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Strategies for mitigation of pollution and environmental management in metallurgical industries

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ABSTRACT

The paper deals with different strategies that can be adopted for mitigation of pollution from metallurgical industries. It discusses various management aspects in connection with pollution mitigation especially the policy options for environment management. The technology options available have been discussed in details.

INTRODUCTION

Environmental problems in India can be classified into two broad categories : Those arising as negative effects of the very process of development, and those arising from conditions of poverty and under development. Major problems in the area of environmental management encompass[1] - (i) High pollution increase and its impact on life support system which negate the positive impacts of the developmental programmes, (ii) Rapid growth in the population of domestic animals over the past few decades accompanied by a loss of area under grassland and pastures, (iii) Out of total area of about 329 million hectares, 175 million hectares require special treatment to restore such lands for productive and profitable usage, (iv) Land degradation is caused by water and wind erosion salinity and alkalinity, (v) The annual rate of loss of the forest cover is 47,500 - hectares , (vi) Major rivers of the country are facing problems of pollution and siltation, (vii) The quality of groundwater is being affected due to chemical and biological pollution and due to the ingress of sea water in coastal areas, (viii) A large number of industries and other development projects are sited close to heavily populated urban centres leading to over congestion and over pollution as also the diversion of population and ecologic resources from rural areas.

Policy options for environment management

The concept of sustainable development[2] indicates that the correlation between population, poverty and pollution must be analysed against the backdrop of ecosystem to provide supportive capacity for development and assimilative capacity for maintenance of acceptable quality of environment. Accordingly, the agenda that ensues for sustainable development is : (i) carrying capacity based developmental planning process, (ii) structural changes in economic sectors, (iii) preventive environmental policy, and (iv) environmental impact assessment. While the first two of the above agenda would be applicable as planning process and sectorial planning, the later two are of more concern to any industrial/developmental sector. In order to effectively restore the quality of environment, the direction of environmental policy must be shifted towards anticipative and preventive strategies which focus on actions necessary to prevent potential environmental damage. Preventive environmental policy should essentially deal with the conditions that give rise to environmental problems and should readjust these to obviate environmental damage.

The concept can be implemented by the prevention of all harmful emissions that exceed the assimilative capacity of the ecosystem through greater and improved recycling, introduction of low/non emission technologies, and pre-emptive substitution of environmentally harmful raw materials and products; conservation of non-renewable resource base through its greater use. Efficient use of ecologically significant resource is likely to have a number of positive environmental effects like decreased resources consumption and reduced production cost; less expensive preventive environmental protection measures vis-a-vis end-of pipe treatment; more effective environmental control due to use of integrated production technologies vis-a-vis environmental media based technologies.

Environmental impact assessment

Environmental impact assessment is potentially one of the most valuable interdisciplinary and objective decision making tools with regard to alternative routes for development, process technologies and project sites facilitating internalization of environmental concerns. The most appropriate stage for implementing EIA is at the level of district planning since at this stage a reasonable number of alternatives are available to the developer. Environmental assessment of regional supportive and assimilative capacities during formulation of development plans could greatly reduce the requirement for project level EIA.

EIA should necessarily include the following steps : Collection of baseline data on all environmental components, identification of impacts with the help of process details using cause-condition effect relationship, prediction and evaluation of impacts, environmental management plan, disaster management plan and post-project monitoring to be pursued by implementing agency. Technological options for minimization of waste load also need to be identified.

Technological options for Waste Management

Management of wastes necessarily should aim at : (i) Resource recovery, (ii) Waste stabilization, (iii) Controlled waste disposal methods based on assimilative capacity.

Resource Recovery

Environmental biotechnology refers to waste treatment with emphasis on resource recovery. The emergence and acceptance of the concept of sustainable development, however, warrants that the scope of environmental biotechnology be enlarged to address issues like environmental monitoring, restoration of environmental quality, resource/residue waste recovery/utilization/ and substitution of non-renewable source base with renewable resource. Bioleaching of metal containing wastes is one of the options for recovery of resource.

Alternatives for recovery and segregation of metals

There are large number of separation processes applicable for recovery of metals from industrial waste (Table-1). Many of these processes have reached a mature state of development and are being practiced by many companies. There area number of processes that have potential application to secondary metal recovery that can be incorporated by waste generators as a component of their existing manufacturing processes. The technologies for separation have been broadly reviewed[3] for wide spectrum of nonferrous metals with emphasis on hydrometallurgical processes espe-

Table-1 : Separation Alternatives

Soluble metals	Adsorption Cementation Electrowinning Ion exchange Membrane separation Precipitation Solvent extraction
Solid Wastes	Biological separation Floatation Magnetic separation Pyrometallurgy Solvent partition

cially keeping in view the energy conservation during low temperature processing, the physical character of waste streams and the economics. Consideration is also given to pyrometallurgical and biological processes when relevant to the principal emphasis on hydrometallurgy. The primary concern is processing of metals in aqueous or non-aqueous solution or insoluble form as oxide/hydroxide/carbonate/sulphide sludges or dusts, and secondarily the processing of metallic scrap.

The separation processes applicable to metals in aqueous, acid or alkaline solution such as adsorption, cementation, electrowinning ion exchange, membrane processes, precipitation and solvent extraction have been reviewed by Brooks[3].

The separation processes applicable to solid wastes consist of biological separation, flotation, magnetic separation, pyrometallurgy and solvent partition. The processes delineated for liquid wastes can be applied to solids provided solubilization of solid waste is carried out. Biological processes which are considered as cleaner options for metal recovery have been reviewed in greater details in this paper.

Biological Separations

Biological processes play an important role in the separation of metals. One type of process arises from the solubilization effect of organisms, (such as certain bacteria), on minerals and various solid wastes. The leaching of copper sulfide ores with *Thiobacillus ferrooxidans* has been used for some time as a commercial process for copper recovery. There are a number of other biological systems, such as Sulfolobus, Pseudomonas, Spirogyra, Oscillatoria, Rhizoclonium, Chara, and Synechocus, that have also received attention as offering promise for the extraction of metal (such as iron, cadmium, copper, chromium, mercury, nickel, manganese, lead, molybdenum, selenium, uranium, tin, cesium, radium and aluminum) from ores or solid wastes.

Another type of separation process that has been considered is the accumulation by adsorption-ion exchange of metal cations in aqueous solution by algae such as Chlorella pyrenoidosa, Spirulina and by fungi such as, Penicilium, and Cladosporium. Accumulation processes on organic substrates offer promise for removal of soluble metals from liquid wastes, and it has been known for some time that passage of polluted waters through fresh and marine wet lands provides a significant amount of cleanup.

One interesting example[4] for purification of nuclear industry wastes is the use of an aerobic recovery of ^{242}Pu, ^{241}Am, ^{134}Cs, ^{85}Sr, ^{60}Cu, U, Ru, Sr, Co, Cs, Ce, and Zr with Bacillus subtilis with subsequent recovery of the metals by magnetic separation. In addition, the anaerobic action of Desulfovibrio in a sulfate-lactate culture collects copper sulfate for subsequent magnetic separation. Another interesting biological separation process involves precipitation of copper or other metals from leach solutions or waste waters as sulfides with Desulfovibrio vulgaris, followed by oxidation of the resultant H_2S with Chromatium vinosum bacterium[5].

Practical success with the biological separation processes requires coping with large volume reaction systems and patience needed for low-temperature reaction kinetics. A summary of the various waste and mineral systems that have been examined, the types of metals involved, the identified organisms and an indication of whether or not the process is appropriate for leaching or accumulation separations has been provided in Table 2.

Table-2 : Metal Separations Using Biological Agents

Waste system	Metal	Biological agent	Mode of metal action
Ores	Fe	Thiobacillus ferro-oxidans	Leach
Polluted water	Mo, Ra, Se, V	Spirogyra, Oscillatoria	Accumulate
Metal finishing waste	Cd, Cu, Pb	Chlorella pyrenoidosa	Accumulate
Sewage sludge	Cd, Cu, Ni, Zn	Chlorella pyrenoidosa	Leach
Wastewater or leachate	Cu	Desulfavibrio vulgaris	Accumulate
Nuclear wastewater	^{241}Am, Ce, Co Cs, Cu, ^{242}Pu, ^{134}Cs, ^{85}Sr, Zr	Bacillus subtilis	Accumulate
Metal wastewater or leachate	Cu, U	T.Ferrooxidans, T. thiooxidans, Lepto-spirillam ferrooxidans	Accumulate
Metal wastewater	Cd,Cu,Ni,Pb,Zn	Penicillium, Cladosporium	Accumulate
Metal wastewater	Ag,Al,Cd,Cr,Co,Cu Hg,Ni,Pb,Zn	Chlorella pyrenoidosa, Spirulina	Accumulate
Ores	Ag,Cd,Cu,Pb,Zn	T.ferrooxidans, Chlamy-domonas reinhardtii	Leach

Bioleaching of Ores

Bioleaching of ores has been widely studied as :

- Ores remain unutilized due to iron and other impurities
- Biotechnology presents an economic alternative where
  - high grade minerals are depleting
  - energy cost is increasing and
  - adverse environmental impacts are on the rise

- o It is a cleaner technology that minimizes the adverse impacts on the natural systems and permits maximum utilization of natural resource for economic development.

Bioleaching Process

Bioleaching is a process where specific micro-organisms are applied for removal of metal from crude ore. This is effective for leaching of copper, iron, manganese, uranium from ores. The factor which influence bioleaching are :

- availability of ores with high metal concentration
- selection of proper microbial conditions
- optimization of environmental conditions
- proper design of a reactor

Limitations :

- Bioleaching is a slow process
- Inorganic matter associated with ore is not used by microbes
- microbial culture is usually not competitive
- nutrition needs to be supported from outside

Disposal Alternatives

A hierarchy of waste disposal priorities commonly accepted consists of the following :

- o Waste volume reduction
- o Waste recycling
- o Detoxification treatment
  - Physical
  - Chemical
  - Biological
- o Incineration
- o Solidification-stabilization
- o Landfill
- o Deep well injection

Metal recovery from waste effluent contributes to instrumentation of the first three of these categories.

Delineation of Strategy for Management

A strategy that can be delineated for any metal processing or ore processing industry should involve the following steps.

- Assessment of baseline environmental status and assimilative capacity of environment in the region.
- Identification of likely impacts due to air emission, waste water discharges and solid wastes on air, water and land components
- Prediction of likely impacts and their quantitative evaluation
- Mitigation of impacts through technological option reviewed with emphasis as preventive policies rather than end of the pipe treatment
- Options for resource recovery should be given priority over waste treatment
- Disposal techniques should be within the frame work of standards and as per the norms set up by Pollution Control Boards and regulatory agencies.

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