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ENVIRONMENTAL GUIDELINES  
ALUMINIUM INDUSTRY

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TABLE OF CONTENTS

	<u>Page No.</u>
<b>1.0 INTRODUCTION AND EXECUTIVE SUMMARY .....</b>	<b>1</b>
<b>2.0 MANUFACTURING PROCESS .....</b>	<b>2</b>
2.1 Bauxite Facilities .....	2
2.2 Alumina Facilities .....	5
2.3 Aluminium Smelter Facilities .....	7
<b>3.0 WASTE SOURCES AND CHARACTERISATION .....</b>	<b>10</b>
3.1 Bauxite Facilities .....	10
3.2 Alumina Facilities .....	11
3.3 Aluminium Smelter Facilities .....	12
<b>4.0 WASTE MINIMISATION OPPORTUNITIES .....</b>	<b>15</b>
4.1 Bauxite Facilities .....	15
4.2 Alumina Facilities .....	16
4.3 Aluminium Smelter Facilities .....	16
<b>5.0 CONTAMINANTS OF CONCERN .....</b>	<b>17</b>
<b>6.0 IMPACT ON RECEPTORS .....</b>	<b>17</b>
6.1 Environmental Impact Assessment (EIA) .....	18
6.2 Specific Impact Problems of Concern .....	19
<b>7.0 OCCUPATIONAL HEALTH AND SAFETY ISSUES .....</b>	<b>21</b>
<b>8.0 SURVEY OF EFFLUENT GUIDELINES .....</b>	<b>22</b>
8.1 Particulate Standards .....	22
8.2 Fluoride Standards .....	22
8.3 Opacity Standards .....	23
8.4 Emission Control Standards - Power and/or Steam Generation Plant .....	23
8.5 Wastewater Control Standards .....	24
8.6 Noise Standards .....	25

**ENVIRONMENTAL GUIDELINES  
ALUMINIUM INDUSTRY**

**TABLE OF CONTENTS (Cont)**

	<u>Page No.</u>
<b>9.0 TARGET GUIDELINES</b> .....	26
<b>10.0 TREATMENT TECHNOLOGY OVERVIEW</b> .....	26
10.1 Bauxite Facilities .....	26
10.2 Alumina Facilities .....	28
10.3 Aluminium Smelter Facilities .....	34
<b>11.0 ALTERNATIVE TREATMENT TECHNOLOGIES</b> .....	38
11.1 Bauxite Facilities .....	38
11.2 Alumina Facilities .....	38
11.3 Spent Pot Lining Treatment .....	38
<b>12.0 CAPITAL AND OPERATING COSTS</b> .....	39
12.1 Alumina Plant Environmental Facilities Cost .....	39
12.2 Aluminium Smelter Environmental Facilities Cost .....	40
<b>13.0 CONCLUSIONS</b> .....	40
13.1 Spent Pot Linings (SPL) .....	40
13.2 Electrolytic Cell and Anode Baking Fume Treatment .....	40
13.3 Red Mud Disposal and Area Reclamation .....	41
13.4 Bauxite Tailings Disposal and Area Reclamation .....	41
<b>14.0 APPENDIX</b> .....	41
14.1 Bauxite Mine Flow Diagram .....	42
14.2 Alumina Plant Flow Diagram .....	43
14.3 Aluminum Smelter Facilities Flow Diagram .....	44
14.4 Threshold Limit Values (TLV) .....	45
14.5 Bibliography .....	46
14.6 Glossary .....	48

**ENVIRONMENTAL GUIDELINES  
ALUMINIUM INDUSTRY**

**LIST OF TABLES**

<u>Table</u>		<u>Page No.</u>
1	Alumina Plant Materials and Energy Usage .....	7
2	Aluminum Smelter Materials and Energy Usage .....	10
3	Atmospheric Emissions from Alumina Facilities .....	11
4	Atmospheric Emissions from Aluminum Smelters .....	13
5	Typical Airborne Emissions before Treatment for a Modern CWPB Pot .....	14
6	Spent Cathode Analysis .....	15
7	Contaminants of Concern in the Aluminum Industry .....	17
8	U.S. EPA Standards for Wastewater Discharge from Aluminum Smelters .....	24
9	Standards for Waste Water Discharges to the Sea from Non-Ferrous Metals Operations .....	25
10	Smelter Fume Capture and Treatment Efficiency .....	35
11	Smelter Airborne Emission Rates .....	36
12	Solid Wastes from Aluminum Smelters .....	38
13	Threshold Limit Values (TLV) for Aluminum Industry Workers .....	45

## 1.0 INTRODUCTION AND EXECUTIVE SUMMARY

This document reviews environmental concerns and guidelines in bauxite mines and beneficiation plants, alumina plants, and aluminium smelters. The manufacturing processes are described and the emissions and discharges are identified. An overview of the basic environmental discharge standards around the world is provided.

Some of the key environmental issues, among the many, discussed in this document are:

- Disposal of spent pot linings (SPL)
- Electrolytic cell fume treatment
- Anode baking fume treatment
- Red mud disposal and area reclamation
- Bauxite tailings disposal and area reclamation
- Bauxite dust control

A great deal of progress has been made in the aluminium industry, particularly by the major international companies, in developing effective environmental safeguards for their facilities. Much development work has been done in the area of new technologies to minimize the impact of bauxite, alumina, & aluminum facilities on the environment.

These technologies are available now and should be utilised to the maximum feasible.

Considerable space is devoted in this report to these preferred technologies:

Some of the more important environmental issues, and their corresponding control technologies, facing the industry today are:

- **Spent Pot Linings (SPL)**

Several promising treatment technologies, based for the most part on incineration, are available. However they are expensive and, at least in the U.S., they have been difficult to utilise due to regulatory problems.

- **Electrolytic Cell and Anode Baking Fume Treatment**

The alumina dry scrubbing technology is being successfully used to control the environmental problems arising from emission of these fumes into the potroom and the atmosphere. This treatment system is expensive to build and operate.

- **Red Mud Disposal and Area Reclamation**

Red mud disposal is a problem because of the large volumes of red mud waste produced (1-2 tons red mud solids per ton of alumina produced), and the difficulty of reclaiming red mud disposal sites.

Technology is now available for reducing the moisture content of the mud waste considerably, thus permitting "dry stacking" of the mud in a reduced area, and easier land reclamation.

- **Bauxite Tailings Disposal and Area Reclamation**

Bauxite tailings disposal is a problem due to the very large volume of dilute slurry material involved. However technology is available for drastically reducing the moisture content of the tailings, which permits the use of "dry stacking" technologies for disposal of the tailings in the mined out areas, and facilitates reclamation of the area.

## **2.0 MANUFACTURING PROCESS**

### **2.1 BAUXITE FACILITIES**

This section will cover the environmental aspects of all of the typical bauxite facilities in use today from excavation of the ore to delivery of the bauxite to the alumina plant.

#### **2.1.1 Process Flow Diagram**

The type and scope of facilities used for the excavation, processing, and transportation of bauxite vary considerably - depending greatly on the type and quality of the bauxite.

For the purposes of this report a generic process flow diagram has been prepared (see Appendix) to demonstrate all of the major processing or treatment steps used in various bauxite mines and beneficiation plants around the world today.

For the purposes of reviewing the environmental aspects of these bauxite handling facilities the process flow diagram has been greatly simplified to show only a 'block' representing each major stage in the process. The major blocks or steps in the block flow diagram are:

- bauxite digging (excavation)
- bauxite crushing
- ore washing
- screening
- cycloning
- filtration
- drying
- product storage
- fines storage
- tailings disposal
- ship loading

Some bauxite mining and beneficiation facilities utilize all of the above steps in their treatment of the excavated bauxite; other bauxite mines use only part of these steps.

#### **2.1.2 Process Description**

The following is basically a summary description of the treatment of the bauxite as it passes from the point of excavation to the point of loading the bauxite for shipment. A more detailed description can be found in References (1) and (2).

Practically all modern bauxite mining operations today are surface mines. Although some older underground mines still exist, e.g. in Greece and Hungary, underground mining is more expensive and tends to not be economically competitive compared to surface mining. Any

new bauxite mines which are established will very probably be of the surface mining type. With a surface mine, the first step in mining the bauxite consists of removing the topsoil with its vegetation, which may include trees, in order to provide access for the removal (stripping) of the overburden.

After the stripping of the overburden, the bauxite is excavated - typically by drilling and blasting if needed, digging, and finally loading the bauxite onto trucks or a conveyor for transportation to the crusher.

At the bauxite crusher the large pieces of bauxite are crushed to a smaller size in order to prepare the bauxite for further processing.

From the bauxite crusher, the bauxite is usually graded by screening and then stacked on stockpiles-ready for shipment.

Beneficiation is used at a few modern bauxite mines to upgrade the quality of the bauxite by removing undesirable ore constituents, such as clay and silica, and for grading of the bauxite.

The beneficiation typically consists of an ore washing station, followed by classification and liquid/solid separation equipment which separates the bauxite into three (3) or more size fractions.

The coarse fraction is sometimes dried to remove the excess moisture before storage and shipping to the alumina plant. Rotary drum dryers are sometimes used to perform the drying function.

### **2.1.3 Economic Factors in Process Selection**

In general terms the economics of a particular bauxite deposit are favorable if -

- the deposit is close to the sea, if the bauxite is to be exported, or close to the alumina plant site if not exported.
- the bauxite has a high extractable alumina content, a low reactive silica content, and a low organic material content.
- the economics are the most favorable if the alumina content is present as practically all gibbsite, all other economic factors being equal. However boehmitic, and sometimes diasporic, bauxite is generally economical to mine if the grade is adequate.
- the overburden above the bauxite layer is easily and economically strippable.

The process used to treat the bauxite prior to use in the alumina plant is designed to reduce the downstream transportation and alumina plant operating costs in the most economic way available.

The alumina plant's operating costs are increased if the bauxite is -

- difficult to crush and/or grind - therefore the crushing and segregation of the bauxite prior to delivery to the alumina plant will lower the alumina plant's costs.

- low in extractable alumina - because this increases the tonnage of bauxite and red mud which must be handled to produce a tonne of alumina. The mining equipment and operating system must be suitable for accurately selecting and separating the suitable bauxite from the uneconomic bauxite in the mine.
- High in reactive silica content - because this increases the amount of caustic soda which is used by reacting with the silica. As in the above case for extractable alumina, the equipment and operating methods used for bauxite excavation must permit accurate selection of suitable quality bauxite.
- In addition, the goal of the beneficiation process and the basis on which the technology is selected should be to lower the content of reactive silica, and other problematical minerals - such as reactive carbonates, to as low a level as technically and economically feasible.
- Very wet - because the excessive free moisture increases the weight of bauxite to be shipped and transported on conveyors - thereby increasing costs; and sometimes creates a sticky bauxite which sticks to conveyors, trucks, chutes, and other equipment.
- In addition, use of a wet bauxite, increases the amount of water introduced to the alumina plant process which results in an added expense for evaporation in the process.
- For the above reasons the installation of bauxite dryers at the beneficiation plant may result in considerable cost savings in bauxite transportation and in-plant evaporation costs.

#### **2.1.4 Environmental Factors in Process Selection**

The main environmental problems encountered at bauxite mine and beneficiation sites are those of dust, tailings disposal, and storm water run-off/erosion.

The process selection should be chosen to minimize the above environmental problems in an economical way.

#### **2.1.5 Water and Energy Usage**

Water and energy usage can vary greatly from mine to mine, however published data for the Boké bauxite mine <sup>(2)</sup> indicates that energy usage in a large, modern, bauxite mine is about

- Electric power - 6.2 Kwh/t bauxite
- Diesel fuel - 0.007 t/t bauxite
- Fuel oil - 0.01 t/t bauxite

Water usage if ore washing is not used will be minimal.

When ore washing is used water usage can be in the region of 3-4 t/t bauxite.<sup>(1)</sup>



## 2.2 ALUMINA FACILITIES

### 2.2.1 Process Description

This description follows the simplified alumina process diagram included in the Appendix.

Bauxite is transported from the bauxite mine/beneficiation area by ship, barge, truck, rail or conveyor depending mainly on the distance between the mine and the alumina plant.

In the alumina plant the bauxite is first crushed and/or ground to the correct particle size for efficient extraction of the alumina in digestion.

In the digestion unit the extractable alumina is extracted from the bauxite using hot, sodium hydroxide liquor, in a series of pressure vessels. In the next step - mud separation - the mud, consisting of the insoluble part of the bauxite, is separated from the process liquor, using thickeners and sometimes filters. The separated, and thickened mud is washed almost free of entrained caustic soda before being pumped to the mud disposal area.

After mud separation, the process liquor still contains a very small amount of solids which is removed in the polishing filtration step using some type of pressurized leaf or sand filter.

The process liquor, now free of all solid impurities, is pumped to the precipitation step, where it is held, typically for 20 - 40 hours, in a series of large tanks (precipitators). The crystallization (precipitation) of alumina trihydrate crystals is promoted in the precipitators by cooling the liquor and by recycling undersize alumina trihydrate crystals as seed to the precipitators.

The net result is that the alumina which went into solution in the plant liquor in the digestion step is 'precipitated' back out of solution in the precipitation step, and the plant liquor is recycled back to digestion, to extract more alumina from bauxite.

The hydrate slurry produced in the precipitators is next classified in the classification step in order to separate the large particle size fraction suitable for the alumina product. The undersize hydrate fraction is returned to the precipitators as seed.

The product hydrate is subsequently calcined, in rotary kilns or fluid bed calciners, in order to convert the alumina trihydrate ( $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ ) to alumina ( $\text{Al}_2\text{O}_3$ ). Fluid bed calciners are the more modern and efficient technology.

Burnt lime is used as an additive in practically all alumina plants. This material may be purchased from an outside source or many plants purchase limestone and convert it themselves to burnt lime in lime burning facilities.

An alumina plant uses both steam and power. If power is available, at an economic rate, from a local power source outside the plant, then the plant may decide to purchase the power rather than generate it using in-plant facilities. In which case only steam generating facilities would be installed.

When power is not available locally, an alumina plant will typically install a steam and power cogeneration facility to supply the plant's requirements.

### **2.2.2 Process Flow Diagram**

A simple, basic, process flow diagram is included in the Appendix.

### **2.2.3 Economic Factors in Process and Equipment Selection**

There are many economic factors in the process selection, the more important are listed below.

- digestion conditions must be selected to extract an economic percentage of the alumina from the particular type of bauxite. Normally this percentage must be greater than 95%.
- the selected process should minimize the consumption of energy, water, and raw materials, such as bauxite and caustic soda.
- the selected process should minimize the amount of land and equipment required to produce the specified plant capacity. For example, one typical goal of alumina plant process selection today is to eliminate the requirement for a separate in-plant evaporation facility, thereby reducing energy requirements, equipment requirements, and land requirements.
- availability and nature of energy source. Cheap coal could be attractive but increases atmospheric emissions of  $\text{SO}_x$ ,  $\text{CO}_2$ , and particulates.
- Economics of scale are in favor of larger size alumina plants. Most new plants under consideration today are in the 600,000 to 1,000,000 tpy alumina production range.

### **2.2.4 Environmental Factors in Process and Equipment Selection**

Environmental problems arising from the alumina plant process as practiced today are not excessive. The process emissions can be effectively controlled if the correct equipment is installed to treat the emissions. The main challenge is the proper disposal of the red mud residue. This subject will be discussed further in Sections 3.0 and 11.0 of this report.

### **2.2.5 Materials and Energy Usage**

The consumption of materials and energy in the alumina process depends to a large extent on the type of bauxite used, the plant location, process selection, and the efficiency of operation.

Table 1 below shows a range of usage. The lower usage numbers are more typical of a high alumina, (e.g. Boké) low silica bauxite and good process design. Whereas the higher consumption rates apply to poorer grades of bauxite in use today and less efficient process design and operations.

Table 1 Alumina Plant Materials and Energy Usage		
<u>Materials</u>	<u>Usage</u>	
Bauxite, dry t/t alumina	1.85	- 3.60
Caustic Soda (100% NaOH) t/t alumina	0.03	- 0.145
Water, t/t alumina	1.0	- 9.0
Power, Kwh/t alumina	220	- 400
Fuel, G. Joules/t alumina	0.00837	- 0.01674
Burnt Lime (90% CaO) t/t alumina	0.015	- 0.10
Sulfuric Acid (98% H <sub>2</sub> SO <sub>4</sub> ) t/t alumina	0.0009	- 0.0014

## 2.3 ALUMINIUM SMELTER

### 2.3.1 Process Description

The Hall-Heroult process for the electrolytic reduction of alumina, remains the only commercially proven method of producing primary aluminum.

There are two main variations of the basic Hall-Heroult process, namely prebake pots in which the anodes are formed and baked externally, or Soderberg pots, in which the anodes are baked in situ. In each case, the pots may be worked from either the top or side.

The Soderberg pot has 2 variants - the vertical stud and the horizontal stud. There are three variations to the prebake cell. One type is the center-worked cell (CWPB), another the side worked cell (SWPB), and the third is the point-fed (PFPB). Continuous improvements to the efficiencies and emission levels from these various pot technologies have been made over the years.

In recent years, there has been a tendency for new aluminum plants to use the prebake cells, largely because of environmental considerations. The centre worked pre-bake (CWPB) cell currently in wide use is a value engineered version of original designs of this type, optimizing electrical and fume collection efficiencies by a combination of engineering design and process control improvements. The following process description will be based mainly on the CWPB technology.

Primary aluminum is produced by the electrolytic reduction of alumina. An aluminum plant combines cells (or pots) where this reduction takes place, casting facilities and plant to manufacture cell components. The process is represented diagrammatically in the aluminium process flow diagram included in the Appendix. Alumina (aluminum oxide) is dissolved in a molten bath of fluoride compounds (the electrolyte) at a temperature of approximately 950°C. Passage of a direct current of electricity through the bath causes the alumina to dissociate to form liquid aluminum and oxygen. Current passages from carbon anodes submerged in the bath to the lining of pots, the cathode. Pots are connected electrically in series to form a potline.

Molten aluminum collecting in the bottom of the cells is periodically removed under vacuum into tapping crucibles. Evolved oxygen combines with carbon from the anodes, necessitating their replacement on a regular basis. Programmed additions of alumina and fluoride compounds are made to the bath to maintain continuous operation. It is necessary to break the crust formed over the bath before such additions are possible.

Fumes evolved from the bath are collected by means of a hood enclosing the pot, and is evacuated for treatment.

Liquid aluminum tapped from the pots undergoes purifying, alloying and casting operations in the cast house. Final product is solid aluminum metal in any of several physical forms.

Anodes are manufactured from a mixture of materials in the carbon plant, a facility which combines mixing, forming and baking operations to produce sufficient anodes to replace on average one anode per pot per day.

Primary aluminum production generates airborne, solid and liquid wastes. Of these, airborne emissions are the most significant from the viewpoint of potential offsite impact.

Typical operating characteristics of the modern CWPB cell are as follows.

- |                      |                           |
|----------------------|---------------------------|
| • Average amperage   | 175,000-280,000 amperes   |
| • Volts per pot      | 4.15 volts                |
| • Power consumption  | 12.9-13.5 dc Kwh/kg metal |
| • Current efficiency | 91-95%                    |

The cathode is contained in an independent shell supported by electrically insulated concrete beams. The lining consists of carbon blocks. Heat losses are controlled with refractory and insulating bricks. The cell sides are similarly protected by carbon blocks. All joints are sealed with carbon paste.

A steel superstructure supports the anode system, the hood and the crust breaking and alumina feeding equipment. Alumina additions are made to the pot from hoppers suspended from the superstructure between the two rows of anodes.

Pot emissions are confined by a combination of fixed hooding and removable side panels. A fixed roof and end pieces are integrated with the superstructure. Panels close the space framed by the hooding and the side of the pots. Emissions are evacuated to collection ducts and thence to a dry scrubbing unit for treatment prior to discharge.

Green (unbaked) anodes are produced using petroleum coke, liquid pitch and recycled anode butts. Proportioned quantities of crushed and classified coke and recycled butts are heated and mixed with liquid pitch. Cooled anodes are transported by overhead cranes either to storage or directly to the baking furnace.

Anode baking is performed in a furnace, which consists of a number of pits into which the green anodes are placed. Burners fired with natural gas or oil heat air which passes around the pits in a controlled manner to achieve the required heating cycle. Exhaust gases are collected for treatment in an alumina dry scrubber before discharge to the atmosphere.

Anode rodding is performed in a separate building. Used anodes are cleaned on vibrating tables and shot blasted to remove adherent bath, and then stripped from the rod assembly. Cast iron used to connect the anode with the stem is removed from the anodes for recycling. Rod assemblies are repaired, if necessary, prior to graphite coating of the pins (which are used to make connection with anode) in preparation for rodding of a new anode.

### **Casting**

Hot metal produced in the pots is vacuum tapped once per day into tapping ladles and then transferred to the cast house.

For some products, impurities are removed by reaction (fluxing) with a nitrogen-chlorine-inert gas mixture. Alloy elements are added and distributed by mixing as required. The product is cast using continuous and semi-continuous casting machines, depending on the end use of the solid metal.

Facilities are provided for cooling and processing cast house dross (waste aluminum/aluminum oxide mixture).

### **Support Operations**

Individual facilities are provided for the following functions.

- Pot lining removal and rebuilding of pots.
- Cleaning and relining of tapping ladles.
- General maintenance of plant and equipment.

### **2.3.2 Process Flow Diagram**

A process flow diagram for the aluminium smelter and auxiliary processes are included in the Appendix.

### **2.3.3 Economic Factors in Process and Equipment Selection**

The typical aluminium smelter is a highly complex and capital intensive installation in which many economic factors come into play in selecting the optimum equipment and process.

The major capital and operating cost item is the electrolytic cell (pot) and its power requirement. Great strides have been made in the last 2 decades in designing bigger and more energy efficient electrolytic cells. At the same time much progress has been made in making the electrolytic cells easier and safer to operate while reducing the amount of toxic emissions escaping from the cells during operation.

### **2.3.4 Environmental Factors in Process and Equipment Selection**

The major environmental factors which have to be taken into consideration are the generation of hazardous fumes and particulates in the electrolytic cells and in the production of carbon anodes, and the generation of difficult to dispose of spent pot linings. There are several electrolytic cells and carbon anode baking technologies available. A careful evaluation of the rate of emissions generation and the efficiency of capturing those emissions should be made before a particular technology or equipment design is selected for use.

### 2.3.5 Materials and Energy Usage

Energy kWh/kg Al	12.5 - 14.0
Alumina (Al <sub>2</sub> O <sub>3</sub> ), kg/kg Al	1.9
Anode Carbon, kg/kg Al	0.37 - 0.43
Anode pitch kg/kg Al	0.10
Cell life, years	5 - 8
<u>Anode Baking</u>	
Typical Gas Consumption (modern unit) GJ <sub>oxide</sub> /t Al	2.5

Based on a modern large center worked prebake cell (CWPB) installation.

## 3.0 WASTE SOURCES AND CHARACTERIZATION

### 3.1 BAUXITE FACILITIES

#### 3.1.1 Bauxite Beneficiation Tailings

Some bauxite production facilities incorporate an ore washing or beneficiation step, in order to upgrade the quality of the bauxite<sup>(1)</sup>. See the bauxite mine/beneficiation flow sheet in the Appendix for information on how the waste is produced. These wastes are not considered to be hazardous, however they can be very detrimental to the flora and fauna of the area, if not disposed of properly.

Typically the quantity of tailing solids can be 1/3 of the weight of bauxite shipped. A typical tailings slurry contains 7-9% solids with a particle size less than 150 mesh<sup>(1)</sup>.

#### 3.1.2 Atmospheric Emissions

The main atmospheric emission problem is bauxite dust. This material is not considered hazardous, but can still pose environmental problems if not properly controlled. Bauxite dust is generated at various locations and by various types of equipment. The main sources are:

- bauxite dryers.
- loading and unloading of ships, trucks, railroad cars.
- bauxite carrying conveyor systems including transfer points.
- truck movement in the bauxite mine.
- blasting.

Some bauxites are more dusty than others, which needs to be taken into account when designing the dust containment systems used on the bauxite handling equipment.

Other emissions which could occur, would be NO<sub>x</sub>, SO<sub>2</sub> and other products of combustion from the bauxite dryers, which can have a deleterious and expensive effect on dust collection equipment.

### 3.1.3 Waste Waters

Waste water, containing small amounts of suspended bauxite solids can be generated (1) by the ore washing and beneficiation process; or (2) by run-off from the mine area. Depending on the amount of rainfall at the mine area, a considerable amount of run-off can be generated. Settling ponds should be considered for removal of the solids contained in the run-off. It is essential that proper drainage ditches and channels be installed at the mine, beneficiation plant, bauxite drying facility, and along all access roads, in order to reduce erosion in these areas (3).

In some underground mines ground water can create severe environmental problems. This type of situation requires careful attention to design of the mining technology, and continuous monitoring of ground water levels and the levels of lakes and rivers in the region.

## 3.2 ALUMINA FACILITIES

Refer to the Alumina Plant process flow diagram in the Appendix for the source of the wastes and emissions discussed below.

### 3.2.1 Atmospheric Emissions

Table 3 Atmospheric Emissions from Alumina Facilities	
<u>Unit Process</u>	<u>Type of Emission(s)</u>
Bauxite unloading, conveying, transfer points, stacker/reclaimer, crushers and/or mills, stockpiles and bins	Bauxite dust
Limestone receiving/unloading, bins and conveyors	Limestone dust
Burnt lime conveyors and bins	Burnt lime dust
Alumina ship and car loaders, silo and handling systems (air slide, conveyors)	Alumina dust
Red mud stacks	Red mud dust, sodium salts
Cooling towers and blow-off tanks	Caustic aerosols
Boilers, power co-generators	SO <sub>2</sub> , NO <sub>x</sub>
Calciners	SO <sub>2</sub> , NO <sub>x</sub> , alumina dust
Mobile equipment	SO <sub>2</sub> , NO <sub>x</sub>
Kilns	SO <sub>2</sub> , NO <sub>x</sub> , burnt lime dust

### **3.2.2 Waste Waters**

Under normal operations the alumina facilities do not generate a waste water to be disposed of. However during periods of heavy rainfall a large amount of water can fall on the overall plant area. If this water volume is in excess of what the plant can use in the process then it will have to be discharged from the plant as a waste water.

### **3.2.3 Sludges**

The main waste generated by an alumina plant is the red mud, which is basically the bauxite residue after extraction of the alumina. Red mud contains bauxite minerals not dissolved during digestion and solid and crystalline phases formed in the Bayer Process ( $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{Na}_2\text{O}$ ,  $\text{CaO}$  and others). The pH of this residue is 10-12. The chemically bound NaOH in the form of sodium aluminum hydrosilicates tend to dissolve partially and slowly in a process of hydrolysis. The red mud is washed with water in the plant to recover almost all of the caustic soda in the mud, before pumping the mud to a sealed impoundment.

### **3.2.4 Hazardous Wastes**

The main hazardous waste in the alumina refinery is the spent acid resulting from the cleaning of scale from tanks and pipes in the plant.

If the process incorporates a liquor purification process then salt-cake and other oxalates may be produced.

The plant laboratory and maintenance shops can also generate hazardous waste but in relatively small quantities.

### **3.2.5 Fugitive Emissions**

See under 3.2.1 Atmospheric Emissions.

## **3.3 ALUMINIUM FACILITIES**

Refer to the Aluminium Plant process flow diagram in the Appendix for the source of the wastes and emissions discussed below.

### **3.3.1 Atmospheric Emissions**

Generation of atmospheric emissions in the aluminum smelter and carbon baking facilities constitute one of the most serious environmental problems associated with aluminum production facilities.



The main emissions are listed below:

<u>Unit Process</u>	<u>Type of Emissions(s)</u>
Alumina unloading, conveying, handling and storage	Alumina dust
Coke unloading, conveying, handling and storage	Coke dust
Potline	Gaseous fluorides, particulate fluorides, SO <sub>2</sub> dusts from handling various materials, CO <sub>2</sub> tars
Baking furnace	Gaseous fluorides, particulate fluorides, SO <sub>2</sub> tar vapor, carbon particulate
Green carbon and anode forming plant	Coke dust, pitch tar vapors
Rodding room	Carbon dust
Metal service building	Fluxing emissions dependent on type of fluxing, carbon oxides

#### **Waste Characterization**

The electrolytic reduction cells are the major source of airborne emissions. Gases including hydrogen fluoride, sulphur dioxide and carbon oxides are generated by the thermal decomposition of fluoride compounds and the oxidation of anode constituents. During an anode-effect (a normally short term increase in cell resistance), carbon tetrafluoride is evolved.

Particulates originate from the volatilization of the cryolite bath and subsequent condensation, from mechanical entrainment of bath material by gases evolved from the cell surface, and from dusting of raw materials during handling. They include alumina, cryolite, aluminum fluoride, sodium fluoride and carbon.

The green anode manufacturing process gives rise to pitch tar vapors and dust. The anode baking operation evolves gaseous fluorides, sulphur dioxide, carbon oxides and tar vapors and particulates.

The casting complex is a minor source, and its contribution depends largely on fuel choice and fluxing practice. Carbon oxides are the major potential emissions.

Of the above, the only compounds released in normal quantities sufficient to have adverse effects on the surrounding environment are gaseous and particulate fluorides.

The estimated source emission rates are summarized below.

<b>Table 5 - Typical Airborne emissions before treatment for Modern CWPB Pot generated at source (long term average)<sup>(4)</sup></b>		
<u>Source</u>	<u>Emission</u>	<u>Quantity kg/t.Al</u>
Reduction cells	Gaseous fluoride	16
	Particulate fluoride	16
	Sulphur dioxide, SO <sub>2</sub> *	24
Anode furnace	Gaseous fluoride	0.25
	Particulate fluoride	nil
	Carbon particulates	1.2
	Tar vapor	0.6
	Sulphur dioxide, SO <sub>2</sub>	0.8
*Depends on sulphur content of anode.		

### 3.3.2 Waste Water

The only waste water of concern is storm water run-off which can be contaminated with very small amounts of process generated particulates such as fluorides.

### Waste Characterization

Rain falling within the plant boundaries dissolves available fluoride from roofs of buildings and paved areas. Maximum concentrations of fluoride are usually experienced in the first rainfall of the season. Subsequent runoff, particularly in wet climates, will have lower levels of dissolved fluoride.

### 3.3.3 Solid Wastes

A 250,000 tpy aluminum plant produces approximately 40-60 kg of mixed solid wastes per tonnage of product. Spent cathodes (spent pot linings) are the main source of the solid waste.

Under normal operating conditions cathodes (the cell lining) are expected to last approximately 4 to 5 years. During this time, they are impregnated with fluorides, sodium, iron and cyano-complexes, in addition to suffering plastic intrusions of liquid metal.

At the end of their useful life, pots are delined using pneumatic drills, yielding a mixture of materials and size fractions. Approximately 50 per cent of the spent cathode is impregnated carbon, and the remainder is refractory material. Typical bulk analyses are:

Species	Carbon		Refractories	
	Average %	Maximum %	Average %	Maximum %
Carbon	45	60	1	2
Al <sub>2</sub> O <sub>3</sub>	15	20	35	40
SiO <sub>2</sub>	1	3	35	38
CaF <sub>2</sub>	9	5	3	4
AlF <sub>3</sub>	10	15	4	5
NaF	15	25	16	20
CN-	<400 ppm	400 ppm	<50 ppm	50 ppm
N	1	2	< 1	1

Refractories that have failed largely due to thermal shock are derived from the anode baking furnace, the cast house and the crucible repair shop. Contaminant levels are generally low.

Other solid waste or by-products which are generated in lesser quantities including skim, dross, fluxing slags, road sweepings, packaging and domestic wastes.

#### 4.0 WASTE MINIMIZATION OPPORTUNITIES

##### 4.1 BAUXITE FACILITIES - TAILINGS VOLUME MINIMIZATION

If beneficiation or ore washing are in use, a large volume of tailings may be produced. For example, one 5 million tpy bauxite mine<sup>(1)</sup>, produces 1.7 million tons per year of tailings solids which amounts to 19-24 million tons per year of tailings slurry at the 7-9% solids reported.

The technology of choice is to minimize the volume of this waste by concentrating the slurry to a much higher percent solids and returning it to the mined out area of the bauxite mine.

One bauxite mine<sup>(1)</sup> uses a large pond to concentrate the tailings solids to 25-30%, (6.8-5.7 million TPY slurry) which reduces the volume of tailings waste considerably. However, the opportunity exists to reduce the volume of tailings waste even further by the use of a high-efficiency thickener<sup>(5)(6)</sup>. With proper design, such a thickener could increase the concentration of the tailings waste to 30%-50% solids, equivalent to 3.4-5.7 million tons per year of tailings slurry.

## 4.2 ALUMINA PLANT FACILITIES

### 4.2.1 Red Mud Waste Minimization

Alumina plants typically produce a large volume of red mud waste, which can range as high as 2 tons of red mud solids per ton of alumina produced by the plant. This mud leaves the red mud washing circuit typically as 25-30% solids slurry which represents as high as 3.3 million tons per year of slurry for a one million ton per year alumina plant. Many alumina plants today still dispose of their red mud in this form, i.e. 25-30% slurry.

The opportunity is available to reduce the volume of this waste, and several plants are doing this today.

The technology exists in the form of high-efficiency, deep thickeners<sup>(5)</sup>, or large diameter conventional thickeners<sup>(6)</sup>, to reduce the volume of red mud waste much further by thickening the slurry to 50-60% solids. In this case 3.3 million TPY of red mud slurry waste would be reduced to 1.7-2.0 million TPY of waste slurry.

### 4.2.2 Lime Waste Disposal

All the lime added to the process forms insoluble waste material which is normally discarded with the red mud. The amount of this lime based waste material can be minimized by recycling the lime used as a filtering aid to digestion to displace the fresh lime which is usually added at this point.

### 4.2.3 Waste Water

The waste water discharge from the alumina plant can be minimized and in certain cases eliminated by good process design and good operating practice, i.e.,

- minimizing the water added to the process
- efficient segregation of condensates and recycling to appropriate process areas.
- efficient storm water handling (See 10.2.9)

## 4.3 ALUMINIUM FACILITIES

### 4.3.1 Spent Pot Lining (SPL) Waste Minimization

Spent pot lining (SPL) constitutes a major hazardous waste problem from aluminum smelters. Spent pot linings are removed from the electrolytic cells after failure of the lining, typically due to cracking and/or heaving of the lining.

Construction and operation of the cell can have a significant effect on the life of the pot lining leading to a large variation in pot life from 3-10 years<sup>(25)</sup>.

The opportunity exists for reducing the amount of SPL produced by a plant if cathode construction and cell operating techniques are used which increase the life of the SPL to a maximum. Reducing the number of pot liners which fail at less than 5-6 years would be a significant reduction.

## 5.6 CONTAMINANTS OF CONCERN

Type of Facility	Contaminants
<b>BAUXITE</b>	<ul style="list-style-type: none"><li>• Bauxite dust</li><li>• Bauxite tailings</li><li>• SO<sub>2</sub>, NO<sub>x</sub> from bauxite dryers</li><li>• Oils and solvents (machine shop, garage)</li></ul>
<b>ALUMINA</b>	<ul style="list-style-type: none"><li>• Caustic soda (NaOH)</li><li>• Sulphuric acid (H<sub>2</sub>SO<sub>4</sub>)</li><li>• Red Mud</li><li>• Burnt lime dust</li><li>• Limestone dust</li><li>• Alumina dust</li><li>• Oxalates</li><li>• Oils and solvents (machine shop, garage)</li><li>• SO<sub>2</sub>, NO<sub>x</sub> (boilers, calciners, etc.)</li></ul>
<b>ALUMINUM</b>	<ul style="list-style-type: none"><li>• Hydrogen fluoride - vapors and particulates</li><li>• Tar and pitch vapors (PAH)</li><li>• Coke/pitch dust</li><li>• Alumina</li><li>• Cyanides and fluorides (spent pot linings)</li><li>• Sulphur dioxide (SO<sub>2</sub>)</li><li>• Carbon oxides</li><li>• Cryolite/aluminum fluoride/sodium fluoride dusts</li><li>• Skim</li><li>• Dross</li></ul>

## 6.0 IMPACT ON RECEPTORS

The siting, design, and operation of aluminium industry facilities (bauxite, alumina, and aluminium) can have a significant effect on the environment of the plant area.

The impact on the various receptors in the proposed location of the plant site must be thoroughly evaluated before the plant is constructed.

It is highly advisable and usually mandatory that an environmental impact assessment (EIA) be carried out at any proposed plant site.

## 6.1 ENVIRONMENTAL IMPACT ASSESSMENT

Items requiring consideration include:

### 1. Physical Environment Factors

#### a. Present Land Use

- Population density.
- Natural vegetation.
- Agricultural crops and their growth season.
- Livestock.
- Ground water uses and soils stability.
- Existing industry.

#### b. Future Land Use

- Population growth projections.
- Regional agricultural needs.
- Regional livestock needs.
- Recreational potential.
- Silvicultural potential.
- Future industrialization.

#### c. Water Availability and Use

- Quantity available.
- Surface water quality.
- Ground water quality.
- Present and future water requirements for:
  - a. Industry.
  - b. Residential.
  - c. Recreational.
- Relationship between water quality and vegetation cover.
- Flood plain location and flood frequency.
- Receiving stream characteristics and availability of dilution water.
- Present and future discharge inventory into river basin.
- Water quality impacts of present and projected discharges.

#### d. Meteorological Factors

- Climate - humidity, temperature range, rainfall, seasonal variations, prevailing wind patterns, wind speed, wind variability, inversion conditions, sea breeze effects, valley downwash conditions, ventilation potential.
- Surrounding topography - ground cover, terrain, orographic effects, channelling effects, surface roughness, effects of water bodies.
- Atmospheric dispersion characteristics, terrain characteristics, typical lapse rates, nocturnal and subsistence inversions, wind variability.

#### e. Ambient Air Quality - Background Levels

- Ambient air monitoring data available.
- Air emission inventories for the surrounding area, air quality impact predictions for present and projected emissions for all sources in the area.
- Fugitive emission air quality impacts, i.e. roads, ploughed fields, forest, bulk loading and handling facilities, mining operations, transportation.

**f. Waste Disposal Potential**

- Soil permeability conditions.
- Ground water location and use.
- Vegetation cover characteristics.
- Aesthetics of land fills in the area.
- Proximity to coastal areas.
- Requirements for top soil segregation.

**g. Coastal Management**

- Estuarine water flow and quality.
- Beach erosion from dock, pier or breakwater construction.
- Water quality and recreational impacts from construction runoff, plant runoff, waste water disposal.

**2. Social Environment**

**a. Demography**

- Population location.
- Indirect impact on transportation requirements.
  - a. People.
  - b. Raw materials.
  - c. Products.
- Impact on population growth in urban and rural areas.
- Housing needs resulting from plant operation.

**b. Aesthetics and Economics**

- Impact on property values.
- Aesthetics of the plant.
- Need for professionals, i.e. medical, legal, governmental, educational, commercial, etc.
- Impact on tax base and public spending requirements.

**c. Impact on Historical, Cultural and Archaeological or Sacred Sites in the Area**

**3. Economic Environment**

- Plant impacts on wages and wage rates.
- Plant impact on cost of living for plant employees and non-employees.
- Plant impact on community growth and commercial development.

**6.2 SPECIFIC IMPACT PROBLEMS OF CONCERN**

**6.2.1 Fluoride Emissions from Aluminium Smelters**

Fluoride emissions, if excessive, can adversely effect the vegetation and animals in the area around the plant.

Vegetation is variably susceptible to fluorides. The impact of fluoride emissions on vegetation and animals has been studied at length.<sup>(7)(8)(9)</sup>

In some locations, close to farming areas, especially stock farming areas, the amount of fluorides in forage may need to be measured and controlled, and comply with applicable standards. Generally, the emission standard is expressed in terms of concentration of fluorides in exhaust gas and compliance with standards of performance expressed as amount of fluorides emitted per tonne of aluminium produced.

### **6.2.2 Spent Pot Lining (SPL)**

Spent pot lining contains soluble cyanides and fluorides. In the past a considerable amount of this material was stored in piles in the open, with no particular attempt to contain the cyanide and fluoride containing leachate. As a consequence cyanides and fluorides found their way into the local ground water and surface water. This practice created a problem if these contaminants found their way into drinking water supplies.

A safe, leak proof, building on the plant site should be provided for storage of all SPL until it is treated.

### **6.2.3 Red Mud Waste**

Although red mud, per se, is classified as non-hazardous by the EPA it can have a considerable impact on the land due to its large volume.

The red mud from a one million TPY alumina plant could cover a land-fill area from one quarter square kilometer to one square kilometer every 5 years. If feasible a good disposal site would be in the mined out area of the bauxite mine supplying the bauxite, but this is only feasible if the alumina plant is located very close to the bauxite mine.

The red mud disposal area must be designed so as to prevent seepage of toxic materials, such as caustic soda, into adjacent ground water systems, and excessive dusting of adjacent land.

### **6.2.4 Process Spills**

Each area of plant containing process equipment will have a sealed concrete slab with 14 cm high concrete kerbs (wall) in order to keep any accidental spill of process liquids inside the kerbed area. Sumps with pumps are provided to return the spilled liquor back into a process tank. The concrete slab and sumps are designed to be leak-proof — however historical alumina plant operating experience suggests that it is very difficult to construct and maintain a leak-proof concrete slab. Leaks occur at cracks in the concrete or at failed concrete joints. This can allow toxic process spills containing caustic soda and sulfuric acid to penetrate the slab and contaminate the groundwater.

### **6.2.5 Waste Water**

The plant waste water could conceivably contain all of the contaminants of concern listed under 5.2 Alumina Facilities. However, this is not normally a serious problem if good process design and good operating practice are observed (See Section 4.2.3).



## 7.0 OCCUPATIONAL HEALTH AND SAFETY ISSUES

The regulations of industrial health and safety which apply in the mining, chemical and process industries, particularly in the alkaline extractive industries, should be implemented to protect the worker and make the working environment safe. Raw materials, equipment, machinery, product, by-product, wastes, gaseous, solid and liquid effluents, noise and heat should all be characterized, evaluated and standards set and mechanisms established for their monitoring and control. Worker protection devices and methods for monitoring their use should be issued and implemented. Monitoring systems should aim for consistency, regularity, efficiency and effectiveness. A medical clinic should be established within the plant. Workers should be involved in safety and industrial health management planning and their implementation.

In designing the facilities provisions should be made for:

- Safe working conditions for workers.
- The safe storage, transportation and handling of chemicals.
- Providing workers with appropriate safety equipment and apparel.
- Establishment of standards for safe periods of exposure to toxic and other chemicals, heat and noise.
- Safety regulations to be established and workers to be trained and instructed to follow them.
- A safety monitoring system among workers to be instituted to ensure that workers adhere to safety instructions.
- Periodic inspection of the plant to be carried out by independent inspectors, usually from a government organization, to ensure that safe working conditions are maintained.
- A system of reporting accidents and their investigation to be established.
- An industrial health clinic to be established at the plant site.
- Wearing of respiratory and ear protection should be mandatory in areas of the plant where personal exposure exceeds the published legally enforceable occupational exposure limit for the contaminant or noise, and encouraged in other areas.
- A health protection program should be developed and implemented including periodic monitoring of workers' exposure and health condition (fluorine content in urine, lung function, hearing acuity etc.)<sup>(8, 9, 10)</sup>.
- Standards for occupational exposure limits for airborne contaminants are contained in the Appendix - Table 13.

The main health and safety hazards to which workers may be exposed are:

- Electrolytic Cell Fumes - (See Section 3.5.1 for details of fume constituents). The atmosphere in the potroom can become hazardous if the systems for capturing and removing pot fumes are not designed and operated properly. Breathing masks must be available for use by pot room operators.
- In the re-melt operations molten metal explosions are possible which can lead to serious injury. Extreme care should be taken when charging metal or scrap material to the cast-house furnace to ensure no entrapped water is present.

## **8.0 SURVEY OF EFFLUENT GUIDELINES**

This section contains a sampling of discharge standards/guidelines from those countries where major bauxite, alumina, or aluminium facilities exist today.

### **8.1 PARTICULATE STANDARDS**

The emission standard of 50 mg/dsm<sup>3</sup> (50 milligrams per dry standard cubic meter) is applied by the U.S. EPA for alumina handling operations. Japan has an emission standard of 100 mg/m<sup>3</sup> for reaction furnaces, which is applicable to alumina and aluminum processes. Japan has a fluoride emission limit of 1.0 mg/m<sup>3</sup> in aluminum reduction gases.

A particulate emission standard of 100 mg/m<sup>3</sup> is enforced in West Germany for alumina calcining and primary reduction. Britain has an emission standard of 120 mg/m<sup>3</sup> for aluminum smelters. New Zealand has a particulate emission standard of 100 mg/m<sup>3</sup> for all ferrous and nonferrous processes.

Mexico has regulations that require 80% particulate emission control for smelting furnace gases.

Emission guidelines provided by the State of Bahrain for an aluminum rolling mill are 300 mg/m<sup>3</sup>.

In Sweden particulate emission guidelines are 8 Kg/tonne aluminium for vertical Soderberg cells (VSE) and 1.5 Kg/tonne aluminium for point fed prebaked electrode (PFPB) cells.

### **8.2 FLUORIDE STANDARDS**

The U.S. EPA fluoride emission standards for the aluminum industry are 1 kg/t aluminum (30 day average-potroom).

In Sweden the guidelines are 1 Kg total/tonne aluminium for VSE cells and 0.5 Kg total per tonne aluminium for PFPB cells.

West Germany and Australia have the same fluoride emission standard which is 50 mg/m<sup>3</sup> in the exhaust gases.

### **8.3 OPACITY STANDARDS**

The standard enforced by the U.S. EPA for smelter emissions is 10% (potroom) and 20% (anode bake area).

Britain has an opacity standard of Ringelmann II for the exhaust gas from a stationary source.

A Ringelmann III standard for exhaust gases has been adopted by Columbia.

Opacity standards of Ringelmann III and Ringelmann IV has been adopted by the Philippines and Guam, respectively.

### **8.4 EMISSION CONTROL STANDARDS - POWER AND/OR STEAM GENERATION PLANT**

Power and/or steam facilities are frequently an integral part of alumina plants and aluminium smelters, and must be considered a possible source of air pollution in the aluminium industries. The major pollutants of the exhaust from these facilities are particulates, sulfur dioxide and nitrous oxides.

#### **8.4.1 Particulate Standards**

The particulate emission standard of 11.43 gms/10<sup>6</sup> Kcal for oil and coal-fired boilers is essentially a new source performance standard presently enforced by United States regulations. The particulate emission standard of 200 mg/m<sup>3</sup> has been adopted by Japan.

The particulate emission standards of 51.4 gms/10<sup>6</sup> Kcal and 300 mg/m<sup>3</sup> for oil and coal-fired boilers, respectively, have been adopted by Denmark and West Germany.

A particulate discharge standard for boilers of 1.0 kg/10<sup>6</sup> Kcal has been adopted by Mexico.

A particulate emission standard of 900 mg/m<sup>3</sup> has been adopted by the Philippines for all stationary sources.

#### **8.4.2 Sulfur Dioxide Standards**

A sulfur dioxide emission limit of 362.9 gms/10<sup>6</sup> Kcal for coal-fired boilers is the standard enforced by U.S. EPA.

A sulfur dioxide emission standard of 20 kg/ton of oil for oil-fired boilers was adopted by Sweden and 2,400 mg/m<sup>3</sup> for coal-fired boilers adopted by Spain.

Greece and Portugal have regulations that limit the use of heavy fuel oil and coal containing more than 3.5% and 4% of sulfur by weight, respectively.

#### **8.4.3 Nitrous Oxides (NO<sub>x</sub>) Standards**

Nitrous oxide standards of 34.3 gms/10<sup>6</sup> Kcal for oil-fired and 80 gms/10<sup>6</sup> Kcal for coal-fired boilers are the new source performance standards presently enforced by U.S. EPA. The

nitrous oxide emission standard of 180 ppm in exhaust gases adopted by Japan is comparable with the United States standard of 34.3 gms/10<sup>6</sup> Kcal for oil-fired boilers.

Spain has a nitrous oxide emission standard of 300 mg/m<sup>3</sup> in the exhaust gases.

Singapore has a standard of 2,000 mg/m<sup>3</sup> for nitrous oxide discharge in the exhaust gas from all stationary sources.

#### 8.4.4 Opacity Standards

An opacity of 20% in the exhaust gases is the standard enforced by U.S. EPA.

Britain has an opacity standard of Ringelmann II for the exhaust gas from a stationary source.

Ringelmann III standard for exhaust gases has been adopted by Columbia.

Opacity standards of Ringelmann III and Ringelmann IV were adopted by the Philippines and Guam, respectively.

### 8.5 WASTEWATER CONTROL STANDARDS

Some of the companies producing alumina and aluminum are located in countries commonly referred to as Least Developed Countries (LDC's). Standards for wastewater discharges from such industries are scant.

#### 8.5.1 Standards in the United States

The United States standards for wastewater discharges for new sources are:

- Alumina Refining:

There shall be no discharge of process wastewater pollutants to navigable waters.

- Primary Aluminum Smelting:

Table 8 U.S. EPA Standards for Wastewater Discharge from Aluminum Smelters		
<u>Effluent Characteristic</u>	<u>Maximum for any one day</u>	<u>Average of daily values for 30 consecutive days shall not exceed</u>
	(kg/100 kg of product)	
Fluoride	0.05	0.025
Total suspended Solids	0.01	0.05
pH	Within the range of 6.0 to 9.0	

### 8.5.2 Wastewater Standards in other Countries

In general, most countries outside the United States have adopted a policy for wastewater discharge based on a "site specific" evaluation of the environment in the vicinity of the non-ferrous metals smelting and/or refining plant. The United Kingdom, for example, "... sees little justification for (pollution control) systems based on fixed concentrations of pollutants in effluents regardless of the nature and use of the receiving body in which the effluent flows."

The State of Bahrain has adopted the following standards for nonferrous metals' wastewater discharges to the sea.

<u>Material</u>	<u>Allowable Discharge to the Sea, mg/l</u>
Total Suspended Solids	200
Chemical Oxygen Demand	160
Aluminum	10
Copper	1
Lead	1
Zinc	10
pH	6.0 to 9.0

### 8.6 NOISE STANDARDS

Noise standards are generally applicable to every industry and applied to all the process and material handling areas.

#### 8.6.1 Standards in the United States

The OSHA (Occupational Safety and Health Administration) of the United States permits eight hours per day exposure to noise levels of 90 dBa. The exposure time limit is halved for each 5 dBa increase up to the maximum permitted continuous noise level of 115 dBa.

Community noise codes are generally based on annoyance and sleep interference. Permitted levels for noise that intrudes on residential properties are much lower than permitted levels within the plants. The various industrial and city standards in the United States generally allows continuous noise levels to be between 60 to 65 dBa during the day time and 50 to 55 dBa during night time, due to industrial operation.

## **8.6.2 Noise Standards in Other Countries**

Continuous equipment noise exposure (8 hours per day) to a level above 90 dBa will substantially increase the risk of developing a hearing handicap. The OSHA exposure level indicated above is generally accepted for an industrial facility built anywhere in the world.

Allowable community noise levels indicated above depends largely on the residential activities and type of community such as rural and urban. In some communities a sound barrier may be required to surround an adjacent plant.

## **9.0 TARGET GUIDELINES**

Clearly, any new plant or major expansion must comply with regulations in the country concerned; if these rules are seen as inadequate by modern environmental standards, then more stringent requirements may be appropriate.

### **9.1 Air Emission Standards**

Air emission standards in the aluminum industry vary widely from continent to continent. The best available control technology (BACT) does not. As a target guideline, all new or expanded plants should use the best available control technology (BACT) taking into account capital and operating costs and site location.

For the most part, the technologies presented in the Treatment Technology Overview section, and especially Table 11, of this report, and to a lesser extent the Waste Minimization and Alternative Technologies sections may be used as a guide for BACT.

### **9.2 Waste Water Standards**

The waste water discharge standard should be site specific - taking into account the nature and use of the receiving body in which the effluent enters. In the absence of adequate local regulations, existing standards in the US and elsewhere may be used for guidance - see Sections 8.4.1 and 8.4.2.

### **9.3 Noise Standards**

Continuous noise exposure (8 hours per day) to workers on the plant site should be less than 90 dBa, preferably less than 85 dBa. Allowable noise levels at the plant boundary should depend on local conditions and standards. In the absence of adequate local regulations, existing standards in the US and elsewhere may be used for guidance - see Section 8.6.

## **10.0 TREATMENT TECHNOLOGY OVERVIEW**

### **10.1 BAUXITE FACILITIES**

#### **10.1.1 Bauxite Dust**

##### **a) Bauxite Dryers**

The bauxite dryers are the major potential source of dust emissions. The large amount of dust contained in the dryer exhaust gases must be captured before it enters the

atmosphere. Two types of suitable equipment are available to reduce the dust load in the dryer exhaust to atmosphere, i.e.

- electrostatic precipitators (esp)
- bag house dust collectors.

With proper design engineering both of these methods of dust collection can reduce the dust load exiting the dryer by 99.5%. Without proper dust collection equipment, the surrounding area can be covered with brown bauxite dust for a kilometer or more depending on the prevalent wind pattern.

b) Loading/Unloading of Ships, Trucks, and Railroad Cars

Some bauxites (e.g. some Jamaican) are more dusty than others (e.g. Greek diasporic). Most bauxites will generate dust during handling - such as when loading or unloading, ships, trucks and railroad cars. Typically, dust generation takes place at any transfer point when the bauxite is allowed to fall freely from one elevation to another without total enclosure of the bauxite.

With dusty bauxites consideration should be given to the complete enclosure of the bauxite dust point source together with a vacuum dust pick-up to generate a negative pressure in the dust collecting enclosure.

With less dusty bauxites, it may be possible to reduce the degree of dust formation to acceptable limits by the use of a water spray at the dust point source.

c) Conveyors

For dusty bauxites and areas of high winds it is necessary to fully enclose all conveyors and transfer points. The transfer points should be equipped with vacuum dust pick-up points which should be connected to a bag type dust collector.

For non-dusty bauxites and in the absence of high winds it may not be necessary to install conveyor covers and it may be possible to control dust generation at conveyor transfer and discharge points with a water spray system.

d) Truck Movement

Dust generation on truck roads can be minimized by reducing bauxite spills onto the roads. In virtually all mines it will be necessary to treat the road surfaces with special materials, and/or spray the roads with water to keep the dust down to reasonable levels.

e) Bauxite Stockpiles

Bauxite stockpiles can be a source of considerable dust generation - particularly in an area of high winds - and with dusty bauxites. This is particularly true if bauxite beneficiation generates a fine or superfines stockpile. This dust can be controlled by the use of water sprays (cannot be saline), or more expensively, by enclosure of the stockpile in a building.

### **10.1.2 Bauxite Beneficiation Tailings**

As mentioned before (in Sect. 4.1), beneficiation generates large volumes of tailings solids.

If feasible, a preferable environmental choice is to return the tailings to the mined out areas in the mine, and reclaim the mined out areas. In order to reduce pumping costs, it is preferable to locate the beneficiation plant close to the mine.

An example of modern practice is the use of a large intermediate pond as provided at the Trombetas mine<sup>(1)</sup>. In this case a special dredge is used to pump the 25% or 30% settle slurry from the intermediate pond to a series of cells built in the mined out area using overburden material. The slurry in these cells continues to settle to a higher density. It is expected that reclamation activities will be able to start roughly two to three years after filling individual cells.

Other methods of tailings disposal include dry stacking, which will also permit reclamation of the tailings area in a relatively short time, and the use of dammed sites. All play a part in tailings disposal.

### **10.1.3 Bauxite Mine Rehabilitation**

The necessity for rehabilitation of the mined out areas of bauxite mines is widely recognized today. Rehabilitation procedures are well established among the major aluminum companies (10), (11), (12), (13). Rehabilitation procedures typically include:

- removal of topsoil and storage for replacement
- landscaping and contouring
- building of soil banks to stop erosion from run-off
- ripping of the compacted areas of the mine floor
- replacement of overburden soil
- replacement of top soil
- planting with suitable native trees, shrubs, grasses, etc.
- fertilizing

## **10.2 ALUMINA FACILITIES**

### **10.2.1 Bauxite Dust**

The same comments apply as cited in Section 10.1.1 b, c, e above.

In addition, alumina plants operate bauxite unloading equipment and bauxite storage bins. The type of equipment used to contain the bauxite dust will depend on how dusty the bauxite is. The most restrictive, and expensive equipment is required for dusty bauxites (e.g. some



Jamaican), which will require covered conveyors, enclosed transfer points with vacuum dust collection to a bag dust collector, plus dust collection facilities on all dry bauxite storage bins.

### **10.2.2 Limestone Facilities**

A bag dust collection system will effectively prevent the release of limestone dust at limestone conveyor transfer points and the limestone storage bins.

### **10.2.3 Lime Kilns**

These kilns can be fired with various fuels. However, even if a high sulphur fuel is used, sulphur dioxide (SO<sub>2</sub>) emissions will not be a problem since most of the SO<sub>2</sub> formed from the fuel will be absorbed by the burnt lime in the kiln.

The lime dust in the kiln exhaust can be removed by a bag dust collection system before exhaust release to the atmosphere.

### **10.2.4 Burnt Lime Conveyors**

These conveyors will be enclosed and all transfer points plus the burnt lime bin should have dust pick up points connected to a bag dust collector.

### **10.2.5 Alumina Calcination**

Stationary or rotary calciners fired by natural gas or fuel oil are used. Alumina dust losses are usually satisfactorily controlled using electrostatic dust precipitators. SO<sub>2</sub>, NO<sub>x</sub>, etc. emissions are reduced to acceptable levels by contact with the alumina being processed in the kiln. However these gases will be subsequently released in the smelters.

### **10.2.6 Alumina Conveyors and Storage Silos**

Bag dust collectors can be used to collect the fine dust generated in these areas and the alumina ship loading station.

### **10.2.7 Alumina Loading of Ships, Trucks, & Rail Cars**

The alumina product is very fine and dusty. It is necessary to totally contain the alumina inside the loading equipment and use vacuum dust pick-up points at all equipment/alumina transfer points.

The use of telescopic alumina loading arms together with a skirt or apron at the end of the arm - resting on the alumina pile - plus vacuum dust pick-up points provides for a practically dust free alumina loading operation in modern plants. Problems with dust release may occur at the end of the loading phase if the seal between the alumina pile and the loader apron is lost.

### **10.2.8 Red Mud Disposal**

The technology of choice for the treatment of red mud produced by the alumina plant is the so-called, "dry stacking" system followed by reclamation of the mud impoundment area. This impoundment, ideally, should be located relatively close, i.e. not more than 3kms distant, to

the alumina plant, in order to keep the cost of pumping mud to the mud impoundment area, and the cost of pumping water back to the plant at a reasonable level.

Dry stacking, is a terminology which is not defined very well in the literature. For the purposes of this report, it has been used to indicate a system wherein the mud is dewatered to a high enough solids concentration (approx. 50%) before deposit in the impoundment area so that, for practical design purposes, no significant horizontal hydraulic pressure is developed in the deposited mud. The results are that, 1) the mud does not flow freely in the impoundment and 2) the mud exerts very little horizontal pressure upon any dams erected to contain the deposited mud<sup>(32)</sup>.

There are several methods for obtaining the high solids concentration in the mud necessary for dry stacking. Three economic alternatives, which are in use today, are shown below:

- Deep thickeners<sup>(5)</sup>.
- Large diameter thickeners<sup>(16)</sup>.
- Rotary drum vacuum filters<sup>(31)</sup>.

Of these 3 alternatives, the vacuum filter installation would normally provide a mud residue with the highest percentage solids (typically 50% - 60%). However, it is typically the most expensive alternative. It is necessary to review all the design parameters and constraints for any particular red mud disposal facility in order to select the best economic and environmentally satisfactory solution.

In any design the high concentration mud slurry will be pumped to the impoundment area where the design concept is to dewater and dry the mud solids to a low enough water content (typically about 25% moisture) that the mud impoundment area can be reclaimed and returned to it's former condition, or better.

The process of drying the mud can be speeded up by depositing the mud slurry in layers up to 8 cms. thick<sup>(32)</sup> and using solar drying to "dry" the layer, before adding another layer of mud.

It is important to design the impoundment area and the plant mud thickening system to provide for an angle of repose of the mud in the impoundment of 2.3% to 2.9%. At this angle, rainfall runs off the mud surface rapidly, without serious erosion effects. Fortunately, drying red mud quickly becomes impervious to rain water. As a result, this system can be used successfully in high rainfall areas of the world. The rain water, together with other liquors, is collected in drainage ditches surrounding the impoundment and pumped to the plant for further use, thus reducing the plant demand for fresh water.

The impoundment area is divided into separate sections, so that the mud feed can be rotated between these sections on a timed basis to allow sufficient time for drying of the mud to 65% - 75% before deposition of another layer.

In areas of low or zero rainfall the use of dry stacking and solar drying provides a very efficient red mud disposal and reclaim system.

In certain climatic conditions, a fine dust can be blown off the surface of the dried red mud - containing red mud and sodium salts (predominately sodium carbonate). In this case water can be sprayed on the surface to control the dusting.

In some plants<sup>(6)</sup> underbed drainage has been found advantageous to the overall dewatering performance of the mud bed, but the inclusion of such drainage should be justified for each individual plant depending on the characteristics of the particular mud produced and local conditions.

A geologic/hydrologic investigation of the subsurface of the proposed mud impoundment area must be done to confirm its suitability for the purpose. The mud impoundment area must be sealed with an impervious membrane prior to mud disposal commencement. Some companies have had success using a dried layer of the red mud itself as an impervious layer<sup>(24)</sup>.

Monitoring wells must be installed at strategic locations surrounding the impoundment area to make sure that no leakage of contaminants occurs. Leakage can be easily detected by an increase in the pH above the normal groundwater pH in the monitoring well.

An excellent, up to date, review of red mud disposal is contained in reference (36) - see Bibliography.

### **10.2.9 Reclamation of Mud Impoundments**

#### Problems.

There are two major problems with the reclamation of red mud impoundments, these are,

- the water content of the red mud
- the high pH of the liquor with the red mud.

In order to prepare the red mud in the impoundment for reclamation the mud moisture must be less than 25%, in order to provide a firm, supportive surface, and the pH should be close enough to neutral that plant growth will not be inhibited.

Methods for achieving the 25% moisture content in the mud are included in Section 10.2.8 Red Mud Disposal above. In addition the IPAI has discussed methods for improving mud consolidation rates and leaching of the caustic soda from red mud<sup>(35)</sup>.

Various methods are available<sup>(14)</sup> for neutralization of the red mud. These include treatment with

- seawater
- gypsum and phosphoric acid waste
- ferrous sulphate (copperas -  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ )
- ferrous sulphate/sulphuric acid
- most waste acids

Of these, the use of ferrous sulphate and gypsum could be beneficial in improving the capability of the red mud area to sustain plant life.

Sea water neutralization has been used successfully <sup>(15)</sup> at the Queensland Alumina Plant in Australia.

Sea water neutralization may create an excess salinity (ie. NaCl) in the red mud impoundment, however certain types of plants will grow in these conditions.

Other investigators <sup>(17)</sup> have successfully found plants which will grow under alkaline and saline conditions.

### Reclamation Methods

A good example of the reclamation of red mud impoundments is described by Queensland Alumina <sup>(15)</sup>. More than 175 hectares had been successfully reclaimed according to their publication.

At QAL the red mud was slurried with sea water and pumped to a disposal pond. After the mud dried out, top soil was used to cover the mud and native grasses planted. A study by the University of Queensland (Australia) into rehabilitation of refinery solid waste areas provided the basis for the revegetation program. The aim was to achieve a grass cover which would eliminate potential dusting of the dry surface.

Glasshouse and field trials recommended a 450mm layer of topsoil for plant growth and sowing of Rhodes grass, Couch grass and Sirato legume. With time, Rhodes grass has tended to dominate and virtually eliminated Sirato and Couch.

Natural colonization by acacias native to the area took place within three years of rehabilitation, while salt couch and other salt tolerant species have replaced the original grass cover in some low lying saline areas.

A controlled burn of the grass resulted in a noticeable increase in species diversity along with more even distribution of sirato and natal grass.

It is anticipated that increased colonization by native grasses and shrubs will occur and that Rhodes grass will remain the dominant species.

Halophyte plants have also demonstrated the ability to grow in brackish or salty water. Research at Al-Jubail, Saudi Arabia, has been conducted on these plants. Halophytes are salt and drought resistant plants, some of which actually grow in brackish or salt water or can be irrigated with salt water. The genus *Salicornia* shows promise as a commercial oilseed crop. It was reported in the June 1992 issue of the Jubail Development Review published by the Royal Commission that research is to be expanded into the development farming stage by Halophyte Enterprises. Previous research on halophytes at Al-Jubail has been conducted, among others, by the Environmental Research Lab of the University of Arizona.

In another location in Western Australia, Alcoa reports <sup>(16)</sup> that, - "Rehabilitation of several small Kwinana ponds is well advanced. The surfaces of the ponds have been reclaimed and commercial crops ranging from lucerne to vegetables have been established. Recovery of liquor from these ponds has been possible by slow pumping of a sand layer which was installed immediately above the clay seal during construction. Rehabilitation of one of the Pinjarra ponds is underway. Reclamation of the surface has been in progress for the past 5 years, but is not yet complete".

In addition, successful recultivation tests on red mud have been made at the Ajka Alumina Plant (Hungary) <sup>(18)</sup>. Successful recultivation <sup>(19)</sup> was also achieved at the Almasfuzito Alumina Plant (Hungary).

#### **10.2.10 Storm Water**

This is the water that falls as rain on the alumina plant area. All rain water run-off is directed via ditches to a pond from which it is recycled as process water into the plant. In the event that excess rainwater is available, this water may be diverted off-site so long as the level of contaminants in the water meets the environmental standards for that location.

#### **10.2.11 Waste Acid**

A relatively small amount of waste acid is formed from the descaling of heat exchangers. Disposal is not usually a problem. This acid can be neutralized by adding to the red-mud immediately before pumping to the storage area.

#### **10.2.12 Salt Cake and Oxalate Disposal**

These materials are usually disposed of in the red mud storage area. The sodium form of the salts can be rendered less toxic by conversion to the calcium salt by treatment with a burnt lime slurry.

#### **10.2.13 Steam and Power Generation Facilities**

The environmental problems with the steam and power generating facilities are primarily dependent on the type of fuel being used.

If coal is being used, consideration must be given to removing dust from the stack exhaust by using electro-static precipitators (ESP's) or equivalent. The fly ash produced can be disposed of in the red mud impoundment area, or other land fill.

If the coal has a high sulphur content, then some type of sulphur dioxide scrubber must be installed in order to remove the SO<sub>2</sub> from the stack exhaust gases. A wet scrubber using a lime slurry are efficient in this service and would be advantageous in that the sludge produced could be added to the mud being pumped to the mud lake and help to neutralize the high pH liquor associated with mud. The same type of scrubber could also be used for treating the combustion products from burning a high sulphur fuel oil.

In the case of natural gas, no treatment of the exhaust gases would be required.

#### **10.2.14 Noise Control**

Engineered noise controls should be incorporated into the plant design to protect both plant employees from auditory damage, and the surrounding community, if any, from nuisance noise.

In addition, all plant mobile equipment must be fitted with efficient silencers.

All plant air compressors should be fitted with efficient silencers.

## 10.3 ALUMINIUM SMELTER FACILITIES

### 10.3.1 Treatment of Airborne Emissions

The control of airborne emissions relies on the effective capture of fumes at the source, and a subsequent high level of treatment prior to discharge.

Fume emitted from the reduction cells will largely be confined by the enclosing hooding, allowing its withdrawal to collecting ductwork and subsequent treatment in a dry scrubbing unit. This primary emission comprises on average 97.5 percent of the total cell emissions - the remaining 2.5 percent, the secondary emission, escapes untreated into the potroom and passes by means of natural draft, through the roof ventilators to atmosphere.

#### Potline fume - primary emissions

The use of dry scrubbing systems for both pot fume and anode baking furnace fume treatment is the most efficient and proven technology available for airborne emissions control.

Wet scrubbing is sometimes used, however, it has the disadvantage of generating large volumes of waste toxic liquor which subsequently has to be treated and/or disposed of.

The dry scrubbing process is used in several forms throughout the world, but the basic mechanisms and efficiencies are well understood and catalogued. The methods's potential disadvantages lie in its recycling of minor impurities to the pots and its lack of effect on sulphur dioxide emissions. By strictly controlling feed alumina and coke quality, the impact of both these aspects is minimized. In addition, the maintenance of high hooding efficiencies and high rates of potroom air exchange ensures that working environmental conditions remain satisfactory.

Dry scrubbing does not generate waste products and recycles valuable raw materials, i.e. up to 16 Kg/t aluminum of particulate fluoride and the same amount of gaseous fluoride, see Table 5. Consequently dry scrubbing is seen to be the most suitable method for treating collected fume prior to discharge.

#### Secondary Emissions

Secondary emissions arise as a result of the need to perform various operations on the cells, necessitating the removal for short periods of one or more of the cells hood panels. The replacement of spent anodes provides the major source of such emissions, with cells requiring approximately one new anode per day. The task is achieved using the pot tending assemblies, and involves the removal of several hooding panels for a total of about fifteen minutes.

The treatment of secondary emissions exhausted through the roof ventilators is possible only by wet scrubbing, the volumes of air being too great to allow treatment in a dry process.

The high volume, low concentration characteristics of the fume result in only low scrubber efficiencies being attainable even when using wet scrubbing. Efficiencies of the order of 40 percent can be achieved only by expending large amounts of initial capital and continuing high inputs of operating capital and energy. The initial capital investment required for such an installation was estimated to be \$40 million (1980). The additional electricity requirements is 300 kW.h/t aluminum. In addition, a large volume of liquid effluent is produced.

For these reasons, the scrubbing of roof emissions cannot be justified from either the standpoint of effectiveness, energy conservation or economics.

Anode Bake Oven Emissions

The technology of choice for treatment of Anode bake oven emissions is the alumina dry scrubbing process. This treatment has the major advantage of being free of waste products, all enriched alumina and absorbed material being recycled directly to the reduction cells. The high scrubbing efficiency combined with relatively low source emission rates result in the bake oven contributing to overall plant emissions in a very minor way.

Wet electrostatic precipitators can be used to effectively remove both tars and fluorides and a portion of the sulphur dioxide. However, a liquid effluent rich in both fluorides and hydrocarbons is created, with major subsequent disposal problems.

As a result of these factors, alumina dry scrubbing is considered to be the only feasible alternative for the treatment of anode bake oven emissions.

The relevant levels of efficiency for fume capture and treatment are listed in Table 10.

On the basis of typical source emission rates, and the treatment efficiencies in Table 3-4, the total plant airborne emissions are detailed in Table 11. Ninety seven percent of all fluorides emitted in the process are captured and recycled.

Smelter Fume Capture and Treatment Efficiency

Table 10 - Smelter Fume capture and treatment efficiency (long term average) <sup>(21)</sup>		
<u>Item</u>	<u>Target Species</u>	<u>Efficiency (Percent)</u>
Hooding (Collection) efficiency	Pot Fume	97.5
Capture efficiency	Anode furnace fume	100
Dry scrubber efficiency (pot fumes)	- Gaseous fluoride	99.5
	- Particulates	90
	- Sulphur dioxide	Zero
Dry scrubber efficiency (Anode- - Baking furnace)	- Gaseous Fluoride	90
	- Tar vapor	90
	- Carbon particulates	90

**Table 11 - Airborne emission rates (long term average rounded to one significant figure)<sup>(21)</sup>**

<u>Source</u>	<u>Emission</u>	<u>Quantity kg/t.A1</u>	<u>Monitoring</u>
Potroom room	Gaseous fluoride, Fg	0.4	Continuous at vents, plus local checks.
	Particulate fluoride, Fp	0.4	
	Sulphur dioxide, SO <sub>2</sub>	0.6	
Potroom dryscrubbers	Gaseous fluoride, Fg	0.08	Continuous on stack.
	Particulate fluoride, Fp	0.08	
	Sulphur dioxide	23.4	
Anode furnace dryscrubber	Gaseous fluoride, Fg	0.03	Continuous on stack.
	Particulate fluoride, Fp	nil	
	Carbon particulates	0.01	
	Tar vapor	0.06	
	Sulphur dioxide	0.8	

### 10.3.2 Treatment of Solid Wastes

#### Spent Pot Lining (SPL)

Various processes are available in relation to the disposal of spent pot lining (cathode waste) generated by the plant, these include cryolite recovery, recycling SPL in cement, steel, mineral wool, and bricks. Also recovery of carbon through steam hydration is in practice.

The most common disposal method has been engineered land fills.

Engineered landfill relies on the burial of dry cathode waste within pits or cells physically separated from potentially impacted surrounding systems.

Disposal pits established on the site, lined with clay and/or artificial liners, provide a high level of security to the surrounding environment, however it is not possible to guarantee that no leakage would occur after the passage of long periods of time, extending beyond the operating life of the plant. The detection of leaks would be relatively easy, but it is probable that any remedial action would be difficult and expensive.

In the case of the use of clay or plastic lined cells, typical operating procedure includes the following:

- Construction of approximately 2 m deep pits, lined with clay and/or one or more layers of specialized synthetic liners (e.g., elasticized polyolefin).
- Provision of a layer of soil over the lining to prevent mechanical damage during waste dumping.
- Use of only one pit at any time. Pump out of rainfall and removal through evaporation of any contaminated water.



- Immediate covering and sealing of pits (with clay and/or plastic sheeting) when full.
- Provision of monitoring points beneath and surrounding pits, using a system of horizontal drains and vertical bores.

The principle of operation of disposal cells within competent clay is similar, with the choice of location in this case depending on the availability of clay in sufficient thickness and of suitably low permeability to allow the excavation of cells directly into the stratum. The relative long term security of these disposal strategies varies according to the specific characteristics of the geographic area under study.

Further research is concentrating on two aspects:

- Reclaiming and recycling of valuable constituents and/or energy
- Transformation of toxic components into other forms.

Techniques being considered or investigated include the following:

- Cryolite recovery by extraction with caustic soda
- Pyrohydrolysis
- Extraction with lime
- Calcination
- Steam hydration
- Digestion with strong acids
- Fluorspar substitute in cupola iron melting and basic oxygen steel making.

Within the industry, to date, returns achieved in the form of reusable chemical components or energy have not provided an economic justification for the processing involved. However, more cost-effective solutions are being sought.

#### Other Solid Wastes

Table 12 lists all of the solid wastes generated by a typical aluminum smelter with indicated preferred treatment method.

Aluminum oxide and bath generated by skimming of ladles is sold for recycling. Domestic wastes will be removed from the site and disposed of in solid waste disposal sites. Spalled refractories and other chemically stable materials are disposed of offsite in landfill sites.

**Table 12 - Solid Wastes<sup>(21)</sup> from Aluminum Smelters**

	<u>Source</u>	<u>Type</u>	<u>Description</u>
1.	De-lining shop	Spent cathodes	Mixed size fraction, various solid components
2.	Cast house dross reclamation	Dross reclamation residue	Fine product 8-10% aluminum
3.	Electrode paste plant	Carbon material floor sweepings	Carbon contaminated with foreign materials
4.	Rodding shop	Electrolyte, floor sweepings	Electrolyte material which cannot be recycled because of contamination
5.	Rodding shop	Shot blaster refuse	Bath and shot and carbon and Fe mixture
6.	Potline	Bath and carbon dust	Solidified bath contaminated with carbon fines and pieces
7.	Plant sweepings	Spilled contaminated material	Mixture of coke, bath, carbon and other material
8.	Potline services	Ladles	Refractory material
9.	Electrode bake oven	Refractory lining	Refractory brick non contaminated <sup>(1)</sup>
10.	Electrode bake oven	Bag filter dust	Fine coke dust
11.	Cast house furnace refractories	Refractory lining	Refractory brick non-contaminated
12.	Rodding shop	Ladles and cast iron furnace	Refractory brick non-contaminated
13.	Potline	Ladle skimming	Aluminum oxide and bath
14.	Plant wide	Packaging and domestic waste	Packaging, paper, putrescible waste, etc.

<sup>1</sup> Fluoride contaminated within the brick (less than 1.0%) is in a non leachable, highly insoluble form.

<sup>2</sup> For a typical center worked prebake cell (CWPB) smelter.

## 11.0 ALTERNATIVE TREATMENT TECHNOLOGIES

### 11.1 BAUXITE FACILITIES

See Section 4.1

### 11.2 ALUMINA FACILITIES

See Section 4.2

### 11.3 SPENT POT LINING TREATMENT

A considerable amount of work has been done in searching for an efficient, economical, and effective method for treating spent pot lining material. A lot of progress has been made in this area. Some examples are discussed briefly below.

### 11.3.1 The COMTOR Process<sup>(25)</sup>

Comalco Aluminum is developing the COMTOR process to detoxify spent pot lining. A 5000 TPY treatment facility was constructed.

Preliminary results are encouraging; with >99% destruction of the cyanide content. The process is designed to calcine the SPL at >550°C, in the presence of oxygen and water, under controlled conditions in which the cyanide compounds break down into CO<sub>2</sub> & N<sub>2</sub>.

The process uses a new type of calciner, known as a 'TORBED' which overcomes many of the problems associated with other types of calciner in this service.

After calcination of the SPL, the residue is leached for the recovery of 80% - 90% of the fluorine which can be recycled to the electrolytic cells. A pilot test of the fluoride leaching step is being developed.

### 11.3.2 Calcination in a Rotary Kiln<sup>(26)</sup>

Reynolds Metals have developed a process for treating SPL in which the SPL is blended with limestone and an anti-agglomeration agent and thermally treated in a rotary kiln. The process is very effective at destroying the cyanides and significantly reduces the soluble fluoride content in the kiln residue.

Reynolds claims the process to be economically competitive to landfilling. Reynolds has successfully treated more than 300,000 tons of SPL.

### 11.3.3 Other Alternative Technologies

- Recycle of SPL through Pot Anodes<sup>(27)</sup>
- Recycle of SPL through Pot Cathodes<sup>(28)</sup>
- Circulating Bed Combustion of SPL<sup>(29)</sup>
- Cryolite Recovery<sup>(30)</sup>
- SPL as a fuel supplement in cement kilns<sup>(33)</sup>

## 12.0 CAPITAL AND OPERATION COSTS

### 12.1 ALUMINA PLANT ENVIRONMENTAL FACILITIES COST<sup>(23)</sup>

#### 12.1.1 Environmental Facilities Capital Costs (1992 U.S. \$)

	<u>U.S. \$ (Millions)</u>
Bauxite Handling	0.3 - 0.8
Red Mud Filtration	6.0 - 16.0
Red Mud Disposal	2.5 - 7.5
Starch and Lime Systems	0.9 - 2.6
Alumina Calcination and Handling	1.0 - 3.0
Power Plant (incl. SO <sub>2</sub> scrubber, ESP, 2 stage combustion, coal or oil)	15.0 - 40.0

### 12.1.2 Operating Costs

Estimated total operating (incl. maintenance) costs = U.S. \$1.2-2.4 million per year

## 12.2 ALUMINIUM SMELTER ENVIRONMENTAL FACILITIES COST<sup>(22)</sup>

### 12.2.1 Environmental Facilities Capital Costs (1992 U.S. \$)

	<u>U.S. \$ (Millions)</u>
Carbon Plant	6.0 - 16.0
Potroom	0.3 - 0.5
Casting Facilities	0.3 - 0.5
Fume Control System (Potroom + Carbon Plant)	30.0 - 80.0
General	2.0 - 5.0
Wastewater	0.7 - 1.8
Materials Handling	1.1 - 3.3

### 12.2.2 Operating Costs

Estimated total operating (incl. maintenance) cost = \$U.S. 2.5-5.0 million per year.

Note: All the costs shown above will vary considerably depending on the size and location of the plant.

## 13.0 CONCLUSIONS

The conclusion of this document is that some of the key environmental issues, facing the bauxite-alumina-aluminum industry today are:

- Treatment and disposal of spent pot linings (SPL)
- Electrolytic cell fume treatment
- Anode baking fume treatment
- Red mud disposal and area reclamation
- Bauxite tailings disposal and area reclamation.

### 13.1 SPENT POT LININGS (SPL)

Several promising treatment technologies, based for the most part on incineration, are available. However they are expensive and, at least in the U.S., they have been difficult to utilise due to regulatory problems.

### 13.2 ELECTROLYTIC CELL AND ANODE BAKING FUME TREATMENT

The alumina dry scrubbing technology is being successfully used to control the environmental problems arising from emission of these fumes into the potroom and the atmosphere. This treatment system is expensive to build and operate.

### **13.3 RED MUD DISPOSAL AND AREA RECLAMATION**

Red mud disposal is a problem because of the high alkalinity and large volumes of red mud waste produced (1-2 tons red mud solids per ton of alumina produced), and the difficulty of reclaiming this land.

Technology is now available for reducing the moisture content of the mud waste considerably, thus permitting "dry stacking" of the mud in a reduced area, and easier land reclamation.

### **13.4 BAUXITE TAILINGS DISPOSAL AND AREA RECLAMATION**

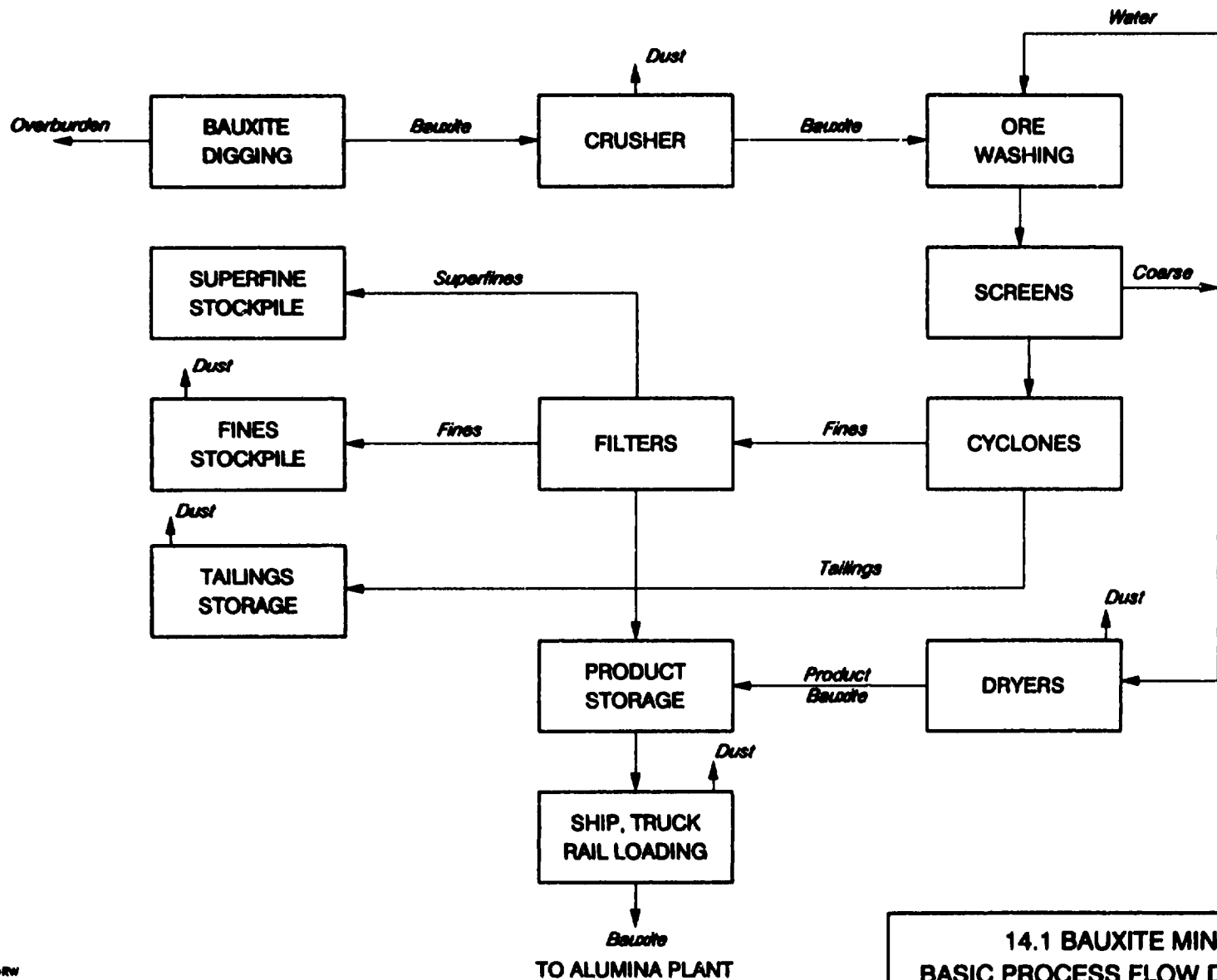
The tailings disposal is a problem due to the very large volume of dilute slurry material involved. However technology is available for drastically reducing the moisture content of the tailings, which permits the use of "dry stacking" technologies for disposal of the tailings in the mined out areas, and facilitates reclamation of the area.

### **14.0 APPENDIX**

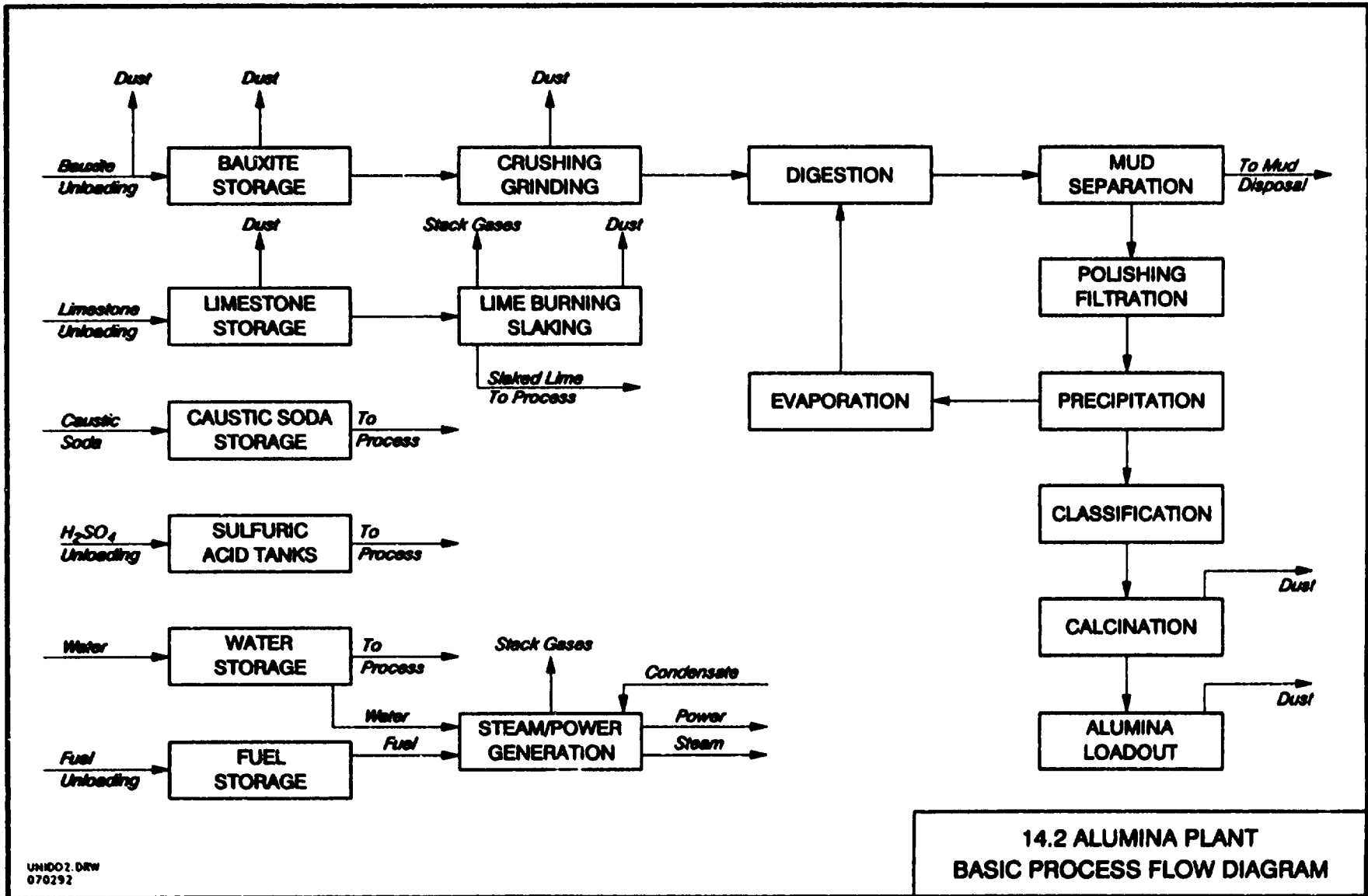
The items included in the Appendix continue on the next page.

These items include:

- 14.1 Bauxite Mine Flow Diagram
- 14.2 Alumina Plant Flow Diagram
- 14.3 Aluminum Smelter Facilities Flow Diagram
- 14.4 Threshold Limit Values (TLV)
- 14.5 Bibliography
- 14.6 Glossary

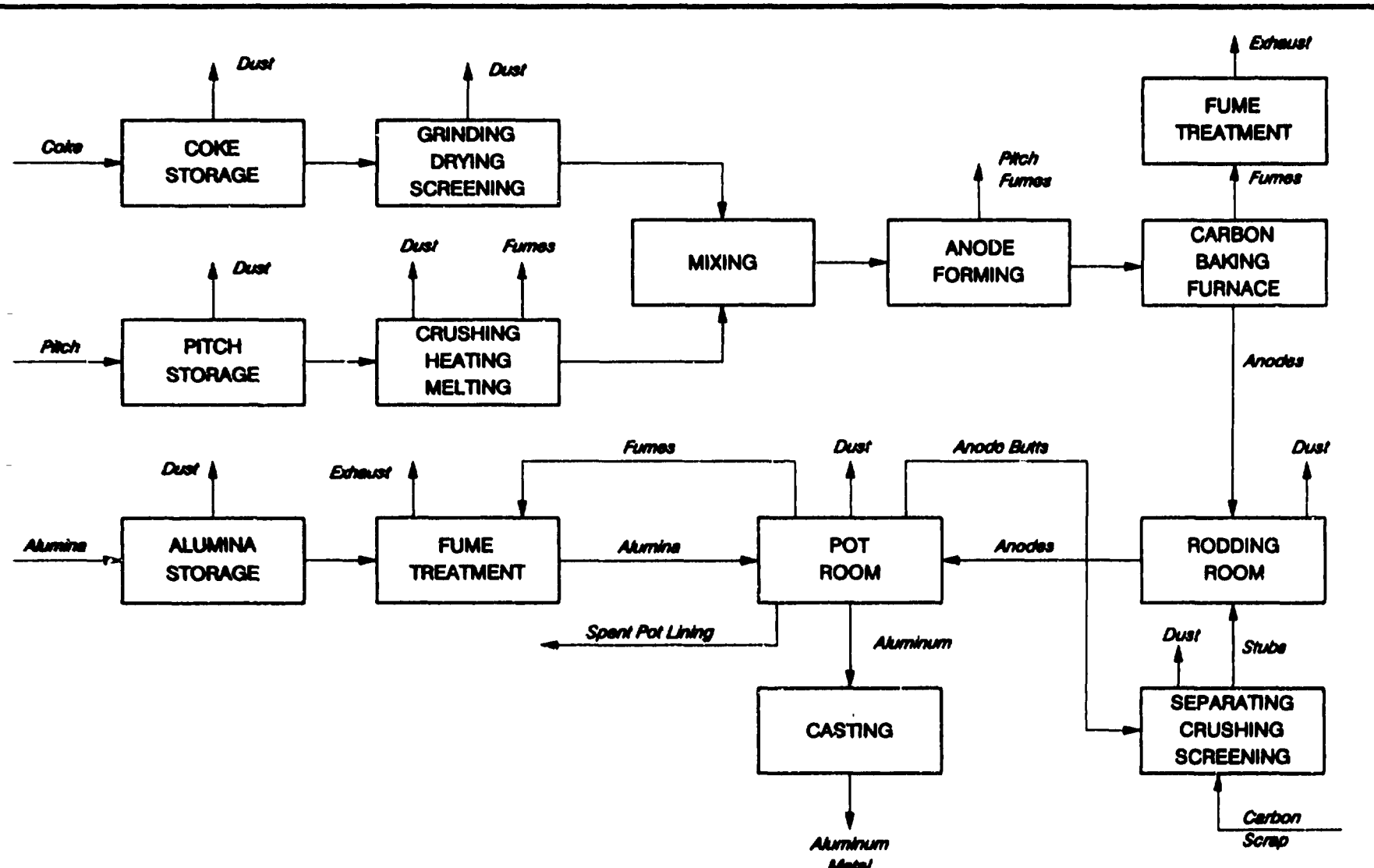


14.1 BAUXITE MINE  
BASIC PROCESS FLOW DIAGRAM



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14.2 ALUMINA PLANT  
BASIC PROCESS FLOW DIAGRAM



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**14.3 ALUMINUM SMELTER  
BASIC PROCESS FLOW DIAGRAM**



#### 14.4 THRESHOLD LIMIT VALUES

<b>Table 13 Regulatory Threshold Limit Values (TLV) for Aluminium Industry Workers</b>	
<u>Item</u>	<u>Threshold Limit Value (TLV)</u>
<b>1. <u>Fluoride (USA, NIOSH)</u></b> <ul style="list-style-type: none"> <li>• HF as F</li> <li>• Particulate Fluorides as F</li> <li>• Total HF as F and Particulate Fluorides as F</li> <li>• F- in urine (*) and</li> </ul>	2 mg/m <sup>3</sup> 2.5 mg/m <sup>3</sup> 2.5 mg/m <sup>3</sup> 4 mg/l preshift after 48 h. of non-exposure 7 mg/l postshift taken on 4th or later day of the workweek
<b>2. <u>Other Contaminants (USA)</u></b> <ul style="list-style-type: none"> <li>• SO<sub>2</sub></li> <li>• Total Suspended Particulate</li> </ul>	5 mg/m <sup>3</sup> 10 mg/m <sup>3</sup> (respirable 5 mg/m <sup>3</sup> )
<b>3. <u>Coal Tar Pitch Volatiles (USA)</u></b> <ul style="list-style-type: none"> <li>• Benzene Soluble Organics</li> </ul>	0.2 mg/m <sup>3</sup>
<b>4. <u>Polycyclic Aromatic Hydrocarbons (PAH) (Thin Layer Chromatography)</u></b> <ul style="list-style-type: none"> <li>• Norway - Total PAH</li> <li>• Sweden - B-3-4-P alone</li> </ul>	40 µg m <sup>3</sup> 5 µg/m <sup>3</sup>
<b>5. <u>Noise</u></b> <ul style="list-style-type: none"> <li>• USA - OSHA</li> <li>• USA - ACGIH</li> </ul>	90 dBA 85 dBA
These values are time weighted average concentrations for a normal 8-hour workday or 40-hour workweek.	
(*) Not an official TLV, but applied at many smelters. Both of these values of 4 mg/l and 7 mg/l are applicable to work groups (e.g. anode changer, spike setters, etc.) and the number represents geometric mean values for each of these individual job groups.	

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## 14.6 GLOSSARY OF ENVIRONMENTAL TERMS <sup>(34)</sup>

**Adsorption:** 1. Adhesion of molecules of gas, liquid, or dissolved solids to a surface.  
2. An advanced method of treating wastes in which activated carbon removes organic matter from wastewater.

**Airborne Particulates:** Total suspended particulate matter found in the atmosphere as solid particles or liquid droplets. Chemical composition of particulates varies widely, depending on location and time of year. Airborne particulates include: windblown dust, emissions from industrial processes, smoke from the burning of wood and coal, and the exhaust of motor vehicles.

**Air Pollutant:** Any substance in air which could, if in high enough concentration, harm man, other animals, vegetation, or material. Pollutants may include almost any natural or artificial composition of matter capable of being airborne. They may be in the form of solid particles, liquid droplets, gases, or in combinations of these forms. Generally, they fall into two main groups: (1) those emitted directly from identifiable sources and (2) those produced in the air by interaction between two or more primary pollutants, or by reaction with normal atmospheric constituents, with or without photoactivation. Exclusive of pollen, fog, and dust, which are of natural origin, about 100 contaminants have been identified and fall into the following categories: solids, sulfur compounds, volatile organic chemicals, nitrogen compounds, oxygen compounds, halogen compounds, radioactive compounds, and odors.

**Air Quality Criteria:** The levels of pollution and lengths of exposure above which adverse health and welfare effects may occur.

**Air Quality Standards:** The level of pollutants prescribed by regulations that may not be exceeded during a specified time in a defined area.

**BACT—Best Available Control Technology:** An emission limitation based on the maximum degree of emission reduction which (considering energy, environmental, and economic impacts, and other costs) is achievable through application of production processes and available methods, systems, and techniques. In no event does BACT permit emissions in excess of those allowed under any applicable Clean Air Act provisions. Use of the BACT concept is allowable on a case by case basis for major new or modified emissions sources in attainment areas and applies to each regulated pollutant.

**Baghouse Filter:** Large fabric bag, usually made of glass fibers, used to eliminate intermediate and large (greater than 20 microns in diameter) particles. This device operates in a way similar to the bag of an electric vacuum cleaner, passing the air and smaller particulate matter, while entrapping the larger particulates.

**Caustic Soda:** Sodium hydroxide, a strong alkaline substance used as the cleaning agent in some detergents.

**Contaminant:** Any physical, chemical, biological, or radiological substance or matter that has an adverse affect on air, water, or soil.

**Effluent:** Wastewater—treated or untreated—that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

**Electrostatic Precipitator (ESP):** An air pollution control device that removes particles from a gas stream (smoke) after combustion occurs. The ESP imparts an electrical charge to the particles, causing them to adhere to metal plates inside the precipitator. Rapping on the plates causes the particles to fall into a hopper for disposal.

**Emission:** Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts.

**Emission Standard:** The maximum amount of air polluting discharge legally allowed from a single source, mobile or stationary.

**Environmental Impact Statement:** A document required of federal agencies by the National Environmental Policy Act for major projects or legislative proposals significantly affecting the environment. A tool for decision making, it describes the positive and negative effects of the undertaking and lists alternative actions.

**Flue Gas:** Vented air coming out of a chimney after combustion in the burner. It can include nitrogen oxides, carbon oxides, water vapor, sulfur oxides, particles, and many chemical pollutants.

**Fluorides:** Gaseous, solid, or dissolved compounds containing fluorine that result from industrial processes; excessive amounts in food can lead to fluorosis.

**Fluorosis:** An abnormal condition caused by excessive intake of fluorine, characterized chiefly by mottling of the teeth.

**Fresh Water:** Water that generally contains less than 1,000 milligrams-per-liter of dissolved solids.

**Fugitive Emissions:** Emissions not caught by a capture system.

**Fume:** Tiny particles trapped in vapor in a gas stream.

**Ground Water:** The supply of fresh water found beneath the Earth's surface (usually in aquifers) which is often used for supplying wells and springs. Because ground water is a major source of drinking water there is growing concern over areas where leaching agricultural or industrial pollutants or substances from leaking underground storage tanks are contaminating ground water.

**Hazardous Air Pollutants:** Air pollutants which are not covered by ambient air quality standards but which, as defined in the Clean Air Act, may reasonably be expected to cause or contribute to irreversible illness or death. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride.

**Hazardous Waste:** By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

**Hood Capture Efficiency:** The emissions from a process which are captured by hood and directed into the control device, expressed as a percent of all emissions.

**Impoundment:** A body of water or sludge confined by a dam, dike, floodgate, or other barrier.

**Landfills:** 1. Sanitary landfills are land disposal sites for non-hazardous solid wastes at which the waste is spread in layers, compacted to the smallest practical volume, and cover material applied at the end of each operating day. 2. Secure chemical landfills are disposal sites for hazardous waste. They are selected and designed to minimize the chance of release of hazardous substances into the environment.

**Liner:** 1. A relatively impermeable barrier designed to prevent leachate from leaking from a landfill. Liner materials include plastic and dense clay. 2. An insert or sleeve for sewer pipes to prevent leakage or infiltration.

**Mobile Source:** A moving producer of air pollution, mainly forms of transportation such as cars, trucks, motorcycles, airplanes.

**Monitoring Wells:** Wells drilled at a hazardous waste management facility or Superfund site to collect ground-water samples for the purpose of physical, chemical, or biological analysis to determine the amounts, types, and distribution of contaminants in the ground water beneath the site.

**Neutralization:** Decreasing the acidity or alkalinity of a substance by adding to it alkaline or acidic materials, respectively.

**Nitrogen Oxide (NOx):** Product of combustion from transportation and stationary sources and a major contributor to acid deposition and the formation of ground level ozone in the troposphere.

**Opacity:** The amount of light obscured by particulate pollution in the air; clear window glass has zero opacity, a brick wall 100 percent opacity. Opacity is used as an indicator of changes in performance of particulate matter pollution control systems.

**Run-Off:** That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface-water. It can carry pollutants from the air and land into the receiving waters.

**Salinity:** The degree of salt in water.

**Scrubber:** An air pollution device that uses a spray of water or reactant or a dry process to trap pollutants in emissions.

**Sulfur Dioxide (SO<sub>2</sub>):** A heavy, pungent, colorless, gaseous air pollutant formed primarily by industrial fossil fuel combustion processes.

**Tailings:** Residue of raw materials or waste separated out during the processing of crops or mineral ores.

**Threshold Limit Value (TLV):** Represents the air concentrations of chemical substances to which it is believed that workers may be exposed daily without adverse effect.

**Well:** A bored, drilled, or driven shaft or a dug hole, whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.

**Well Monitoring:** The measurement, by on-site instruments or laboratory methods, of the quality of water in a well.