUM INDUSTRY

Red Mud Disposal

Red mud is an alkaline waste containing oxides of iron, silicon, titanium and water soluble soda. It is stored in specially constructed leach proof ponds. Prior to 1985, most of the alumina refineries in the world used to store red mud in slurry form. Indal was the first Indian alumina refinery to adopt dry mud stacking. In this process the mud is stacked in cake form and by this practice the life of ponds has increased from 5 to 25 years. In addition to this, water and caustic soda are also recovered and recycled into the process.[3] Investigators throughout the world have developed many processes for recovery of metals from red mud. However, they have not been successful techno-economically and have not been commercialised.

Emission of Perfluorocarbon and Hydrofluoric Acid

During aluminium production several perfluorocarbons (PFC) gases are evolved. These are not generated during normal smelting conditions. They are only produced during brief upset conditions that can be related to anode effect. These conditions occur when the level of the dissolved alumina in the cell drops too low and the cryolytic bath itself begins to undergo electrolysis. The main gases are CF_4 and C_2F_6 but also other PFC gases such as C_3F_6 and C_3F_8 may be formed in minor quantities. Apart from PFC's, HF gas is also formed from two principal sources. One of them is during the reaction occurring in the bath between AlF_3 and moisture. The other is hydrolysis of $NaAlF_4$ vapour present above the bath surface. Excess emission of HF is due to the chemical process occurring in the filter dust, involving particulate fluoride compounds originating in the electrolytic bath and moisture present in the pot gas.

PFC Reduction

Research efforts have been continuing on the better understanding of process parameters related to PFC generation as well as their reduction. Restructuring new and improved gas cleaning equipment and continuous improvements in the smelter operation have contributed to considerable reduction of the fluoride emissions from aluminium smelter. Today's smelters use two types of electrode technologies: Soderberg and Prebaked.

(1) Soderberg technology uses a continuous anode which is delivered to the cell (pot) in the form of a paste and which bakes in the cell itself. The Soderberg technology has two variants based upon how the electricity is introduced to the cell, namely Vertical Stud Soderberg (VSS) and Horizontal Stud Soderberg (VSS)

(2) Prebaked technology uses a multiple anode in each cell which are prebaked in a separate facility and attached to rods that suspend the anode in the cell. New anodes are exchanged for spent anodes. Prebaked technology has two variants referring to how alumina is added, namely Centre Worked (CWPB) and Side Worked (SWPB).

The newest primary smelters use the centre worked prebake technology. This technology provides use of multiple point feeders and other computerised controls for precise alumina feeding. A key feature of CWPB plants is the closed circuit nature of the process. Fugitive emissions from these cells are very low which is less than 2% of generated emissions. The balance of the emission is collected inside the cell itself and carried away to a very efficient scrubbing system. US aluminium industry achieved 46% reduction of PFC's from 1990 to 1998 through technical improvements such as reduction of frequency and also to some extent the duration of the anode effect in pot line cells. Significant progress has also been made in improving environmental performance through these technological developments (Table - 1).[4]

Table-1 : CF_4 Emission from Aluminium Smelter using Soderberg and Prebake Technology

Technology type	kilograms CF_4 per tonne of aluminium produced	
	1990	1997
CWPB	0.36	0.15
VSS	0.70	0.45
SWPB	1.88	1.34
HSS	0.36	0.46

Disposal/Use of Spent Potling/Black Mud

The cathode lining of electrolytic cells gets degenerated after a life of around 2000 days due to adsorption of fluoride bearing materials. World over, this material is disposed in secured landfills as it is highly toxic. Some aluminium plants in India recovers cryolite from this waste material and recycles it back to the electrolyte cell. Black mud generated during cryolite recovery is sold to cement plants as a fuel-cum-mineraliser.

Disposal/Use of Wet Scrubber Sludge

Aluminium electrolytic cells emit fluoride fumes. These are collected in a wet scrubber and then neutralised with lime to produce a solid waste called "Scrubber sludge". This waste is also disposed in secured landfills as it contains toxic fluoride chemicals. A process has been developed to convert this hazardous waste into a product that can act as a flux in alloy steel refining.

MAJOR ENVIRONMENTAL PROBLEMS IN COPPER INDUSTRY

Even though copper is least harmful amongst the non-ferrous metals, copper based industries do generate a lot of industrial wastes which can contaminate the environment. Copper mining, smelting and refining activities are associated with generation of large quantities of overburden and mine tailings, sediments from concentrator effluents, acidic fumes and smoke from smelters, effluent from refinery tank house etc., all from a single industrial complex. Major smelter refinery complexes are usually set up close to mine sites, which are generally away from urban centres. However, some of the new copper smelter refinery units based on imported concentrates are, however, located closer to the end use markets and hence thickly populated areas. The increased awareness of pollution problem has forced some of the units to change the location of the new plants. Moreover, the new plants do have adequate provisions for pollution mitigation integrated into the plant and machinery.[5]

The downstream processing and fabrication industries on the other hand are mostly located in and around major industrial or metropolitan centres and hence deserve greater attention. Capacity of each processing or fabrication unit is much smaller compared to a smelter and the quantum of pollutants generated is also much lower. Moreover, majority of the units in the unorganised sector are not fully aware of the adverse effects of environmental pollution and the means of their control. This coupled with the apathy of the larger units add to the magnitude of the problem. Some of the important sources of pollution from metal processing and fabrication units include:

- Flue gases from fuel fired melting or preheating furnaces
- Furnace fumes with volatile metallic and other contaminants
- Liquid effluents from pickling, electroplating, etching, chemical and electro-polishing, anti-tarnishing treatments, etc.
- Solid wastes such as slag, scales, ashes, dross, slimes, floor dust, effluent sludge etc.

It may be noted that most of these wastes not only contribute to environmental pollution but also affect the yield, productivity and even quality. It may be of interest to note that nearly 50% of the surface tarnishing problem of processed semis and fabricated components are caused by many of the atmospheric pollutants. Moreover, generation of copper bearing wastes mean loss of metal value and generation of waste effects yield and productivity, besides its adverse influence on production economics.

FUTURE ROADMAP FOR NON-FERROUS PROCESSING

A broad R&D road map for improving environmental performance of non-ferrous metals sector in India is summarized below. For convenience it is divided into four sections: Energy targets, process development, metal unit recycling and environmental issues.

(a) **Energy Targets :** Opportunities for energy savings involve the applications of technology to measure, control and improve processes. Some will produce near net shape products to maximize yield; others will make products with optimum as-processed microstructure and properties to avoid traditional post processing heat treatments. Other opportunities will relate to the capture and re-use of the energy lost in current processes. Some opportunities, related primarily to cost and the environment, involve the production and recycling of metal units. A comprehensive R&D programme should be taken up to reduce energy consumption in this sector which in turn will significantly reduce environmental pollution.

(b) **Process Development :** Research priorities and technical barriers to success should be identified for each of major minerals and metallurgical processes. Where appropriate, targets and timelines for critical technologies should be established. Technical developments are needed to create a furnace design that will maximize the use of energy inputs, optimize productivity, and allow flexibility in charge materials and fuels.

(c) **Metal Recycling :** Increased recycling of by-product wastes requires significant advances in technology and presents one of the largest opportunities for further metal recovery. Current technologies offer limited ability to use fine materials in large quantities. However, more R&D work is needed to develop agglomerates with the required strength and properties. Although uses for low-metal bearing wastes, such as slag, are well developed, they represent most of the metal units lost in the product life cycle.