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POLLUTION PREVENTION AND ABATEMENT GUIDELINES FOR THE ALUMINIUM INDUSTRY*

prepared by

the UNIDO Secretariat

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*This document is one of the chapters prepared for a forthcoming set of pollution guidelines jointly prepared by the World Bank, UNIDO and UNEP. This document has not been edited.

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1. 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

2. INTRODUCTION

Much 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.

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 becoming available. However they are expensive and, at least in some countries, they have been difficult to utilise due to regulatory problems.

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

    The alumina dry scrubbing technology can successfully control fume emissions from both the electrolytic cell and the anode baking furnace. Dry scrubbers are expensive to build and operate, however, the recovery of fluoride and alumina gives a payback on the investment. Moreover, dry scrubbers integrate very well with modern reduction technology.

- **Red Mud Disposal and Area Reclamation**

    Red mud disposal is a problem because of the large volumes involved (1-2 tons red mud solids per ton of alumina produced), and high alkalinity and salinity of the residue. This makes the whole process of safe disposal and subsequent reclamation resource demanding and difficult. 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 difficult due to the very large volume of dilute slurry material involved when bauxite is washed. 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.

3. MANUFACTURING PROCESS

3.1 BAUXITE FACILITIES

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

3.1.1 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. The simplified generic process flow diagram in the Appendix shows all of the major processing or treatment steps used in various bauxite mines and beneficiation plants around the world today. The major process steps in the 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 use all of the above steps in their treatment of the excavated bauxite; other bauxite mines use only part of these steps.

3.1.2 Process Description

The following is 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, 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 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 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.

3.1.3 Economic Factors in Process Selection

In general terms the economics of a particular bauxite deposit is 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 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 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 before 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.

3.1.4 Environmental Factors in Process Selection

The main environmental problems encountered at bauxite mine and beneficiation sites are: dust, tailings disposal, and storm water runoff/erosion. The processes should be selected to minimize the above environmental problems in an economical way.

3.1.5 Water and Energy Usage

Water and energy usage can vary greatly from mine to mine, however published data for the Boké bauxite mine [2] suggests 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 applied will be minimal. When the ore is washed water usage can be in the region of 3-4 t/t bauxite.[1]

3.2 ALUMINA FACILITIES

3.2.1 Process Flow Diagram

The below description follows the simplified alumina plant process flow diagram in the Appendix.

3.2.2 Process Description

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 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, to convert the alumina trihydrate ($Al_2O_3 3H_2O$) to alumina (Al_2O_3). The fluid bed calciner is 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. When power is not available locally, an alumina plant will typically install a steam and power cogeneration facility to supply the plant's requirements. If power is available at an economic rate from a local power source, only steam generating facilities would be installed.

3.2.3 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 atmosp' ric emissions of SO_x, CO_2, and particulates.

- Economics of scale favor larger size alumina plants. Most new plants under consideration today are in the 600,000 to 1,000,000 tons per year alumina production range.

3.2.4 Environmental Factors in Process and Equipment Selection

Potential environmental problems arising from the alumina plant process as practiced today are related to dust generation and red mud disposal. 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 Section 5.

3.2.5 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

Materials	Usage		
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, GJ/t alumina	8.4	-	16.7
Burnt Lime (90% CaO) t/t alumina	0.015	-	0.10
Sulfuric Acid (98% H_2SO_4) t/t alumina	0.0009	-	0.0014

3.3 ALUMINIUM SMELTER

3.3.1 Process Flow Diagram

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

3.3.2 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 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 is the center-worked cell using a bar breaker (CWPB-BB), the second the side worked cell (SWPB), and the third is the center worked cell using a point breaker feeder (CWPB-PBF). 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 prebake (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, requiring 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 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 a modern CWPB-PBF cell are as follows.

- Average amperage   175,000-280,000 amperes
- Volts per pot   4.1 - 4.5 volts
- Power consumption   12.9-14.5 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 by collection ducts to, normally, 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. After forming the 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 several 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 before discharge to the atmosphere.

Anode rodding is performed in a separate building. Used anodes are cleaned to remove adherent bath, and then stripped from the rod assembly. Commonly used cleaning methods are vibrating tables and shot blasting. Cast iron used to connect the anode with the stem is removed from the anodes for recycling. Rod assemblies are repaired, if necessary, before 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.

3.3.3 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 two 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.

3.3.4 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.

3.3.5 Materials and Energy Usage

Data on aluminum smelter materials and energy usage are given in Table 2.

Table 2 Aluminum Smelter Materials and Energy Usage

Energy kWh/kg Al	12.9 - 14.5
Alumina (Al$_2$O$_3$), 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
Anode Baking	
Typical gas consumption (modern unit) GJoule/t Al	2.5

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

4. WASTE CHARACTERIZATION AND IMPACTS

Current waste materials such as spent oil, solvents, wood, scrap metal, etc., and sanitation effluent are generated by all aluminium production steps. Although requiring proper attention, this report concentrates on wastes typical for the aluminium industry.

4.1 BAUXITE FACILITIES

4.1.1 Bauxite Beneficiation Tailings

Some bauxite production facilities incorporate an ore washing or beneficiation step, in order to upgrade the quality of the bauxite[1]. 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[1].

4.1.2 Atmospheric Emissions

The main atmospheric emission concern 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_x, SO_2 and other products of combustion from the bauxite dryers, which can have a deleterious and expensive effect on dust collection equipment.

4.1.3 Waste Waters

Waste water, containing small amounts of suspended bauxite solids can be generated by the ore washing and beneficiation process; or by runoff from the mine area. Depending on the amount of rainfall at the mine area, a considerable amount of runoff can be generated. Settling ponds should be considered for removal of the solids contained in the runoff. 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.

4.2 ALUMINA FACILITIES

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

4.2.1 Atmospheric Emissions

Table 3   Atmospheric Emissions from Alumina Facilities

Unit Process	Type of Emission(s)
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 cogenerators	SO_2, NO_x
Calciners	SO_2, NO_x, alumina dust
Mobile equipment	SO_2, NO_x
Kilns	SO_2, NO_x, burnt lime dust

4.2.2 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.

4.2.3 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 (Al_2O_3, SiO_2, Fe_2O_3, TiO_3, Na_2O, 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.

4.2.4 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.

4.3 ALUMINIUM FACILITIES

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

4.3.1 Atmospheric Emissions

Generation of atmospheric emissions in the aluminum smelter and carbon baking facilities can cause serious environmental problems if not correctly controlled. The main emissions are listed below:

Table 4 Atmospheric Emissions from Aluminum Smelters

Unit Process	Type of Emissions(s)
Alumina unloading, conveying, handling and storage	Alumina dust
Coke unloading, conveying, handling and storage	Coke dust
Potline	Gaseous fluorides, particulate fluorides, SO_2, dusts from handling various materials, carbon oxides, tars (mainly Horizontal Stud Söderberg), CF_4, C_2F_6
Baking furnace	Gaseous fluorides, SO_2, tar vapor, carbon particulate, NO_x, carbon oxides
Green carbon and anode forming plant	Coke dust, pitch tar vapors
Rodding room	Carbon dust
Cast house	Fluxing emissions dependent on type of fluxing, carbon oxides, NO_x, SO_2

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 and small amounts of C_2F_6 evolve. Evolution of these gases, which have a very high global warming potential, are estimated to 1-3 kg/t Al. Good control of the reduction process can reduce these emissions to about 0.06 kg/t Al.

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. Tar vapors and particulates contain polycyclic aromatic hydrocarbons (PAH), many of which are known carcinogens.

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 quantities sufficient to have adverse effects on the surrounding environment are gaseous and particulate fluorides provided there is adequate stack height to limit ambient ground level concentration of SO_2 and tar vapors. Emissions of SO_2 may however be of national or regional concern. Typical source evolution rates are summarized below.

Table 5 Typical Gaseous and Particulate Evolutions Before Treatment For Modern CWPB Pot[4]

Source	Emission	Quantity kg/t Al
Reduction cells	Gaseous fluoride	16
	Particulate fluoride	16
	Sulphur dioxide, SO_2[a]	24
Anode furnace	Gaseous fluoride	0.25
	Particulate fluoride	nil
	Carbon particulates[b]	1.2
	Tar vapor[c]	0.6
	Sulphur dioxide, SO_2	0.8

[a]Depends on sulphur content of anode.
[b]or total particulates. High molecular weight PAH are adsorbed on the surface.
[c]or gaseous hydrocarbons, which include PAH.
Note: The sampling, analysis and definition of total PAH varies and is subject to international standardization.

4.3.2 Waste Water

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

Adequate treatment of effluent from cast house, paste plant and anode baking facility etc. should be provided with respect to pH, suspended solids, COD/BOD, tar (PAH) and fluoride.

4.3.3 Solid Wastes

A 250,000 tons per year aluminum plant produces approximately 40-60 kg of mixed solid wastes per tonnage of product. Spent cathodes (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 given in Table 6.

Table 6 Spent Cathode Analysis[6]

Species	Carbon		Refractories	
	Average %	Maximum %	Average %	Maximum %
Carbon	45	60	1	2
Al_2O_3	15	20	35	40
SiO_2	1	3	35	38
CaF_2	9	5	3	4
AlF_3	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 include skim, dross, fluxing slags, road sweepings, packaging and domestic wastes. Table 7 lists all the solid wastes generated by a typical aluminium smelter.

Table 7 Solid Wastes from Aluminum Smelters[21]

	Source	Type	Description
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*
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.

* Higher Al-levels from cast houses producing alloys
* Fluoride contaminated within the brick (less than 1.0%) is in a non leachable, highly insoluble form.
* For a typical center worked prebake cell (CWPB) smelter.

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.

4.4 IMPACT ON RECEPTORS

Contaminants of concern in the aluminium industry are summarized in Table 8.

Table 8 Contaminants of Concern in the Aluminium Industry

Type of Facility	Contaminants
BAUXITE	• Bauxite dust • Bauxite tailings • SO_2, NOx from bauxite dryers
ALUMINA	• Caustic soda (NaOH) • Sulphuric acid (H_2SO_4) • Red Mud • Burnt lime dust • Limestone dust • Alumina dust • Oxalates • SO_2, NOx (boilers, calciners, etc.)
ALUMINUM	• Hydrogen fluoride - vapors and particulates • Tar and pitch vapors (PAH) • Coke/pitch dust • Alumina • Cyanides and fluorides (spent pot linings) • Sulphur dioxide (SO_2) • Carbon oxides • Cryolite/aluminum fluoride/sodium fluoride dusts • CF_4, C_2F_6

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. A checklist for carrying out an EIA is given below.

Checklist for Environmental Impact Assessment

1. Physical Environmental 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 subsidence 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 condition.
- Ground water location and use.
- Vegetation cover characteristics.
- Aesthetics of land fill 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 value.
- 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 Archeological 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.

4.4.1 Fluoride Emissions from Aluminium Smelters

Fluoride emissions, if excessive, can adversely effect the vegetation and, through the food chain, 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.[7][8][9]

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. Even if emission standards are expressed in terms of concentration of fluorides in exhaust gas and/or as amount of fluorides emitted per tonne of aluminium produced, the degree of impact on the surroundings depends on the total amount being discharged and its distribution. In order to arrive at site-specific discharge targets that are truly sustainable, it is necessary to carry out adequate environmental impact studies.

4.4.2 Spent Pot Lining (SPL)

Spent pot lining contains soluble cyanides and fluorides. When stored in piles in the open, with no particular attempt to contain the cyanide and fluoride containing leachate this may find ist way into and contaminate local ground and surface waters.

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

4.4.3 Red Mud Waste

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

- area of land used and impact on other land users
- seepage of alkaline or saline leachates into groundwater
- overflow of rainfall runoff containing salt and solids into surrounding surface waters
- dust deposition on surrounding land and neighbours
- spillages resulting from dyke instablity or pipeline failures
- unsafe conditions for personnel, wildlife etc.
- due to high alkalinity and soft soils
- visual impact of dykes and deposits
- difficult surface revegetation conditions

4.4.4 Alumina Plant Process Spills and Waste Water

Spillage or leakage of solutions from the process areas can contaminate ground and surface waters. Total containment of process solutions should be provided including special design provisions for concrete slabs, perimeter kerbing, sumps for recycling to the process and controlled overflows to a sealed containment system. If process solutions are allowed to contaminate the foundation soils then weakening or swelling can occur which will exacerbate the leakage problem and possibly create structural problems.

The plant waste water could conceivably contain all of the contaminants of concern listed in Table 8. Therefore it is important to design and maintain a negative water balance so that all process water, inclusive runoff from the red mud pond and storm water, can be recycled and no discharges occur.

5. POLLUTION PREVENTION AND CONTROL

5.1 BAUXITE FACILITIES

5.1.1 Bauxite Dust

a) <u>Bauxite Dryers</u>

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) <u>Loading/Unloading of Ships, Trucks, and Railroad Cars</u>

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 emissions occur at any transfer point when the bauxite is allowed to fall freely 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) <u>Conveyors</u>

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) <u>Truck Movement</u>

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 areas of high wind - 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.

5.1.2 Beneficiation Tailings

If beneficiation or ore washing are in use, a large volume of tailings may be produced. For example, one 5 million tons per year bauxite mine[1], 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. An example of modern practice is the use of a large intermediate pond as provided at the Trombetas mine[1]. 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.

The opportunity exists to reduce the volume of tailings waste further then mentioned above by the use of a high-efficiency thickener[5][6]. 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.

5.1.3 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 runoff
- 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

5.2 ALUMINA PLANT FACILITIES

5.2.1 Lime Waste Minimization and 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.

5.2.2 Waste Water

The waste water discharge from the alumina plan' 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 and maintaining a negative water balance which includes the runoff from the red mud disposal site and plant storm water, so that all contaminated water is recycled to the process and none is discharged.
- efficient segregation of condensates and recycling to appropriate process areas.
- efficient storm water handling.

5.2.3 Storm Water

This is the water that falls as rain on the alumina plant area. All rain water runoff 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.

5.2.4 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.

5.2.5 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.

5.2.6 Bauxite Dust

The same comments apply as cited in Section 5.1.1 b), c), and 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.

5.2.7 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.

5.2.8 Lime Kilns

These kilns can be fired with various fuels. However, even if a high sulphur fuel is used, sulphur dioxide (SO_2) emissions will not be a problem since most of the SO_2 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.

5.2.9 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.

5.2.10 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_2, NOx, 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.

5.2.11 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.

5.2.12 Alumina Loading of Ships, Trucks, & Rail Cars

The alumina product is often 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.

5.2.13 Red Mud Waste Minimization and Disposal

Alumina plants typically produce a large volume of red mud waste, which can range as high as 2 tons of red mud solids and sand residue 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 of choice for the treatment of red mud produced by the alumina plant is, in most cases, the so-called, "dry stacking" system followed by reclamation of the mud impoundment area. This impoundment, ideally, should be located close to the alumina plant to keep pumping costs low. Topographic and soil conditions are essential parameters when chosing the disposal site.

Dry stacking, 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 before deposit in a well drained impoundment area such that there is no long term containment of free liquor in the disposal area. The result is that the mud exerts very little horizontal pressure upon any dams erected to contain it[27]. Dams can therefore be built higher and thus contain more mud within a given area and it is possible to reclaim the disposal site.

There are several methods for obtaining the high solids concentration (over 50%) in the mud necessary for dry stacking. Three economic alternatives, which are in use today, are shown below:

- Deep thickeners[5].
- Large diameter thickeners[16],[6].
- Rotary drum vacuum filters[31].

Of these three alternatives, the vacuum filter installation would normally provide a mud residue with the highest percentage solids (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 it is further dewatered and dried by evaporation to a low enough water content (about 25% moisture) that the mud impoundment area can be reclaimed and returned to its former condition, or better.

A carefully designed dry stacking system can perform satisfactory also in areas of high rainfall. Low rainfall areas are particularly suited but the rainfall and evaporation patterns are more important than the total amount.

Often the impoundment area is designed with an angle of repose. This allows the mud to flow and spread evenly when discharged in the impoundment, and rain water to run off the mud surface rapidly without serious erosion effects.

Adequate drainage of the disposal area is essential. The rain water, together with other liquors, is collected in drainage ditches surrounding the impoundment. Some plants use full underbed drainage to enhance the overall dewatering performance of the mud bed[6]. Whether or not such drainage is necessary depends on the particular mud produced and local conditions. Under no circumstances must rain water from the surroundings be allowed to enter the disposal area.

The runoff water must be collected and stored for reuse in the plant or treated and discharged. If pumped to the plant for reuse, plant demand for fresh water will be reduced.

The process of drying the mud can be speeded up by depositing the mud slurry in layers up to 8 cm thick[32] and letting the sun dry the layer, before adding another layer of mud. 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 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.

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, low permeability clay or synthetic membrane system, to protect ground waters[24]. In some situations, such as with sea water neutralization in coastal areas, this may not be necessary.

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.

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

5.2.14 Reclamation of Mud Impoundments

The major problems with the reclamation of red mud impoundments are related to high alkalinity and salinity, poor drainage and lack of nutrients.

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 discussed above. In addition the International Primary Aluminium Institute (IPAI) has discussed methods for improving mud consolidation rates and leaching of the caustic soda from red mud [15].

Various methods are available [14] for neutralization of the red mud. These include treatment with: seawater; gypsum and phosphoric acid waste; ferrous sulphate (copperas - $FeSO_4.7H_2O$); 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 [15] 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 [17] have successfully found plants which will grow under alkaline and saline conditions.

A good example of the reclamation of red mud impoundments is described by Queensland Alumina [15]. More than 175 hectares have been successfully reclaimed. In another location in Western Australia, Alcoa reports [16] 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.

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

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

If coal is being used, consideration must be given to removing dust from the stack exhaust by using electrostatic 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_2 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.

5.2.16 Alumina Plant Environmental Facilities Costs

Table 9 Alumina Plant Environmental Facilities Costs[23]

Item	Capital Costs (Million US$*)	Operating and Maintenance Costs (Million US$/year*)
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	Total 1.2-2.4
Alumina Calcination and Handling	1.0 - 3.0	
Power Plant (incl. SO₂ scrubber, ESP, 2 stage combustion, coal or oil)	15.0 - 40.0	

*(1992 U.S. $)

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

5.3 ALUMINIUM SMELTERS

5.3.1 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 method'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. Wet scrubbing downstream of dry scrubbers is practiced in countries/regions with strict SO₂ emission limitations. Maintenance of high hooding efficiencies and high rates of potroom air exchange ensures that working conditions remain satisfactory.

Dry scrubbing does not generate waste products other than used filter bags 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 and low contaminant concentration 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 kWh/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 varies depending on the type of oven but is generally 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 (ESPs) 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. Dry ESPs are used on some furnaces to collect tar for reuse. No liquid effluent is then generated.

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 evolution rates, Table 5, and the treatment efficiencies in Table 10, the total plant airborne emissions are detailed in Table 11. Ninety seven percent of all fluorides emitted in the process are captured and recycled.

Table 10   Smelter Fume Capture and Treatment Efficiency for BACT[21]

Item	Target Species	Efficiency[a] (%)
Capture efficiency (Hooding)	Pot Fume	97.5
Capture efficiency	Anode furnace fume	100
Dry scrubber efficiency (pot fumes)	- Gaseous fluoride	99.5
	- Particulates	99
	- Sulphur dioxide	Zero
Dry scrubber efficiency (Anode- - Baking furnace)	- Gaseous Fluoride	90
	- Tar vapor	90
	- Carbon particulates	90

[a]Derived from averaging of Environmental Impact Statements for various smelters, data from suppliers of dry scrubbing systems, US EPA studies of fluoride emissions from smelters, and Kaiser Engineers design data.

Table 11   Airborne Emission Rates for BACT [21]

Source	Emission	Quantity[a] (kg/t Al)	Monitoring
Potroom room	Gaseous fluoride, Fg	0.4	Continuous at
	Particulate fluoride, Fp	0.4	vents, plus local
	Sulphur dioxide, SO_2[b]	0.6	checks.
Potgas dry scrubbers	Gaseous fluoride, Fg	0.08	Continuous on
	Particulate fluoride, Fp	0.08	stack.
	Sulphur dioxide[b]	23.4	
Anode furnace dry scrubber	Gaseous fluoride, Fg	0.03	Continuous on
	Particulate fluoride, Fp	nil	stack.
	Carbon particulates[c]	0.01	
	Tar vapor[d]	0.06	
	Sulphur dioxide[b]	0.8	

[a]Derived from averaging of Environmental Impact Statements for various smelters, data from suppliers of dry scrubbing systems, US EPA studies of fluoride emissions from smelters, and Kaiser Engineers design data.
[b]Depends on sulphur content in pitch and coke. (SO_2 wet scrubbing downstream of dry scrubbers, considered BACT in many countries/regions, not accounted for.)
[c]or total particulates. High molecular weight PAH are adsorbed on the surface.
[d]or gaseous hydrocarbons, which include PAH.
Note: The sampling, analysis and definition of total PAH varies and is subject to international standardization.

5.3.2 Spent Pot Lining Minimization, Treatment and Disposal

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[29]. 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.

Various processes are available in relation to the treatment, recycling and disposal of spent pot lining (cathode waste) generated by the plant, these include cryolite recovery[30], recycling SPL in cement[33], steel, mineral wool, and bricks. Also recovery of carbon through steam hydration is in practice in one smelter.

Further research is concentrating on reclaiming and recycling of valuable constituents and/or energy, and transformation of toxic components into other forms. Techniques considered or investigated include the following:

- Cryolite recovery by extraction with caustic soda
- Extraction with lime
- Calcination[29,28]
- Digestion with strong acids
- Recycle of SPL through Pot Anodes[27]
- Recycle of SPL through Pot Cathodes[28]
- Circulating Bed Combustion of SPL[29]
- Treatment in vortex burners
- Pyrohydrolysis process, etc.

Within the industry, to date, returns achieved in the form of reusable chemical components or energy have rarely provided an economic justification for the processing involved.

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.

Intermediate storage of SPL under roof in a building with a concrete floor is practiced in many places. This prevents rain water from transferring contaminants from the SPL to the environment.

5.3.3 Aluminium Smelter Environmental Facilities Costs[22]

Table 12 Aluminium Smelter Environmental Facilities Costs[22]

Item	Capital Costs (Million US$[a])	Operating and Maintenance Costs (Million US$/year[a])
Carbon Plant	6 - 16	
Potroom	0.3 - 0.5	
Casting Facilities	0.3 - 0.5	Total 2.5 - 5.0[b]
Fume Control System (Potroom + Carbon Plant)	30 - 80	
General	2 - 5	
Wastewater	0.7 - 1.8	
Materials Handling	1.1 - 3.3	

[a](1992 U.S. $)
[b]Savings from recovered materials not included. Recovery of 25 kg fluoride per tonne of aluminium would yield savings of about MUS$2.5 annually for a 100,000 tons per year plant assuming a fluoride price of US$1,000 per tonne. The operating costs for all air cleaning (dry scrubbing) facilities for such a plant would be around MUS$1.5-2.0.
Note: Costs shown above will vary considerably depending on the size and location of the plant.

6. 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, solid wastes, air emissions 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 health management planning and their implementation. In designing the facilities provisions should be made for:

- Safe storage, transportation and handling of chemicals.
- Establishment of standards for safe periods of exposure to toxic and other chemicals, heat and noise. Standards for occupational exposure limits for airborne contaminants are contained in the Appendix.
- Safety regulations to be established, monitored and regularly audited and workers to be trained and instructed to follow them.

- 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, in accordance with local legislation.
- A system of reporting accidents and their investigation to be established.
- An industrial health clinic to be established at the plant site if no such facilities are available in the vicinity.
- 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.)[8, 9, 10].
- Providing workers with appropriate safety equipment and ergonomic apparel. Wearing of respiratory and ear protection should be mandatory in areas of the plant where personal exposure exceeds legally enforceable occupational exposure limits, and encouraged in other areas.
- Continuous noise exposure (8 hours per day) to workers on the plant site should be less than 90 dBa, preferably less than 85 dBa. 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 and air compressors must be fitted with efficient silencers.

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

- Electrolytic Cell Fumes - (See 4.3.1 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 and used 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.

7. GLOBAL OVERVIEW OF DISCHARGE REQUIREMENTS

This section contains a sampling of discharge standards/guidelines from those countries where major bauxite, alumina, or aluminium facilities exist today. Considering that sampling and analytical methods vary from one country to another, comparisons are not always straigthforward. Differeices in discharge standards may also reflect that similar emissions can cause different effects in diverse environments.

7.1 PARTICULATE STANDARDS

The emission standard of 50 mg/dsm³ is applied by the U.S. EPA for alumina handling operations. Japan has an emission standard of 100 mg/m³ for reaction furnaces, which is applicable to alumina and aluminum processes.

A particulate emission standard of 30 mg/m³, or 5 kg/t Al, is enforced in West Germany for aluminium smelters. Britain has an emission standard of 120 mg/m³ for aluminum smelters. New Zealand has a particulate emission standard of 100 mg/m³ for all ferrous and nonferrous processes.

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

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

7.2 FLUORIDE STANDARDS

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

In Sweden, fluoride emission standards are 1 kg total/tonne aluminium for VSE cells and 0.5 kg total per tonne aluminium for PFPB cells, in one smelter.

Australia's fluoride emission standard from smelters is 50 mg/m^3 in the exhaust gases. Japan and Germany have a fluoride emission limit of 1.0 mg/m^3 in aluminum reduction gases. The German regulation also specifies that HF should not exceed a daily average of 0.5 kg/t Al.

7.3 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 have been adopted by the Philippines and Guam, respectively. However, opacity standards would hardly be relevant for stack emissions of modern smelters using BACT, since the emissions are nearly invisible.

7.4 POWER AND/OR STEAM GENERATION EMISSION STANDARDS

Power and/or steam producing 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 industry. The major pollutants of the exhaust from these facilities are particulates, sulfur dioxide and nitrous oxides. Another document in this series deals exclusively with power generating plants.

7.5 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.

7.5.1 Standards in the United States

The United States standards for wastewater discharges for new primary aluminium smelters are given in Table 13. The US standards for new alumina producing facilities do not allow any discharge of process wastewater pollutants to navigable waters.

Table 13 U.S. EPA Standards for Wastewater Discharge from Aluminum Smelters

Effluent Characteristic	Maximum for any one day	Average of daily values for 30 consecutive days shall not exceed
	(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	

7.5.2 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's standards for nonferrous metals' wastewater discharges to the sea are shown in Table 14.

Table 14 Standards for Wastewater Discharges to the Sea from Non-ferrous Metals Operations (Bahrain)

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

7.6 NOISE STANDARDS

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

7.6.1 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 and 50 to 55 dBa during night time, due to industrial operation.

7.6.2 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. Many countries therefore draw the line for 8 hours exposure at 85 dBa.

Permitted community noise levels in Sweden and Norway at nearest residental quarters are 50 dBa during the day, 45 dBa during the night, 45 dBa during weekend day and 40 dBa during weekend nights. These levels apply to new and retro-fitted facilities only.

8. TARGET/PREFERRED GUIDELINES

As environmental conditions vary from place to place, an environmental impact assessment should be carried out to decide what levels of discharges are acceptable and satisfy local ambient environmental quality standards. In the absence of local ambient air quality standards Table 15 may be used for guidance. Water quality standards vary with the intended use of the receiving water body.

The determination of permissible discharge levels involves determining background levels for each pollutant of concern as well as other emission sources in the area. Mathematical dispersion models would then have to be applied to tailor the discharges to the desired environmental quality.

For air emissions, not only stack discharges but also fugitive emissions will have to be considered. For practical reasons, the plant fence is generally taken as the physical point in which compliance to the air quality standard should be checked by the appropriate body. Other physical points identified as critical by the dispersion model and the EIA may also be designated as compliance check points.

The discharge targets thus selected should reflect the most cost-effective compromise between environmental and economic considerations at the project site. The BACT (Best Available Control Technology), described in Section 5, and especially Table 11, are examples of the results of this compromise between the environment and economics, and can be used for guidance when setting air emission targets. United States standards for wastewater discharges from new facilities (Section 7.5.1) may be used for guidance when deciding on effluent standards.

However, to reach the design discharge targets (be it stack or fugitive air emissions or liquid effluents), the technology has also to be operated efficiently. This calls for qualified operators, good standard of maintenance, proper operating procedures, and management commitment to achieving environmental goals manifested in a transparent system to monitor, control and report on environmental discharges.

Table 15 Ambient Air Quality Standards in Selected Aluminium Producing Countries

Country	Fluorides (μg/m³)	Sulphur Dioxide (μg/m³)	Particulates (μg/m³)
Australia[c]	0.5[a]	50[a]	90[a]
Germany	1.0[a]	140[a]	150[a]
Hungary	3.0[a]	70[a]	50[a]
Canada	0.2[b]	30[a]	60[a]

[a] annual mean
[b] 3-month mean
[c] Tasmania

Source: Cochran L S; Pielke R A; Selected International Receptor-Based Air Quality Standards. Journal of Air and Waste Management. December 1992. Volume 42, No.12, p.1568-1569.
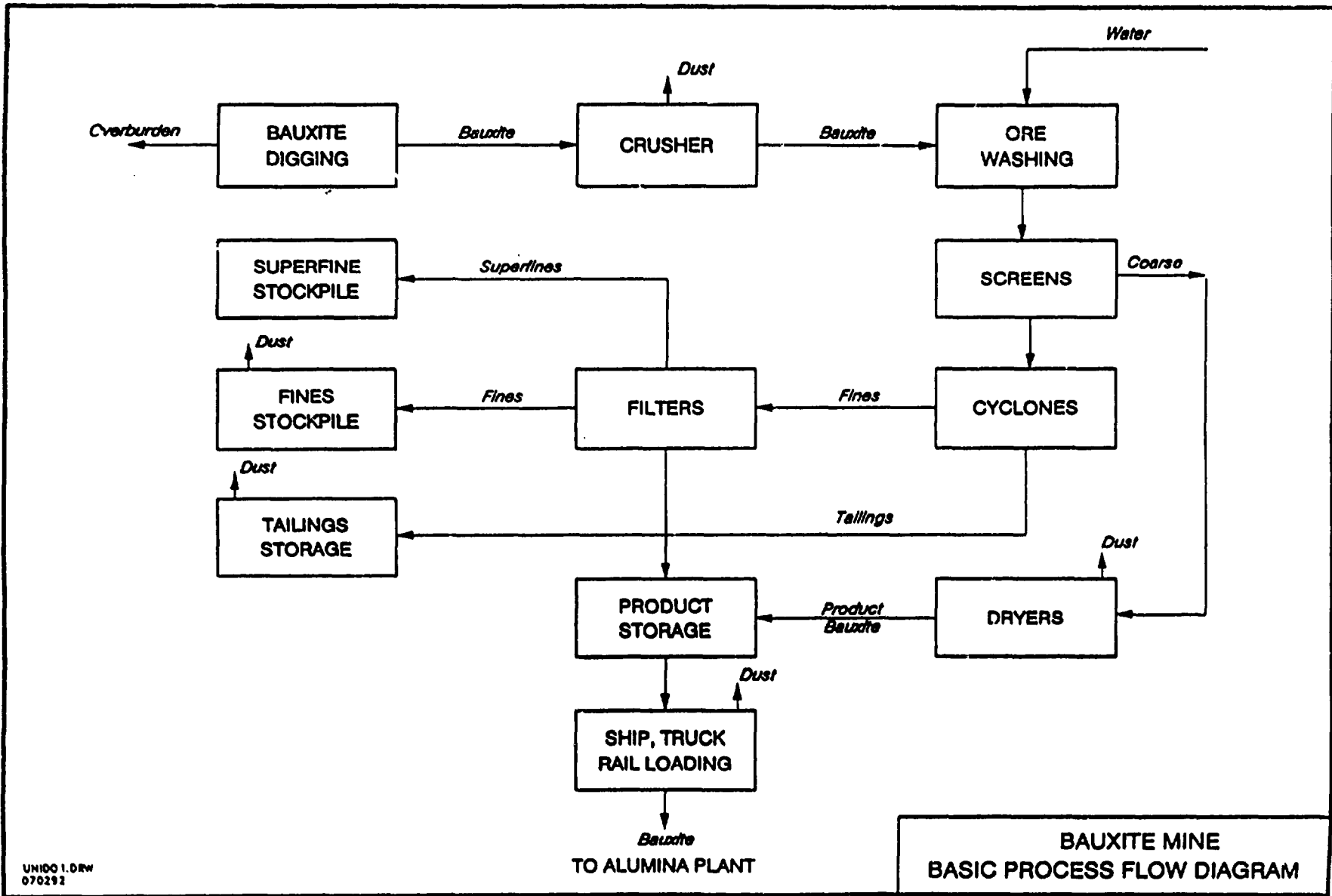
9. MONITORING REQUIREMENTS

Information on monitoring requirements for aluminium smelters is given in Table 11.

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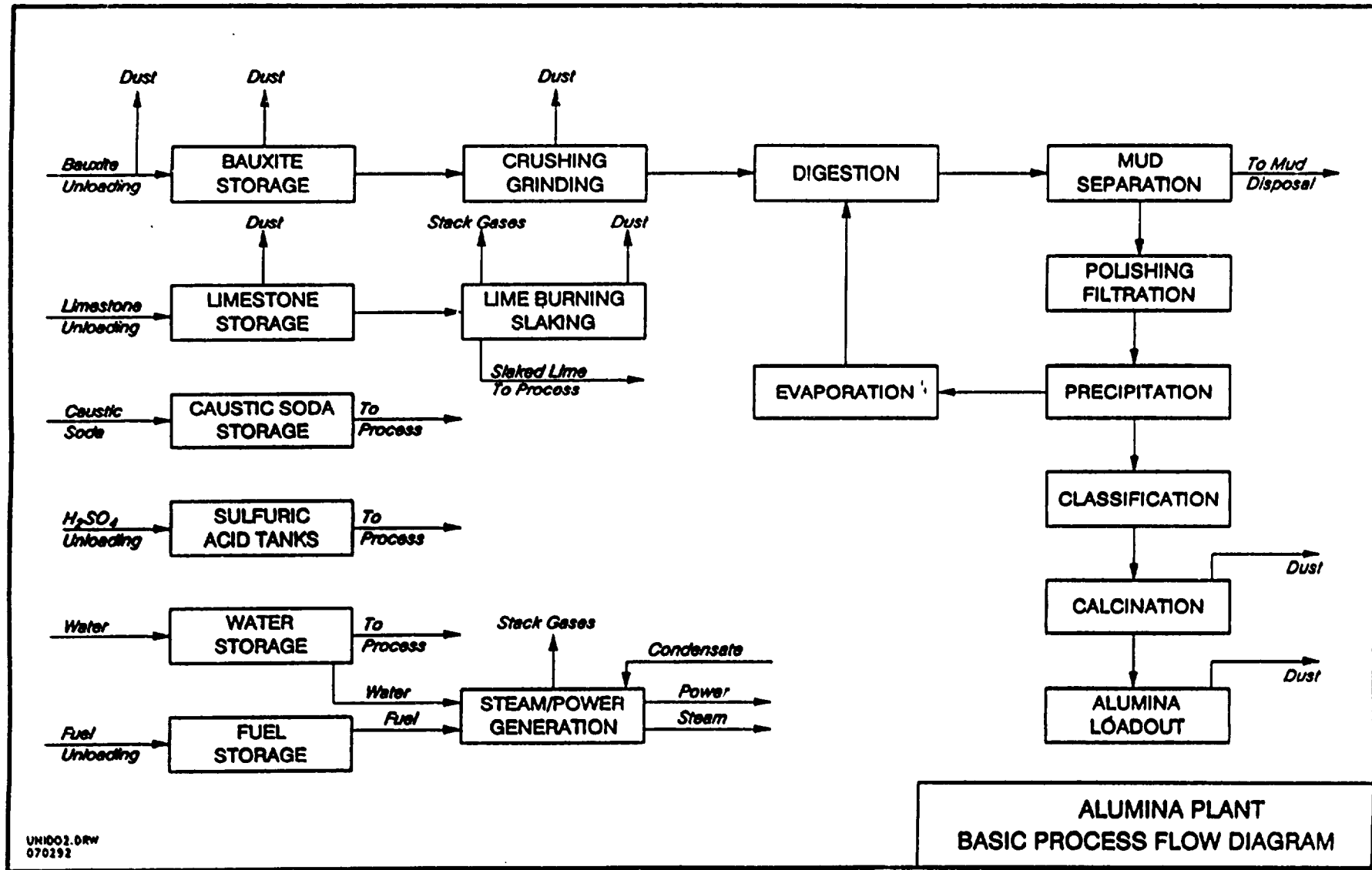(19) UNIDO Report, World Review on Environmental Aspects & Protection in the Bauxite/Alumina Industry, 1983.

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BAUXITE MINE
BASIC PROCESS FLOW DIAGRAM

UNI001.DRW
070292

TO ALUMINA PLANT

Dust

Dust

Dust

Bauxite
Unloading

BAUXITE
STORAGE

CRUSHING
GRINDING

DIGESTION

MUD
SEPARATION

To Mud
Disposal

Dust

Stack Gases

Dust

POLISHING
FILTRATION

Limestone
Unloading

LIMESTONE
STORAGE

LIME BURNING
SLAKING

Slaked Lime
To Process

EVAPORATION

PRECIPITATION

Caustic
Soda

CAUSTIC SODA
STORAGE

To
Process

H₂SO₄
Unloading

SULFURIC
ACID TANKS

To
Process

CLASSIFICATION

Dust

Water

WATER
STORAGE

To
Process

Stack Gases

CALCINATION

Dust

Condensate

Water

Power

Fuel
Unloading

FUEL
STORAGE

Fuel

STEAM/POWER
GENERATION

Steam

ALUMINA
LOADOUT

UNI002.DRW
070292

ALUMINA PLANT
BASIC PROCESS FLOW DIAGRAM

ALUMINUM SMELTER
BASIC PROCESS FLOW DIAGRAM

UNID03.DRW
070292

IV. THRESHOLD LIMIT VALUES

Table 16 Regulatory Threshold Limit Values (TLV) for Aluminium Industry Workers

Item	Threshold Limit Value (TLV)
1. Fluoride (USA, NIOSH)	
• HF as F	2 mg/m³
• Particulate Fluorides as F	2.5 mg/m³
• Total HF as F and Particulate Fluorides as F	2.5 mg/m³
• F- in urine (*) and	4 mg/l preshift after 48 h. of non-exposure 7 mg/l postshift taken on 4th or later day of the workweek
2. Other Contaminants (USA)	
• SO₂	5 mg/m³
• Total Suspended Particulate	10 mg/m³ (respirable 5 mg/m³)
3. Coal Tar Pitch Volatiles (USA)	
• Benzene Soluble Organics	0.2 mg/m³
4. Polycyclic Aromatic Hydrocarbons (PAH) (Gas Chromatography/HPLC)	
• Norway - Total PAH	40 μg/m³
• Sweden - Benso (a)pyrene alone	5 μg/m³
5. Noise	
• USA - OSHA	90 dBA
• USA - ACGIH	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.

V.   GLOSSARY OF ENVIRONMENTAL TERMS [04]

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 produces 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 collect small, intermediate and large 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. NB Dry scrubbers for reduction cell flue gases use bag filters, but not of glass fibers since glass is chemically attacked by fluorides.

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.

CWPB-PBF: Center worked electrolytic cell with prebaked anodes and a point breaker feeder.

dsm³: Milligrams per dry standard cubic meter

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.

Red mud: Residue from the Bayer alumina process containing mainly bauxite and sand.

Runoff: 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 (SO₂): 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.