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ENVIRONMENTAL ASPECTS OF BAUXITE, ALUMINA AND ALUMINIUM PRODUCTION IN BRAZIL

Report by the UNCTAD secretariat*

*The present report was prepared by the UNCTAD secretariat on the basis of a consultant's report by Setepla Tecnometal, São Paulo.

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INTRODUCTION AND SUMMARY

The present study is one of a series of country case studies on various commodities prepared within the UNCTAD programme on "Improved Natural Resources Management in the Commodity Sector". The programme consists of a series of activities which are linked together around the unifying objective of achieving sustainable use of natural resources while maximizing the contribution of the commodity sector to development. The case studies undertaken under the programme have two main objectives:

(a) To formulate, against the background of practical experience, conclusions that can be applied in devising and implementing policies aimed at improving environmental protection and natural resource management in the commodity sector in developing countries;

(b) To raise awareness in commodity importing countries, funding agencies and the international environmental community of the opportunities for, and constraints on improvement of environmental conditions associated with commodity production and processing in developing countries.

This study on Brazil is one of three on bauxite, alumina and aluminium. A report on "Environmental aspects of bauxite and aluminium production in Indonesia" has already been published (UNCTAD/COM/39); a similar report on Jamaica is under preparation. The present report is based on a consultancy report prepared by Setepla Tecnometal of São Paulo, which has been shortened and edited. The factual information contained in the report is almost entirely unchanged from the version prepared by the consultant; however, the conclusions contained in chapter IV have been substantially redrafted. Although the intention is to retain the reasoning and opinions expressed in Setepla's report, the editing process has introduced nuances and emphases which may differ from those of the original report. Accordingly, the UNCTAD secretariat accepts full responsibility for the views expressed in this report.

The study attempts to:

-Identify the environmental effects of bauxite, alumina and aluminium production in Brazil;

-Describe present technical and regulatory measures aimed at dealing with these environmental effects; and

-Evaluate the effectiveness of these measures.

Chapter I provides a brief overview of the Brazilian aluminium sector, including its financial situation and importance to the national economy. The history of the sector can be divided into two periods: before and after bauxite mining by Mineraçao Rio do Norte (MRN) began in the northern region at the end of 1979. Before the startup of MRN, aluminium production was based on the bauxite deposits in the state of Minas Gerais. At that time, about 15 per cent of alumina requirements were covered by imports. Brazil also imported aluminium products corresponding to about 50 per cent of domestic consumption. Following the start of bauxite production by MRN, several large alumina and aluminium projects were implemented in the 1980s. Brazil is now the world's third bauxite producer with almost 10 per cent of world production. The vast majority of reserves are located in the state of Pará in the northern region. Brazil ranks as the world's fifth aluminium producer and the sixth exporter of aluminium ingots, semifabricated and fabricated products. With the exception of the Alunorte alumina project, no major new investments are planned for the 1990's. Installed primary aluminium capacity is expected to be sufficient to supply the domestic market and to assure the export of more than half the production.

Financial indicators based on annual reports for 1992 show that most of the companies in the sector have low liquidity. However, external financing is generally low compared to stockholders' equity. Profitability indexes show that Brazilian companies are strongly affected by the level of international aluminium prices, which were low in 1992, and by domestic energy prices. In 1992 the companies either showed losses or very low profits. Unlike the situation in many other Brazilian sectors, financial costs cannot be blamed, since most companies in the aluminium sector showed a surplus of financial income over financial costs. Electric power accounts for about 30 per cent of the total costs of production of primary aluminium in Brazil, and in an international perspective, power rates are high.

Total earnings of the aluminium sector correspond to 0.7 per cent of GDP and 2.1 per cent of industrial production. The sector's share of exports was 3.7 per cent in 1992 and it accounted for about 2 per cent of government income. The sector is also an important user of inputs produced in the country, in particular energy.

Chapter II reviews the environmental effects of bauxite, alumina and aluminium production and the measures taken by producing companies to mitigate negative effects.

The main environmental problems associated with bauxite mining are related to the rehabilitation of mined-out areas and the disposal of tailings. Emissions of dust consisting of clay and bauxite particles from dryers' chimneys can also pose problems. Brazil's largest bauxite mine, the MRN mine in Oriximina in the state of Pará, has an ambitious programme for revegetating mined-out areas. This operation is also the site of an unusual attempt to restore a lake in which residue from the washing of bauxite was dumped during the early years of mining. The integrated companies in the State of Minas Gerais also carry out rehabilitation of mined-out areas and have successfully revegetated most of the areas affected by mining.

In alumina production, the disposal of bauxite residue saturated with caustic soda ("red mud") is the main problem, although emissions to the atmosphere of gases and particles from boilers, calcination furnaces and bauxite dryers may also be important. Worldwide, the most common method of disposal of red mud is to discharge it into deposit lakes constructed for this purpose. An alternative method, which has environmental advantages, is to pump back the sludge in order to recover and reuse the caustic solution. In older installations, however, this is usually not done for reasons of cost. Only the Alumar refinery, located at Sao Luis in the state of Maranhao, recycles all the caustic soda solution, while the other refineries recycle most of it. At the end of their useful life, the residue lakes enter a process of consolidation and their surface is landscaped and revegetated. Groundwater characteristics are monitored after the deposit area is rehabilitated, since the red mud is strongly alkalic and may affect groundwater quality. Sulphuric gaseous emissions from alumina production are generally minimized by the exclusive use of fuel oil with very low sulphur content.

Primary aluminium is produced through the electrolytic decomposition of alumina in a molten bath composed of cryolite and fluorides, in which the carbon anodes collect oxygen released from the decomposition of alumina. The liquid aluminium is deposited on the carbon coating of the crucible - the pot - which acts as the cathode. The aluminium is pumped by suction into crucibles of metal which are taken to the ingot casting area. The ingots are then marketed or transformed into a wide range of fabricated aluminium products. A distinction is made between the Söderberg technology, in which the anode paste is introduced into the pots through the top of the covering, baking itself solid in the heat rising from the pot, and the prebaked anode technology, in which anodes are baked before they are introduced into the pot. In aluminium smelting, the emission of fluorides from reduction cells and of gases, smoke and steam resulting from pitch distillation are considered to be the most important environmental problems. The modern prebaked technology allows pots to be more efficiently covered, reducing fluoride emissions and permitting recovery of alumina and fluorides.

Two different strategies for treatment of gaseous emissions have been adopted in the aluminium industry to reduce fluoride emissions to acceptable levels. One approach is non-recoverable wet scrubbing, where the fluoride is discharged as waste in an acceptable form. The other is to absorb the emissions in a form that allows the fluoride to be recycled to the cell. In recent years, the emphasis has shifted to techniques which enable recycling.

In smelters using the Söderberg technology, the gaseous residues of fluorides and of tar from anode baking are emitted together. Gaseous emissions are treated by wet, non or partially recoverable scrubbing, or in newer installations, by dry scrubbing.

In smelters using the prebaked anodes technology, the gaseous emissions from the cells are free from tarry vapours. The pot gas treatment is based on the dry scrubbing technique with recovery of all fluorides, which are returned to the cells by passing the emitted gas through a bed of alumina used to feed the cells. Smelters using prebaked anodes technology are the newest installations in Brazil.

The disposal of cathode residues presents problems to aluminium smelters, since these residues contain fluorides and cyanides. A system for recycling of the residues for use in ceramic industries has been successfully developed by Alcan. The residues are added to the clay used for production of refractory bricks in a proportion of 5 per cent. The material reduces fuel consumption in furnaces.

The newer Brazilian smelters generally show the best performance with regard to emissions, although all smelters conform to the standards used, which are similar to those in most other countries. It has been estimated that the Brazilian production of primary aluminium is responsible for emissions of fluorides and particulates of about 4,200 tons per year. To put this figure into perspective, it is estimated that one steel plant such as the Usiminas plant, with an annual production of 4.5 million tons of steel (almost 20 per cent of Brazilian steel production), emits about 3,000 tons per year.

In aluminium fabrication, finally, emissions of gases and particles from smelting and re-heating furnaces pose the largest problems. About 300 plants in Brazil produce fabricated aluminium products. Environmental control measures account for a relatively small portion of production costs.

Chapter III provides an overview of environmental policies and regulations at the federal and state levels. The federal Government first addressed environmental policies after the United Nations Conference on Environment in Stockholm in 1972, with the establishment of SEMA, the Environment Secretariat, in 1973. Increased concern over environmental degradation subsequently led to legislation being introduced during the 1970s. In 1981, the basic law on environment was approved and issued by the federal Government. Article 1 of the law established a National Policy for the Environment, including goals and procedures for implementation. At the same time, the National Environment Council (CONAMA) with representatives of the federal and state governments was created, with the goals to:

- Review and propose government policy guidelines on environment and natural resources;

- Decide on standards compatible with environment preservation;

- Establish criteria for environmental impact statements (EIS) with reference to activities subject to environmental permits, ensure public access to information related to environmental damage, and establish procedures for environmental protection.

In 1985, acts damaging to the environment became subject to federal law enforcement and as a result environmental curatorships were created in the largest cities. The law also allows non-governmental environmental organizations to file lawsuits.

The Constitution of 1988 dedicated a whole chapter to the environment, incorporating some aspects already addressed in the 1981 law. Paragraph 2 of that chapter states that anyone who exploits mineral resources is obliged to rehabilitate the environment in conformity with technical methods approved by the appropriate public agency. There are, however, no obligatory provisions for the assurance of availability of funds for rehabilitation. In 1989, a new law abolished SEMA and created the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA), which reports to the President. Its function is to assist, supervise, execute and enforce the national environmental policy.

The Mining Code of 1967 and its accompanying detailed regulations contain no direct references to environmental issues, although the decree states that the miner shall compensate the landowner or squatter for irreversible damages to the land, i.e., if the land cannot be used for crops or pasture. The miner shall also be subject to legal action if he does not avoid air or water pollution as a result of mining or if the waters drained cause damage to his neighbours. There is a specific reference to the environment in a directive issued by the National Mineral Department in 1981 (the objective of the directive was to establish rules for bidding for mineral survey areas). According to this directive, a mining proposal must contain a description showing the compatibility of mining with environment and natural resources preservation.

As regards regulations aimed at the aluminium sector, resolutions issued by CONAMA address several types of impacts on the environment that concern bauxite mining and alumina and aluminium production. Although the resolutions do not refer to the aluminium industry in great detail, environmental problems of importance to the industry are addressed, such as emissions to the atmosphere, surface water and groundwater, effects on soil quality, land subsidence, noise and effects on the landscape.

In addition to federal legislation on the environment, states have also legislated on this subject. Most state legislation is a copy of the federal laws. Exceptions may be found, however, as in the states of Sao Paulo and Rio de Janeiro. The standard for atmospheric emissions of fluoride from primary aluminium production adopted in Rio de Janeiro is generally used as a guideline also in other states, since no federal standards exist. Other states where the aluminium industry is represented have included chapters on environmental issues in their Constitutions, similar to those in the Federal Constitution. Environmental questions are also dealt with in laws, directives and decrees similar to those at the federal level. Only Bahia, São Paulo, Rio de Janeiro, Minas Gerais and Maranhao have state environmental laws with policies and operating procedures.

Environmental agencies at the state level are responsible for monitoring and enforcement of regulations, including federal regulations, since federal law delegates the responsibility for controlling the quality of the environment within state limits to these agencies. Where state legislation exists and environmental agencies are effectively in command of the environmental permit process, monitoring is carried out. Lack of staff and equipment for monitoring is, however, a serious problem both at the federal and state levels.

Chapter IV attempts to assess environmental policies and practices. After the long period of non-democratic government had delayed public dialogue on the subject of the environment, the Constitution of 1988 and the United Nations Conference on Environment and Development led to enhanced environmental awareness. However, this has yet to reach the point where the formulation and implementation of legislation is effectively influenced by public debate. High inflation and political instability have been important recent constraints on the Government’s ability to implement policies, partly because of the resulting strain on government finances. Environmental policies may have suffered more than other policy areas from this situation. Commitments made at the Rio Conference have not been implemented owing to limited budgetary resources and political uncertainty.

As a result of the relative isolation in which policies were previously formulated, federal government agencies still tend to take a narrow view of their responsibilities and appear relatively insensitive to the need for cooperation with industry and to the need to find solutions that satisfy both environment and development concerns. The lack of experienced and qualified staff in agencies contributes to the difficulties. Agencies are understaffed and very seldom have experts in all the fields necessary for reviews of environmental impact statements. Thus, while environmental impact statements were intended to serve as a basis for negotiation and cooperation between government and industries with a view to solving problems, in practice they have become an area for conflicts between governmental personnel concerned about the strict observation of limits and standards and industries interested in proceeding with their investments as quickly as possible. Environmental agencies at the state level, such as CETESB in São Paulo and FEEMA in Rio de Janeiro, are often more effective, mainly because they have been in existence longer and their technical staff has had possibilities to accumulate more experience and qualifications.

As regards the influence of other policy objectives on the formulation and implementation of environmental policies, an examination of the environmental legislation fails to detect any such influence. However, other policies pursued at the federal and state levels would be expected to influence the possibilities of achieving environmental policy objectives, at least indirectly. One example is the granting of incentives to industrial investors by state governments. Incentives such as tax exemptions for certain periods and reduced prices for acquisition of land are common. These policies are likely to have contributed to the location of industries in areas which are less suitable from the point of view of environmental protection. No examples of such policies having affected the location of installations in the aluminium sector are known, however.

Present environmental regulations are based on administrative enforcement of limits and standards. So far, economic incentives have not been used, although this may change in the future as a consequence of commitments made at the 1992 United Nations Conference on Environment and Development. The lack of effective monitoring and enforcement on the part of government agencies has not resulted in non-compliance with standards and legislation in the aluminium sector. This may be partly owing to the influence of the aluminium industry association, which has generally been successful in promoting action on environmental issues. The companies in the aluminium sector have good environmental records and their performance is generally better than that required by federal and state regulations. The international companies active in the Brazilian aluminium sector have successfully introduced environmental practices used abroad. Domestic companies have generally been successful in introducing similar technologies, sometimes benefitting from transfers of technology taking place in the context of joint ventures with international companies.

The relatively good environmental performance of aluminium companies in Brazil also has to be seen in the context of the way that technological change occurs in the industry. At the smelting stage, new installations are standardized with regard to both processing technology *per se* and environment control technology. Only with difficulty could productivity enhancing features be detached from those primarily intended to improve environmental performance. As smelters modernize, or as investments are made in new plants, companies therefore automatically benefit from advances made elsewhere, since introducing modifications to the standard design in order to save on environmental control would result only in very modest savings on investment cost.

At the earlier processing stages of bauxite mining and alumina refining, solutions to the main environmental problems, that is, the rehabilitation of mined-out areas in the case of bauxite mining and the disposal of red mud in the case of alumina production, have to take into account the particular characteristics of the operations and so do not lend themselves easily to standardization. It is significant that in both these areas, the Brazilian aluminium industry has achieved good results in recent years, although it appears that the more impressive progress has been made in those parts of the industry where international companies have a strong interest.

The cost of actions to reduce negative environmental impacts in modern aluminium smelters has been estimated to represent about 10 per cent of total investment costs. High inflation and recession in recent years combined with low international aluminium prices have induced companies to rely more on sub-contracting of certain activities in order to reduce operating costs. It is however difficult to say whether this practice, which is quite recent, is affecting environmental management negatively.

II. THE IMPORTANCE OF BAUXITE, ALUMINA AND ALUMINIUM IN BRAZIL'S ECONOMY[1]

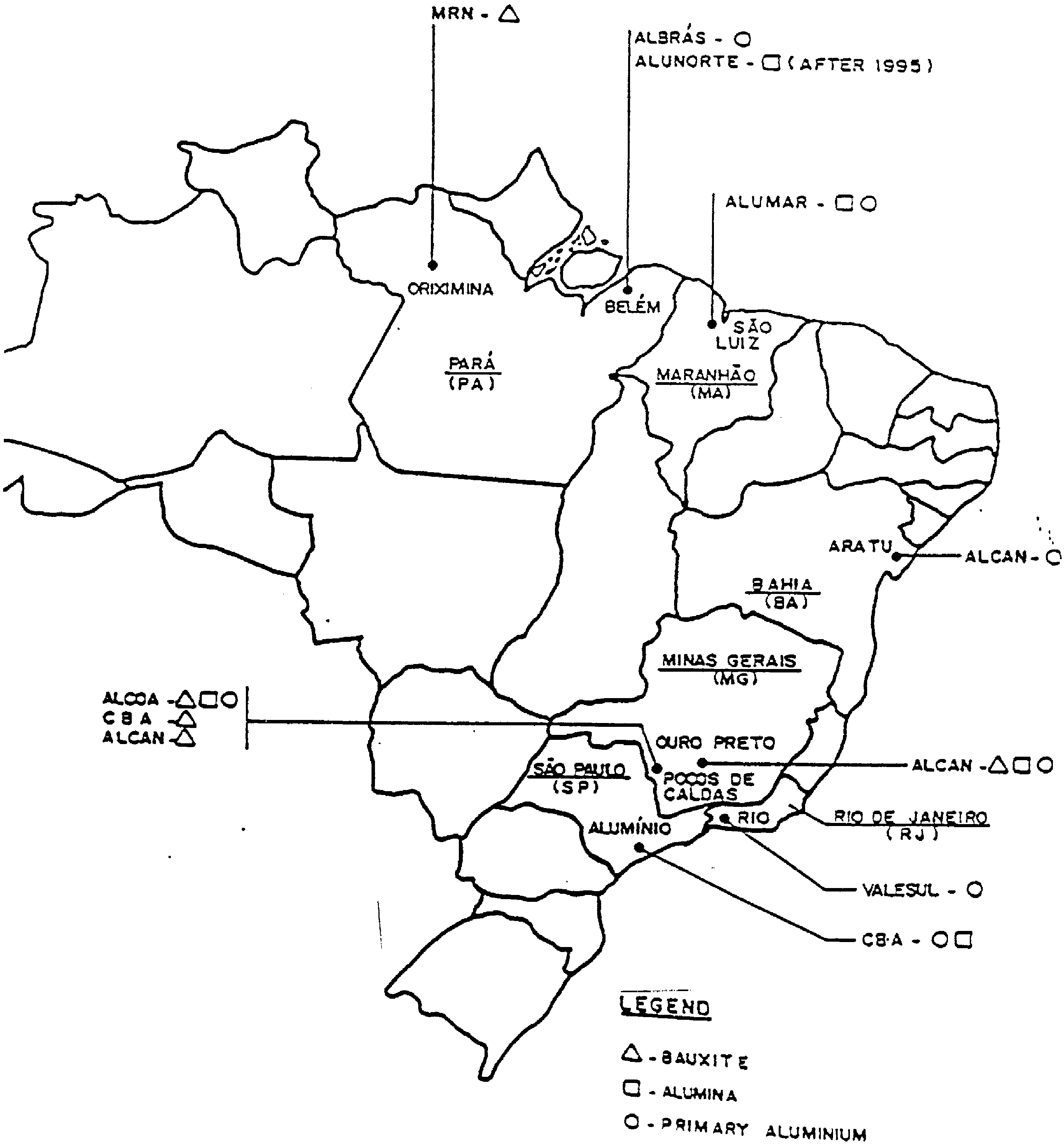
A. Overview of the aluminium sector in Brazil

The history of the Brazilian aluminium sector can be divided into two periods: before and after the beginning of bauxite mining by Mineraçao Rio do Norte (MRN) in the northern region at the end of 1979. Before the startup of MRN, aluminium production was based on the bauxite of Minas Gerais State, with limited mineral reserves. At that time, about 15 per cent of alumina requirements for the 260,000 tons[2] per year of installed primary aluminium capacity were covered by imports. Brazil also imported aluminium products corresponding to about 50 per cent of domestic consumption. Following the start of bauxite production by MRN, several large alumina and aluminium projects were implemented in the 1980s (see box 1). In mid-1993, installed primary aluminium production capacity was 1.2 million tons per year.

Box 1 Main events in the history of the Brazilian aluminium sector

Year	Event	Location
1951	Startup of the 1st ALCAN integrated plant	Ouro Preto, Minas Gerais
1955	Startup of CBA integrated plant	Aluminio, Sao Paulo
1970	Startup of the 1st ALCOA integrated plant	Poços de Caldas, Minas Gerais
1976	Startup of the 2nd ALCAN aluminium plant	Aratu, Bahia
1979	Startup of MRN bauxite production	Oriximina, Pará
1982	Startup of VALESUL aluminium plant	Santa Cruz, Rio de Janeiro
1982	Expansion of CBA integrated plant	Aluminio, Sao Paulo
1983	Expansion of ALCAN aluminium plant	Aratu, Bahia
1984	Startup of ALUMAR integrated plant	Sao Luis, Maranhao
1985	New expansion of CBA primary aluminium plant	Aluminio, Sao Paulo
1985	Startup of ALBRAS aluminium plant	Belém, Pará
1986	Expansion of MRN bauxite production	Oriximina, Pará
1986	Expansion of ALUMAR integrated plant	Sao Luis, Maranhao
1990	New expansion of MRN bauxite production	Oriximina, Pará
1990	Expansion of ALBRAS aluminium plant	Belém, Pará
1990	New expansion of CBA primary aluminium plant	Aluminio, Sao Paulo
1991	New expansion of ALUMAR primary aluminium plant	Sao Luis, Maranhao
1991	Shut-down of the oldest line of furnaces for the production of primary aluminium in Brazil (ALCAN)	Ouro Preto, Minas Gerais
1993	Shut-down of the first line of reduction furnaces (ALCAN)	Aratu, Bahia
1995	Scheduled startup of alumina producer ALUNORTE	Barcarena, Pará

Figure 1 Location of aluminium sector plants



Box 2 Main producing companies

ALCAN ALUMINIO DO BRASIL S.A.
Head Office: Sao Paulo
Subsidiary of ALCAN Ltd. (Canada)
Bauxite mining: Ouro Preto, Minas Gerais, share of 12.5% in MRN
Alumina production: Ouro Preto, Minas Gerais, also takes 10% of ALUMAR production
Primary aluminium production: Saramenha, Ouro Preto, Minas Gerais (52,000 tons/year), Aratu, Bahia (since 1993, 30,000 tons/year)

COMPANHIA BRASILEIRA DE ALUMINIO (CBA)
Head Office: Sao Paulo
100 % private-owned Brazilian company, Votorantim Group
Bauxite mining: Poços de Caldas, Minas Gerais, share of 12.5% in MRN
Alumina production: Aluminio (ex-district of Mairinque), Sao Paulo
Primary aluminium production: Aluminio, Sao Paulo (220,000 tons/year)

ALCOA ALUMINIO S.A.
Head Office: Sao Paulo
Subsidiary of Aluminum Company of America (ALCOA, United States)
Bauxite mining: Poços de Caldas, Minas Gerais, share of 12.5% in MRN
Alumina production: Poços de Caldas, Minas Gerais, share of 54% in ALUMAR
Primary aluminium production: Poços de Caldas, Minas Gerais (90,000 tons/year), also takes 53% of ALUMAR production (186,000 tons/year)

MINERAÇAO RIO DO NORTE S.A. (MRN)
Head Office: Oriximina, Pará
Shareholders: ALUVALE (subsidiary of state-owned CVRD) 40%
ALCAN, ALCOA, CBA, BILLITON 12.5% each
NORSK HYDRO, REYNOLDS 5% each
Bauxite mining: Oriximina, Pará (8.5 million tons/year)

BILLITON METAIS S.A.
Head Office: Rio de Janeiro
Part of SHELL Group
Bauxite mining: Share of 12.5% in MRN
Alumina production: Takes 36% of ALUMAR production
Primary aluminium production: Takes 45% of VALESUL production (45,000 tons/year), takes 47% of ALUMAR production (165,000 tons/year)

ALUMINIO BRASILEIRO S.A (ALBRAS)
Head Office: Rio de Janeiro
Shareholders: ALUVALE (subsidiary of state-owned CVRD) 51%
NAAC (consortium of 32 Japanese companies) 49%
Primary aluminium production: Vila do Conde, Belém, Pará (340,000 tons/year)

VALE DO RIO DOCE ALUMINIO S.A. (ALUVALE)
Head Office: Rio de Janeiro
Subsidiary of state-owned CVRD
Primary aluminium production: Takes 55% of VALESUL production (55,000 tons/year)

VALESUL
Head Office: Rio de Janeiro
Shareholders: ALUVALE 51%
BILLITON 41%
CATAGUASES LEOPOLDINA (power company) 8 %
Primary aluminium production: Santa Cruz, Rio de Janeiro (100,000 tons/year), shared between ALUVALE (55%) and BILLITON (45%)

ALUMAR
Head Office: Sao Luis, Maranhao
Alumina production: Sao Luis, Maranhao (1 million tons/year), shared between ALCOA (54%), BILLITON (36%) and ALCAN (10%)
Primary aluminium production: Sao Luis, Maranhao (351,000 tons/year), shared between ALCOA (53%) and BILLITON (47%)

Brazil is the world's third bauxite producer with almost 10 per cent of world production. Present demonstrated reserves of bauxite of 2,700 million tons, of which 95 per cent are located in the state of Pará in the northern region, represent 11 per cent of world reserves. About 6 million tons per year of bauxite are exported. Brazil is the world's fifth aluminium producer and the sixth exporter of aluminium ingots, semi-fabricated and fabricated products. Figure 1 shows the location of the most important production facilities. Box 2 gives some summary information about the main companies. Tables 1 to 12 in annex I provide detailed historical statistics on the aluminium sector.

With the exception of the Alunorte alumina project, no major new investments are planned for the 1990s. This contrasts with the rapid expansion in the last two decades. However, even if industrial production were to grow fast over the next five years, installed primary aluminium capacity would be sufficient to supply the domestic market and to export more than half the production. Alunorte is expected to start production at the end of 1995, increasing annual alumina production from the present 1.8 million tons to more than 2.9 million tons. The expansion of alumina production will make present annual alumina imports of about 700,000 tons unnecessary. The increase in alumina production will require an increase in annual domestic bauxite production of about 2.3 million tons. This requirement will be filled by an expansion of MRN's mine at Oriximina in the state of Para, where capacity is scheduled to increase from 8.5 to 12 million tons per year.

B. Financial situation and profitability of the Brazilian aluminium sector

Financial indicators based on annual reports for 1992 (see table 12 in annex I) show that the companies in the sector, except for Valesul and CBA, have low liquidity. However, external financing is low compared to stockholders' equity, except for Albrás and Alcan. In Albrás, the high share of external financing is owing to the financial setup of the company, with long term finance provided by the Japanese partners. In Alcan, the external finance represents loans from affiliated companies abroad.

Profitability indexes show that Brazilian companies are strongly affected by the level of international aluminium prices, which was low in 1992, and by domestic energy prices. In 1992 the companies either showed losses or very low profits. Unlike the situation in many other Brazilian companies, financial costs cannot be blamed, since most companies in the aluminium sector showed a surplus of financial income over financial costs. The only exception to the low profitability in the sector was MRN, which made significant gains in 1992, indicating that bauxite prices had not fallen to the same extent as aluminium prices.

Electric power accounts for about 30 per cent of the total costs of production of primary aluminium in Brazil. One reason is that the Brazilian aluminium industry pays US$ 28-32 per MWh, as compared to US$ 10 in Canada, US$ 15 in Norway and US$ 16 in Australia.

C. The importance of the aluminium sector to Brazil

Table 1 shows the importance of the aluminium sector to the national economy in broad terms. It is worth noting that its total earnings are about US$ 3900 millions per year, corresponding to 0.7 per cent of GDP and 2.1 per cent of industrial production. The sector's share of exports was 3.7 per cent in 1992 and government income from the sector was US$571 millions or about 2 per cent of total government income. More than 70 per cent of the aluminium industry's production (including primary aluminium, semi-fabricated and fabricated products) is exported, mainly to Japan (40 per cent) and Europe (45 per cent). Operations in the sector are located in the underdeveloped northern region (states of Pará and Maranhao) and in the more developed states of São Paulo, Rio de Janeiro and Minas Gerais.

Table 1 Economic data for the Brazilian aluminium sector, 1985-1992

	1985	1986	1987	1988	1989	1990	1991	1992
Aluminium industry[a]								
Earnings (million US$)	1700	2400	3800	4600	5500	4200	3800	3800
% of GDP	0.8	0.9	1.2	1.3	0.8	0.7	0.6	0.7
% of Industrial Prod.	2.3	2.5	3.3	3.6	2.4	2.1	2.1	2.1
Government income (million US$)	200	320	500	714	808	568	566	571
Investment (million US$)	368	272	173	324	843	534	511	327
Employment	58515	64593	68215	68852	68211	66780	61907	59662
Primary aluminium[b]	25829	26414	26472	28494	28363	26911	22677	21175
Recycling and foundries	1545	2014	2312	2632	2472	2253	2177	1994
Processing companies	31141	36165	39431	37726	37376	37616	37053	36493
Bauxite mining[c]								
Earnings (million US$)	132	121	139	171	176	208	216	175
Exports (million US$)	94	77	71	125	127	145	154	106
Investment (million US$)	18	53	23	60	59	48	33	24
Employment[d]	2758	2765	3532	3754	3554	3951	2948	2415
Total, aluminium sector								
Earnings (million US$)	1832	2521	3939	4771	5676	4408	4016	3975
Investment (million US$)	386	325	196	384	902	582	544	351
Employment	61273	67358	71747	72606	71765	70731	64855	62077

[a] Six integrated producers of primary aluminium and processed products and about 300 independent processing companies.
[b] Including employment in bauxite mines and alumina refineries owned by the six integrated producers.
[c] Figures refer to MRN only.
[d] Includes both direct employment by MRN (1063 in December 1992) and employees of contractors (1352 in December 1992).

Source: Associaçao Brasileira do Aluminio (ABAL) and Departamento Nacional de Prod. Mineral (DNPM).

The aluminium sector is an important user of domestic inputs. In 1992, primary aluminium production required 2.3 million tons of alumina, 19,000 GWh of electric power, 14,000 tons of fuel oil, 460,000 tons of coke and 145,000 tons of pitch. Alumina production used 4.2 million tons of bauxite, 168,000 tons of fuel oil, 172,000 tons of caustic soda and 1,500 GWh of electric power.

II. ENVIRONMENTAL EFFECTS OF PRODUCING BAUXITE, ALUMINA AND ALUMINIUM

A. Introduction

Box 3 describes the various steps involved in producing bauxite, alumina and aluminium. The main environmental problems associated with bauxite mining are related to the rehabilitation of mined-out areas and the disposal of tailings. Emissions of dust consisting of clay and bauxite particles from dryers' chimneys can also pose problems. In alumina production, the disposal of bauxite residue saturated with caustic soda ("red mud") is the main problem, although emissions to the atmosphere of gases and particles from boilers, calcination furnaces and bauxite dryers may also be important. In aluminium smelting, the emission of fluorides from reduction cells and of gases, smoke and steam resulting from pitch distillation are considered most important. Finally, in aluminium fabrication, emissions of gases and particles from smelting and re-heating furnaces pose the largest problems. The Brazilian experience of dealing with these environmental effects is described below for each production stage.

Box 3 Bauxite, alumina, aluminium production

Activity	Product	Processes and inputs
Mining	Bauxite	De-bushing, removal of overburden Mining Washing, cycloning and filtering/drying
Refining of bauxite	Alumina	Drying of wet bauxite Crushing Digesting, thickening, washing, precipitation Calcination Inputs per ton of alumina: 2.3 tons bauxite 95 kg caustic soda 92 kg fuel oil 800 kWh electric power
Reduction and Smelting	Primary Aluminium	Reduction of alumina in electrolytic cells Casting of ingot Inputs per ton of aluminium: 1.93 tons alumina 370 kg coke 15 to 30 kg fluorides 116 kg pitch 15 MWh electric power
Fabrication	Fabricated Products	Hot and cold rolling (sheets and foils) Extrusion (extruded products) Rod and cables production Foundry (castings)

B. Bauxite mining

1. MRN

Mineracao Rio do Norte S.A. (MRN) is a joint venture of Brazilian and foreign companies, with the Brazilian companies Vale do Rio Doce Aluminio S.A. (Aluval) and Companhia Brasileira de Aluminio (CBA) holding together 52.5 per cent of the ordinary shares. The joint venture was constituted in 1974 to explore for and produce bauxite at Trombetas in the county of Oriximina, state of Pará in the Amazon region. Mining commenced in April 1979. In August of the same year, the first bauxite cargo was shipped to Canada. By the end of 1992, over 70 million tons of bauxite had been produced.

MRN's operations comprise mining, beneficiation, railway haulage and shipping. The orebody lies under an eight metre thick overburden consisting of an organic soil layer, bauxitic gravel in a clayey matrix and ferruginous laterite. The overburden is covered by dense vegetation. De-bushing and overburden removal is required prior to mining. Stripping is done sequentially in regular rows and the topsoil is deposited in the nearest previously mined out row. The ore is hauled by trucks to the crushing station and from there to washing, cycloning and filtering installations. Some 23 per cent of the material goes into tailings after this beneficiation. After beneficiation, the bauxite is hauled by trains from the mine to the port located 30 kilometres away. The wet bauxite is either stored in the port area to feed two dryers or hauled in wet form straight to the ships. The bauxite is shipped both in wet and dry form. The wharf draft is adequate for ships up to 60,000 tons.

In the early years of operation, environmental management efforts were concentrated in the following areas:

- Prohibition of hunting in MRN's areas of influence;
- Rehabilitation of areas cleared of vegetation (mine, railroad and port);
- Disposal of tailings from beneficiation;
- Prevention of emission of solid particles from the dryers' chimneys.

1.1 Revegetation

In 1979, when the plant went on stream, MRN faced the choice of how to rehabilitate the mined-out areas. The alternatives considered for revegetation were:

- exotic species (eucalyptus)
- pastures
- fruit trees
- native species

In accordance with the company's policy of restoring the original characteristics of the rainforest, native species were selected to rehabilitate the mined-out areas. This was a pioneer experience in the Amazon region. Over time, methods for growing and developing transplants improved. The results obtained so far are entirely positive as regards rehabilitation of both flora and fauna. Some 500 hectares (50 per cent of the total) of the mined-out areas have been revegetated.

1.2 Bauxite Tailings Disposal

Initially, MRN opted for discharging tailings from the washing of bauxite into a natural lake (Lake

Batata) in the vicinities of the industrial installations and townsite, close to the port. This resulted in severe degradation of the lake and its banks (see section 1.3) and so the company began investigating alternatives to this procedure. In 1986, after a comparative analysis of ten alternatives, MRN decided on a solution in which the beneficiation tailings were entirely returned to the mined-out areas and, when dry, prepared for reforestation with native species.

The implementation of the project eliminated the risk of silting of rivers and lakes or of inundating large areas of rainforest. MRN invested about US$ 70 million in the transfer of the beneficiation installations from the port to the mine; the new tailings disposal system was completed in November 1989.

The experience illustrates that efforts must be made during project planning and construction in order to avoid environmental problems. Corrective action undertaken at a later stage, when at all feasible, normally costs more and takes more time.

1.3 Rehabilitation of Lake Batata

MRN is rehabilitating the part of Lake Batata which was damaged by the old tailings disposal system. The rehabilitation project, which is unique in the world, has offered opportunities for the training of specialized scientists in tropical lakes recovery.

Located on the right bank of the Trombetas River, Lake Batata originally was a typical unpolluted water ecosystem. However, over ten years, the waste from bauxite beneficiation was discharged into the lake. The effluent, containing 6 to 9 per cent solids, resulted from washing the bauxite with water from the Trombetas River.

The composition of the clayey material, practically the only solid component of the waste, is shown in table 2. Sampling results from four collection stations are shown. Samples were collected during the rainy season. Stations 1, 2 and 3 are located at the part of the lake where tailings were discharged, while station 4 is located in a relatively unaffected part of the lake. As seen from the table, the effluent is characterized by a low concentration of important nutrients such as phosphorus and nitrogen.

Table 2 Main chemical components of sediment in Lake Batata (organic material shown in per cent on dry basis and other components in parts per million).

Station	Org. Mat.	P	N	Al	Cd	Cr	Cu	Zn	Ti	K
1	14.4	127	1000	2042	<2	<2	<2	3	8	12
2	16.4	168	1400	1965	<2	<2	<2	3	8	8
3	15.3	90	1200	2326	<2	<2	<2	4	13	17
4	20.1	472	6200	2866	<2	<2	12	24	8	78

Source: Mineracao Rio do Norte S.A.

The main ecological consequences of the tailings disposal into the lake were:

- part of the flood plain in the region affected by the effluent died;

- the structure of the various aquatic colonies, mainly phytoplanctonic, zooplanctonic and, in particular, benthonic and fish, were altered,

- dynamics of the nutrients were affected, mainly in the area where tailings were discharged.

The rehabilitation project, which was initiated when tailings disposal ceased in late 1989, had two main objectives:

- Formation of a substrate in the area affected by the effluent with characteristics as close as possible to those of the natural sediment;

- Formation of colonies, with native species, on the new flood plains resulting from the tailings disposal and revegetation of areas where the bush had died.

To create an organic substrate on top of the settled effluent, experiments were carried out using different available sources of organic matter were carried out. The objective was to identify methods and materials that would enable colonization, mainly by benthonic fauna during the rainy season, and thus rehabilitate a considerable part of the food chain on which predatory fish depend. Another objective was to avoid re-suspension of the precipitated effluents during high water. Additionally, the creation of an organic substrate would permit the sediments to return to the dark colour typical of Amazon lakes.

The different sources of organic matter used in the experiments were forest humus, tree bark, ground wood chips, coarse sawdust, fine sawdust and ground grass. The preliminary results showed that higher density materials like wood chips and ground tree bark were the most adequate.

Revegetation was one of the most important stages in the rehabilitation of the affected part of the lake. Towards this end, preliminary tests were carried out in which recolonization with species native to flood plains was tried. The main problem was the absence of structure and texture as well as mineral salts in the material deposited.

In January 1989, 13 test areas of 16 x 20 metres each were set aside in order to study the survival conditions and growth of the transplants. Some 104 individuals of about 15 species of flood plains plants were planted in 50 x 50 x 50 cm holes. Half of the holes were filled with a coarse sand mixture to improve the texture and structure of the effluent (clay) and organic matter in equal proportions. Coarse wood bark, fine wood bark, wood chips, sawdust and ground grass were used as sources of organic matter. The remaining holes were filled in the same manner with 370 grams of fertilizer (type 12 nitrogen, 36 phosphorus, 12 potassium). Preliminary results show a high survival rate of the transplants.

More recently, a new technique was tried. It is based on the natural process of flooding typical of the region. The technique originated from field observations during interim monitoring of the lake. Flooding is responsible for the flow into the lake of a great quantity of seeds both from dry land forest and flood plains. Only a small fraction of these seeds grow on the banks of the lake; the remainder are either lost to other ecosystems (rivers, for example) or mixed with the lake waste chain. The technique consists in setting barriers made of dead trees opposing the direction of the water flow. The barriers enable the seeds to settle and to grow later during low water. The great number of species growing on the areas treated this way show that, although simple, the procedure is highly efficient.

The ecological rehabilitation of Lake Batata thus appears to have been successful. However, additional investigations are needed on aspects such as colonization of a new organic substrate for boneless aquatic species and the possibility of re-creating the nutrients cycle in the plants growing on the effluent.

1.4 Control of solid particles emissions

When the drying plant was commissioned in June 1979, emissions of solid particles (clay and fine bauxite) from the dryers' chimneys became a problem. The 4 tons/hour dust volume in the atmosphere tinged the townsite and industrial installations as well as the surrounding forests with red dust.

After two and a half years of studying alternatives, MRN decided to instal gas washers to precipitate the nonsettling particles. The gas washers consist of sprays arranged in spiral form inside a chamber through which the gases flow. The system, which was installed in 1982, is highly efficient and recovers 98 per cent of the particles.

Paving of streets and lanes in Porto Trombetas has also contributed significantly to reducing the volume of solids in suspension.

1.5 MRN's environmental policy

From startup until the end of 1992 MRN invested about US$ 91 million in environment preservation. MRN has developed an Environmental Master Plan which will be updated as and when appropriate solutions for problems are found. The management structure applied relies on specialists being made available to sectors of activity to develop environmental programmes and on the Comissao Interna do Meio Ambiente (Internal Commission for the Environment, CIMA) which includes representatives of various segments of the Porto Trombetas population. The company also relies on external consultants, sometimes funded by outside contributions. A team of engineers and technicians is responsible for the planning and execution of environmental services.

An agreement between MRN and Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA (Brazilian Institute for the Environment and Renewable Natural Resources) ensures protection of the Trombetas River Biologic Reserve (3,550 square kilometres) and Saracá-Taquera National Rainforest (4,296 square kilometres). The purpose of this agreement is to provide for cooperation between the parties in terms of technical and scientific support and for financial aid by MRN to actions aiming at preserving the integrity of the Trombetas River natural resources. As a result of joint action by MRN and IBAMA, propagation of the Amazon turtles in the Trombetas River has been possible.

MRN controls fishing and strictly prohibits hunting in the Porto Trombetas region. Consumption of and trade in wild animals in MRN's areas of jurisdiction are rigorously watched; transgressors are immediately banished from Porto Trombetas.

As part of the company's environmental policy, local and in-house campaigns are carried out to develop the awareness of the local population of the importance of environment preservation. In this context, the role of the local school is highly important.

2. Bauxite mining in the southeastern region

The integrated companies in the State of Minas Gerais also carry out rehabilitation of mined-out areas. CBA has revegetated about 180 hectares in the region of Poços de Caldas since the 1950s. Alcoa has revegetated about 140 hectares since 1987, also in the region of Poços de Caldas. Alcan has revegetated 90 and 42 hectares in the regions of Ouro Preto and Cataguases, respectively. The revegetation is always carried out using native species combined with gramineous and leguminous plants that improve growth conditions for the former.

Since 1978, the bauxite mines of the state of Minas Gerais have produced 24.5 million tons of dry bauxite. If it is assumed that the production of 1 million tons of dry bauxite uses an area of 21 hectares on average, there were a total of 575 hectares to be rehabilitated in the state. On the basis of the figures just given, 452 hectares of the total have been reforested.

2.1 Alcoa

Since 1978, the Bauxite Mining Department of Alcoa, in Poços de Caldas, has a specialized branch charged with the rehabilitation of soil and vegetation. The rehabilitation programme follows standards adopted by Alcoa all over the world. At first, Alcoa planted uniform forests, mainly of eucalyptus, and gramineous plants for pasture, to revegetate the mined-out areas. More recently, native species are relied on for revegetation, aiming at restoring the original landscape and preserving the local fauna.

The method followed by Alcoa for the rehabilitation of mined-out areas includes the following steps:

(a) Before mining, the removed topsoil is stored to be used later;

(b) To avoid soil erosion, mined-out areas are terraced immediately following bauxite extraction and the areas covered with the topsoil previously stored;

(c) A drainage system is installed in the areas;

(d) The areas are planted with native species; and

(e) Organic matter is distributed over the area to encourage faster vegetation growth.

C. Alumina production

The annual production of more than 1.8 million tons of alumina in Brazil is accounted for by:

- Alumar, located 25 kilometres from the city of Sao Luis, State of Maranhao (53%)

- CBA, in the county of Aluminio, State of Sao Paulo (29%)

- Alcoa, in Poços de Caldas, State of Minas Gerais (10%)

- Alcan, in Saramenha, Ouro Preto, State of Minas Gerais (8%)

The main environmental problems in alumina production are the disposal of the bauxite residue, saturated with caustic soda ("red mud"), and emissions of gases and particles from boilers, calcination furnaces and bauxite dryers.

Refining of bauxite from MRN results in 0.7 tons of red mud per ton of alumina. This red mud has the following average composition (levels of iron and titanium oxides are relatively high):

Fe_2O_3 - 37%
Al_2O_3 - 17%
TiO_2 - 4%

Worldwide, the most common method of disposal of red mud is to discharge it into deposit lakes constructed for this purpose. An alternative method, which has environmental advantages, is to pump back the sludge in order to recover and reuse the caustic solution. In older installations, however, this is usually not done for reasons of cost. The deposit lakes are usually built to be 4 to 6 metres deep. Assuming 30 years of use and a production of alumina of 1 million tons per year, the deposit lakes will occupy an area of about 600 hectares. At the end of their useful life, the residue lakes enter a process of consolidation and their surface is landscaped and revegetated. The revegetation is preceded by tests to establish what type of vegetation will be preferable, taking into account future use of the area. Groundwater characteristics are monitored after the deposit area is rehabilitated, since the red mud is strongly alkalic and may affect groundwater quality.

Sulphuric gaseous emissions from alumina production are generally minimized by the exclusive use of fuel oil with very low sulphur content.

1. Alumar

The industrial complex of the Alumar consortium in Sao Luis, State of Maranhao, produces 1 million tons of alumina and 350,000 tons per year of primary aluminium. It has been operating since 1984. The consortium is a joint venture between Alcoa and Billiton. Alcan joined later as a part owner of the alumina refinery.

Since 1981, three years before production started, Alumar has conducted a number of studies and surveys on the region where the project is implemented. Approximately 10 per cent of the project’s total investment cost of US$ 1,600 million was accounted for by environmental measures.

The bauxite is sent to the refinery on conveyor belts and is refined through a computer-controlled hydrometallurgic process. The bauxite residue is discharged into deposit lakes built for this purpose. A double coating of compact clay and PVC sheeting guarantees impermeability of these lakes so as to protect soil and groundwater. Additionally, two drainage systems, one at the surface and one at the bottom of the deposit lake, collect and recycle the remaining caustic soda solution. The lakes also collect rain water, which after a process of decantation of the solids in suspension, provides the system with clean water.

The cooling deposit that receives water from the refinery’s water-cooling systems is also coated on the inside by two impermeable layers, one of clay and one of PVC sheeting.

Special care is taken to reduce any impacts on the environment caused by accidental leakages: all tanks, pumps, valve stations and other equipment holding liquids are installed in paved or impermeable areas, around which concrete walls and containment dikes are built. Oil tanks also have water-oil separation systems.

All gases and particles from equipment such as boilers and the alumina transport system undergo treatment in sleeve filters. In some cases, for example in the calcination furnaces, particles are collected by electrostatic precipitators.

Besides using systems and equipment that minimize the impact on the environment, Alumar has taken preventive steps by monitoring its emissions and carrying out analyses of the quality of the local air, water, vegetation and soil.

In addition to the primary emission sources (chimneys and other points of discharge), the environmental monitoring network includes: a number of wells for the monitoring of groundwater, surface water in the local streams and estuary; collection of vegetation samples; and air quality monitoring sites, including two automatic stations for continuous analysis of fluoride, sulphur dioxide and particles in suspension in the atmosphere. The purpose of the monitoring system is to determine whether legal standards are being met and to gauge the impacts on the environment. Based on the monitoring results, new projects or plans of action can be developed to improve the quality of the environment both in the plant and the areas in its vicinity.

2. Other alumina producers

The refineries of CBA, Alcan and Alcoa are located in the hinterland of the States of Sao Paulo and Minas Gerais, far from urban centres. In these operations, the red mud is discharged into deposit lakes with partial (about 80 per cent) recovery of the caustic solution. The deposit lakes, up to 10 meters deep, are built on flat land or by damming natural valleys. The overflow from the lakes is monitored to guarantee adequate neutralization of alkali contents.

D. Production of primary aluminium

The production process consists of the electrolytic decomposition of alumina in a molten bath composed of cryolite and fluorides, in which the carbon anodes collect oxygen released from the decomposition of alumina. The liquid aluminium is deposited on the carbon coating of the crucible - the pot - which acts as the cathode. The aluminium is pumped by suction into crucibles of metal which are taken to the ingot casting area. The ingots are then marketed or transformed into a wide range of fabricated aluminium products. A distinction is made between Söderberg technology, where the anode paste is introduced into the pots through the top of the covering, baking itself solid in the heat rising from the pot, and the prebaked anode technology, in which anodes are baked before they are introduced into the pot. The modern prebaked technology allows pots to be more efficiently covered, reducing fluoride emissions and permitting recovery of alumina and fluorides.

The annual production of 1.2 million tons of primary aluminium in Brazil is accounted for by the seven plants shown in table 3.

The design and location of smelters have traditionally been influenced by the knowledge that they produce gaseous emissions that are difficult to prevent completely. Therefore, they are often located on a site where the prevailing wind carries off these emissions to areas where the harm is negligible.

The operating procedures for the present generation of cells - particularly anode changing and setting, metal tapping, and alumina feeding - make it impossible to operate with a completely closed cell. Therefore, loosely fitted hooding, designed for easy removal in sections, is used. Among emissions from the cells, the fluoride compounds present the greatest potential hazard. The loss of fluoride compounds from the cell also represents a significant cost factor because it causes operation control problems as well as material losses.

The waste gas composition depends on the type of anode used, with prebaked anode cells being fairly free from pitch distillation and pyrolysis products. Even with afterburners, the Söderberg cells emit 2 or 3 kg of tar products per ton of aluminium produced. Handling this tar is the main difference that Söderberg cells present for emission treatment purposes. The total fluoride consumption in cells varies from 20 to 50 kg per ton of aluminium produced. Approximately half of this leaves the cell in waste gases. Usually the losses are greater for Söderberg cells, depending on operating temperature, current density, bath ratio and alumina content. Oxides of sulphur are also emitted with the waste gases. They originate from the anode carbon plant and typically constitute 5 to 15 kg sulphur per ton of aluminium produced.

Table 3 Aluminium smelters in Brazil, production capacity in 1992

Company	Location	Production capacity	
		Thousand tons/year	Share, %
Alumar	Sao Luis, Maranhao	350	28.9
Albrás	Belem, Para	340	28.1
CBA	Aluminio, Sao Paulo	220	18.2
Valesul	S. Cruz, Rio de Janeiro	100	8.2
Alcoa	Poços de Caldas, Minas Gerais	90	7.4
Alcan	Aratu, Bahia	60	4.9
Alcan	Ouro Preto, Minas Gerais	52	4.3
Total		1,212	100.0

Box 4 describes the effects of fluoride absorption on humans, animals and plants. As a consequence of the problems that can arise from fluoride emissions, legislation has been introduced in many countries restricting the fluoride content of emissions to the atmosphere. Ambient air quality standards for fluoride emissions in different locations are given in table 4. The limit of fluoride emissions in USA has been fixed at 0.9 kg per ton of primary aluminium since 1976. In Brazil, standards for Rio de Janeiro, which are also applied in other states, limit emissions to 1.25 kg per ton of aluminium.

Two different strategies for treatment of gaseous emissions have been adopted in the aluminium industry to reduce fluoride emissions to acceptable levels. One approach is non-recoverable wet scrubbing, where the fluoride is discharged to waste in an acceptable form. The other is to absorb the emissions in a form that allows the fluoride to be recycled to the cell. In recent years, the emphasis has shifted to techniques which enable recycling. Fluoride recovery units installed in smelters are based on either a wet or a dry scrubbing technique. Wet scrubbers have been shown to operate more efficiently, but they have corrosion problems. Although the efficiency of the more recently designed dry scrubbers is strongly dependent on the quality of the alumina, the trend has been in the direction of a preference for dry scrubbing.

1. Söderberg technology smelters

In this smelting technology, the gaseous residues of fluorides and of tar from anode baking are emitted together. Gaseous emissions are treated by wet, non or partially recoverable scrubbing, or, in newer installations, by dry scrubbing. The collection efficiency for emissions from well hooded Söderberg cells varies from 60 to 95 per cent depending upon the pot working procedure. For efficient collection it is important that the gas suction be evenly distributed between the cells, that operating disturbances not influence neighbouring cells, that gas velocities be high enough to prevent deposition of solids, and that the temperature be high enough to avoid condensation of tars.

A typical composition of the gas collected from a pot is as follows:

Hydrogen fluoride	700 - 1000 mg per cubic meter STP
Sulphur dioxide	600 - 800 mg per cubic meter STP
Dust	100 - 800 mg per cubic meter STP

(STP = standard temperature and pressure conditions)

Box 4 Effects of fluorides

Effects on humans and animals

The two most thoroughly studied manifestations of the effect of continued exposure to fluorides are dental and skeletal fluorosis. Dental fluorosis causes permanent defects on the teeth in the form of white, chalky patches on the tooth enamel. These are due to imperfections in the calcification process, and normally occur only in the early stages of tooth development, e,g. during childhood up to the age of about 12 years.

Skeletal fluorosis is the main manifestation of chronic absorption and retention of fluoride compounds. Symptoms may include pain in the back or restricted movement of the joints. In advanced stages the symptoms also include neurological effects with radiating pains. Skeletal fluorosis requires exposure to high levels of fluorides for many years before it develops and is rarely found among workers in modern aluminium smelters. As animals approach more advanced stages of fluorosis, they exhibit lameness. A stiff laborious gait and difficulty in rising is often observed in severely affected animals.

Effects on vegetation

For many years confusion persisted as to the effect of fluoride emissions on vegetation since generally the vegetation was simultaneously exposed to sulphur dioxide emissions (from impurities in the anodes). It is now recognized that the gaseous fluoride compounds are amongst the most toxic of all known pollutants. Whereas sulphur dioxide is reported to cause visible injury to susceptible plant organisms exposed to gaseous concentrations of about 1 ppm, in the case of hydrogen fluoride the effects are noticed for gases containing less than one thousandth of a ppm. The toxicity of gaseous fluorides varies with plant species, age and nutritional state of the plant, weather conditions and other factors. While the physiological mechanisms of the poisoning are undoubtedly complex, it is known that it reduces the carbon dioxide intake and adversely affects the respiration and transpiration processes.

Fluorides can be ingested by the plant directly through the leaves or from the soil. In the former case, it usually enters the plant either through the stomata or the cuticle. The amount absorbed through the roots depends on the plant and the weather. Generally, absorption of gaseous fluoride has more noticeable effects, with plants growing side by side sometimes showing markedly different effects.

Table 4 Ambient air quality standards for fluoride emissions (average 24 hour concentration in mg per m^3)

Compound measured	**Location**	**Concentration**
Fluorides as HF[a]	Montana, USA	0.007
Fluorides as HF	New York, rural	0.007
Fluorides as HF	New York, urban	0.0013
Fluorides as HF	New York, industrial	0.0026
Fluorides as HF	Ontario, Canada	0.0026
Fluorides as soluble HF	Pennsylvania, USA	0.005
Fluorine (as total fluorine)	United Kingdom	0.001
Hydrogen fluoride	Netherlands	0.01
Fluorides as HF	Rio de Janeiro	0.0029

[a] Hydrogen fluoride

The cleaning system must be efficient for hydrogen fluoride removal and for condensing the tars. The initial cleaning of the pot gas is usually done in cyclones or dry electrostatic filters. In the wet scrubbing process, hydrogen fluoride is absorbed with 90 per cent efficiency in the sieve plate tower, where fresh water is fed to the process, producing a 5 per cent acid solution. Final scrubbing is done in the potroom gas tower, which is not designed for any additional recovery.

The 5 per cent hydrogen fluoride solution obtained in the re-circulating sieve plate scrubber can be neutralized and converted to aluminium fluoride with aluminium hydroxide. Alumina is used both as a reactant and as a nucleating agent for precipitation of the product. Corrosion is severe in all wet scrubbing systems and this has led many smelters to favour a dry scrubbing approach, despite its tendency to recirculate impurities. Table 5 shows the gas treatment used in existing Brazilian Söderberg smelters.

The disposal of cathode residues presents problems to aluminium smelters, since these residues contain fluorides and cyanides. A system for recycling of the residues for use in ceramic industries has been successfully developed by Alcan. The residues are added in a proportion of 5 per cent to the clay used for production of refractory bricks. The material reduces fuel consumption in furnaces. Alcan is currently giving away the process to other Brazilian aluminium producers.

2. Smelters with prebaked anodes

In this smelting technology, the gaseous emissions from the cells are free from tarry vapours. The pot gas treatment is based on the dry scrubbing technique with recovery of all fluorides, which are returned to the cells by passing the emitted gas through a bed of alumina used to feed the cells. Smelters using prebaked anodes technology are the newest installations in Brazil.

Alumar, which started in 1984, has a capacity of 350,000 tons/year. The gases generated by the cells are collected in exhaust pipes and taken to a reactor system where the fluorides react with alumina fed into the cells. The system recycles 99 per cent of the fluorides, guaranteeing a volume of emissions which is well within legal limits as well as a healthy environment in the smelting rooms and surrounding areas. Several sets of sleeve filters distributed in the smelting area ensure the quality of the air inside the potroom. The waste residue from the cells which consists of used cathode linings and skimmed off dross containing fluorides and cyanides is disposed of in storage areas which are roofed and paved to prevent the waste from polluting the soil. A recycling project aiming at industrial utilization of this waste is being developed by Alumar.

Table 5 Treatment of gaseous emissions in Brazilian Söderberg smelters

Plant	Start-up year	Amperage (kA)	Capacity (thousand tons/year)	Gas treatment
Alcan, Ouro Preto	1945	35	9	Shut down
	1958	65	24	Wet scrubbing
	1976	65	28	
Alcan, Aratu	1970	65	28	Shut down
	1983	65	30	Dry scrubbing
Alcoa, Poço de Caldas	1970	120	30	Wet cleaning and dry scrubbing with alumina bed and some recovery of fluorides
	1976	120	30	
	1979	120	30	
CBA, Aluminio	1955	85	15	Wet scrubbing
	1965	65	40	
	1977	120	40	
	1982	120	40	
	1985	120	40	
	1990	120	40	

Source: Companies

Valesul, with a capacity of 100,000 tons/year, started in 1982. It treats gaseous emissions using a dry scrubbing technique. Fluorides in the off-gases are recovered by passing them through a bed of alumina which is later used in the reduction cells.

Albrás, which started in 1985 and was expanded in 1986, 1990 and 1991, has a capacity of 340,000 tons/year. It also uses dry scrubbers for 70 per cent of gaseous emissions and wet cleaning with acid solution for the remainder.

3. Emissions from Brazilian smelters

The newer smelters generally show the best performance with regard to emissions. According to the standards established by the state of Rio de Janeiro, which are usually applied as a guideline also in other states, emissions of fluoride are limited to 1.25 kg/ton aluminium produced. At Alumar, emissions have declined from 1.23 kg/ton in 1990 to 0.44 in 1992, while at Valesul, they have declined from 0.74 to 0.43 kg/ton. The other smelters emit around 0.9 kg of fluoride per ton aluminium produced. The corresponding regulation for particulates is 5 kg/ton aluminium. Emissions vary from 1.15 kg/ton at Alumar and 1.8 kg/ton at Albrás to between 2.5 and 3 kg/ton at the other smelters.

It has been estimated that the total Brazilian production of primary aluminium is responsible for emissions of fluorides and particulates of about 4,200 tons per year. To put this figure into perspective, it is estimated that a single steel plant such as the Usiminas plant, with an annual production of 4.5 million tons of steel (about 20 per cent of Brazilian steel production), emits about 3,000 tons per year.

E. Fabricated aluminium products

About 300 plants in Brazil produce fabricated aluminium products. This production gives rise to some pollution through emissions of oils and greases used in the processing. Small amounts of heavy metals such as lead may also be emitted. Environmental control measures account for a relatively small portion of production costs.

III. OVERVIEW OF GOVERNMENT POLICIES

A. Chronology of Brazilian environmental legislation 1972-1990

The environment is a major concern for a country such as Brazil which has enormous natural resource assets. After the United Nations Conference on Environment, in Stockholm in 1972, domestic discussions were initiated and in 1973 the Brazilian Government created SEMA, the Environment Secretariat, under the National Affairs Ministry. SEMA was charged with: analysing the relationship between national development and technology and their influence on environment; assisting environmental agencies; preparing standards for environment preservation; coordinating the achievement of established goals; and working together with financial agencies to obtain funds and loans to private and public institutions for the rehabilitation of natural resources affected by pollution.

Government concern over the environment increased in the mid-1970s. A decree in August 1975 made those responsible for industrial activities legally obligated to prevent or correct damages caused by pollution and contamination of the environment. Two months later, a new decree defined industrial pollution in a global manner. Industrial pollution was defined as modifications of physical, chemical or biological environmental conditions provoked by any type of energy or gaseous, liquid or solid substance discharged by industries, capable of directly or indirectly:

- damaging the health, safety and well-being of the population;

- creating adverse conditions for social and economic activities;

- causing damages to vegetation, fauna and other natural resources.

Penalties were also established; thirteen critical areas were listed; these areas were considered critical for industrial installation; projects in them should be subject to government review and approval in order to not increase pollution or put human lives in danger.

Five years after these decrees, in 1980, a new law established the main guidelines for industry location and introduced a system of urban zoning. Three categories of zones were defined:

(a) exclusive industrial use;
(b) mainly industrial use;
(c) mixed use.

Category (a) is for industries whose solid, liquid and gaseous emissions, noises, vibrations and radiation may cause harm to the health or well-being of the population even if industries are using effluent treatment and control equipment. The areas where these industries are to be installed should have a high absorption capacity for effluent; they should have good infrastructure, and they should be surrounded by a "green ring" to protect the surroundings. In these areas, permission to instal, operate or enlarge industrial facilities should be subject to the observance of environmental standards established by SEMA and by local and municipal authorities. Category (b) is for industries that are harmless to the population because they have adequate control of effluent emissions. The installation of industries that need to be near their source of raw material outside areas for exclusive industrial use should be approved by local and state authorities.

In August 1981, the basic law on environment (law 6938) was approved and issued by the federal Government. In article 1 of the law, a National Policy for the Environment, including goals and procedures for their implementation, was established. At the same time, the National Environment Council (CONAMA) with representatives of the federal and state governments was created. CONAMA is assisted by municipalities, government agencies and non-governmental organizations. Its main goals are to:

- Review and propose government policy guidelines on environment and natural resources;

- Decide on standards compatible with environment preservation;

- Establish criteria for environmental impact statements (EIS) with reference to activities subject to environmental permits, ensure public access to information related to environmental damage, and establish procedures for environmental protection.

Natural resources are defined as air, surface and underground waters, estuaries, the territorial sea, soil, sub-soil, atmosphere, fauna and vegetation.

Activities subjects to environmental permits are defined as those which affect:

- Health, security and population well-being,

- Human activities,

- Biota,

- Environment esthetics and sanitation,

- The quality of natural and environment resources.

Article 4 of the same law imposes the obligation on the responsible party to mitigate and/or indemnify damages. According to article 10, the construction, installation, enlargement and operation of activities that are potentially pollutant and capable of provoking environmental degradation are subject to permits by environmental agencies. Article 12 establishes that loan agencies and government banks which grant incentives should condition the approval of applications on fulfilment of CONAMA’s standards and criteria.

Ecological Areas and Environmentally Protected Areas were defined in Law 6902 of 1981. It has been decided that at least 90 per cent of the area included in Ecological Areas should be preserved. For the Environmentally Protected Areas, the Executive shall define norms limiting or forbidding the installation of potentially pollutant industries, earth-filling activities, and trenching and ditching affecting local environmental conditions.

In 1985, acts damaging to the environment became subject to federal law enforcement and as a result environmental curatorships were created in the largest cities. The law also allows non-governmental environmental organizations to file lawsuits.

The current Constitution of 1988 is definitively the most important governmental action acknowledging the links between environmental, social and economic aspects. Non-governmental organizations, the scientific community and other civil affairs associations succeeded in having their goals subsumed under the Constitution and a whole chapter (Chapter 225) was dedicated entirely to the environment, granting Brazilian citizens the right to a harmonious environment. Environment was defined as an asset for the general use of citizens and essential for a healthy life. Other chapters envisage a possibility for citizens to file lawsuits to protect the environment. States and municipalities were granted autonomy to protect the environment through legal actions. The National and Law Ministry also has the power to protect the environment through legal action. The Constitution does not, however, determine obligatory procedures for consulting local communities. Some relevant aspects already addressed in Law 6938 were carried over to the Constitution, for instance:

- Requirement for EIS prior to field work or installation of potentially environmentally damaging industrial activity;

- Protection of flora and fauna and prohibition of actions that put them at risk, that may lead to the extinction of species or inflict damage on animals.

Paragraph 2 of chapter 225 of the Constitution states that anyone who exploits mineral resources is obliged to rehabilitate the environment in conformity with technical methods approved by the appropriate public agency. There are no obligatory provisions for the assurance of availability of funds for rehabilitation. Damages to the environment are subject to legal and administrative sanctions in addition to the obligation to repair damages.

A new law, no. 7735 of 1989, abolished SEMA and created the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA), which reports to the President. Its function is to assist, supervise, execute and enforce national environment policy.

Law 7804 of 1989 introduced some modifications to the previously mentioned laws:

- The creation of a Superior Council for Environment with responsibility for assisting the President in the implementation of the National Policy and for the guidelines on environment and natural resources. The Council, which meets twice a year, includes representatives from all Ministries, three congressmen and five Brazilian citizens nominated by environmental non-governmental organizations;

- CONAMA has additional responsibility for reviewing environmental impact statements in instances where environmental degradation could be caused by work or activities in areas defined as part of the National Patrimony;

- IBAMA should issue an annual Report on Environment Quality;

- Construction, installation, enlargement and operation of activities that use environmental resources and are considered actually and potentially pollutant as well as capable of provoking environmental degradation shall be subject to previous permits by state agencies and IBAMA.

Decree 99274 of 1990 defined the structure of the Environment National System, the functioning and responsibilities of CONAMA, the permit process and other items related to Ecological Sites and Environmentally Protected Areas. Resolutions have been issued by CONAMA since 1986. These resolutions define standards for *inter alia* atmosphere and water emissions, soil quality and noise.

In the beginning of the 1970s, Brazilian laws on the environment were restricted to the preservation of biota. The accelerated development process experienced by Brazil during that decade and the recommendations of the United Nations Conference on Environment in 1972 led to a significant increase in environmental awareness and concern over Brazilian natural resources. With the largest biological diversity in the world - at least 15 to 20 per cent of the world's living species - the preservation of natural resources became mandatory, although some partial destruction of relevant ecosystems has occurred. The environmental laws and environmental policy guidelines issued in the 1980s were a consequence of world concern about the environment and of the necessity to give environmental issues equal importance as the challenge to develop a country with formidable natural resource assets.

B. Environmental references in mining legislation

According to article 5 of the Constitution, mineral resources, including the subsoil, belong to the Union and results of their exploitation shall be shared by states and municipalities. This subject was expanded in Law 7990 of 1989. As already indicated, chapter 225 of the Constitution refers to the necessity to rehabilitate environment damaged as a result of mineral resource exploitation.

The Mining Code of 1967 and detailed regulations issued in Decree 62934 of 1968 contain no direct reference to environmental issues, although the decree states that the miner shall indemnify the landowner or squatter for irreversible damages to the land, that is, if the land cannot be used for crops or pasture. The miner shall also be subject to legal action if he does not avoid air or water pollution as a result of mining or if the waters drained cause damage to his neighbours.

There is a specific reference to the environment in Directive 231 issued by the National Mineral Department in 1981 (the objective of the directive was to establish rules for bidding for mineral survey areas). According to this directive, a mining proposal shall contain a description showing the compatibility of mining with preservation of the environment and natural resources. Another directive (number 139 of 1991) instructs the Mining Environment Control and Safety Department of the Infrastructure Ministry to support environmental control and investigate causes of environmental damage.

C. Environmental legislation affecting the aluminium sector

1. Federal legislation

At the federal level, in addition to the general legislation on environment already referred to, CONAMA's resolutions address several types of impacts on the environment that concern bauxite mining and alumina and aluminium production. Although the resolutions do not refer to the aluminium industry in great detail, environmental problems of importance to the industry, such as emissions to the atmosphere, surface water and ground water, effects on soil quality, land subsidence, noise and effects on the landscape, are addressed.

Resolution 1 from 1986 defines environmental impact as the physical, chemical or biological modification of the environment caused by any material or energy resulting from human activities which, directly or indirectly, affects population health, safety and well-being, human activities, biota, esthetic and sanitary conditions and the quality of environmental resources.

Environmental Impact Statements (EIS) are mandatory for several activities, including mineral handling ports and facilities, mining of all categories of minerals, civil engineering works for exploitation of water resources (dams, dikes), sanitary landfilling and final disposal of toxic or hazardous residues. A short version of the EIS, the "RIMA", is intended to inform the general public in a non-technical manner about the impacts of a proposed project. The environmental impact statement should consider all alternative locations and technologies and compare them with the possibility of not implementing the project. It should assess and identify systematically the environmental impacts of the installation and operation phases. It should also define the boundaries of the area directly or indirectly impacted by the project and take into consideration government plans and programmes proposed and planned in the area influenced by the project. The statement should include:

(a) An environmental diagnosis of the area influenced by the project with a thorough description and evaluation of the environmental resources and their interrelationships, including:

(i) physical environment: subsoil, water, air and climate with emphasis on mineral resources, topography, types of soil, hydrological system, wind conditions;
(ii) biological environment and natural eco-systems: fauna and vegetation, including indications of which species have specific environmental qualities, are rare or under threat of extinction, existing permanent preservation areas;
(iii) human environment: occupation and use of soil and water, socioeconomic activities, historical, cultural and archeological sites, and the community's dependence on natural resources.

(b) Identification of environmental impacts by magnitude, distribution and type: positive and negative, direct and indirect, immediate and medium to long term, temporary and permanent, reversible and irreversible, cumulative and non-cumulative;

(c) Definition of mitigation measures for negative impacts and assessment of their effectiveness;

(d) Follow-up and monitoring programme.

General emission standards are set in the legislation and they apply to all projects. Standards are generally defined in terms of maximum emissions over different periods of time rather than in terms of mitigating procedures to be used. There is, however, some room for individualization of conditions. IBAMA and state environmental agencies are free to impose additional conditions on specific projects.

The EIS is reviewed against the background of the type and magnitude of impacts on the environment. For instance, in the context of bauxite mining, environmental agencies might request more emphasis on reforestation plans and restoration of mined-out areas. Resolution 20 from 1986 classifies waters into three categories with subdivisions according to their destination and main use. For each class, limits of substances contents are determined; control and monitoring of water contents are carried out by state environmental agencies. State agencies should inform IBAMA if they are using or adopting complementary standards and norms. The resolution took as a model the United States Environment Protection Agency standards. Standards have not changed since 1986. Annex II shows water standards and limits adopted in resolution 20.

Resolution 10 from 1987 introduced an obligation to create an Ecological Site adjacent to any area where large-scale industrial activities will lead to the destruction of forests and other eco-systems.

Resolution 6 from 1988 established that the generation of residues must be controlled by state environmental agencies. Industries should submit an inventory of residues generated, indicating origin, contents, quantity, storage area, treatment and destination. The resolution applies to metallurgical industries with more than 100 employees, chemical industries with more than 50 employees, industries of any type with more than 500 employees, industries with water treatment systems, and industries generating dangerous residues as defined by the state environmental agency.

Resolution 5 from 1989 created a National Plan for Air Quality Control with guidelines. The monitoring of actions under the resolution is the responsibility of IBAMA, with practical action delegated to state agencies and municipalities. Resolution 3 from 1990 defined air quality standards as atmospheric pollutant concentrations that, if exceeded, may affect population health, security and well-being and impact on the environment. Standards for particulates, smoke, particles inhalation, sulphur dioxide, carbon monoxide, ozone and nitrogen dioxide were defined. Annex II shows air standards adopted in Resolution 3. Individual states and municipalities may issue their own standards if necessary.

Resolution 9 from 1990 established that mining, with the exception of mining of sands and other quartzites, should be subject to IBAMA environmental permits. There are three types of permits: Previous License, Installation License and Operating License. State environmental laws set the same requirement. Application for the Previous License is made together with submission of the EIS. The application for the Installation License is made when an Environmental Control Plan is submitted containing plans to mitigate environmental impacts identified in the EIS. The Operating License is granted on commencement of activities subject to approval of environmental control actions and plans.

Resolution 1 from 1990 established that noise caused by industrial activities is subject to environment pollution control measures. Technical norms for noise levels are set out in a document called "Noise Assessment in Inhabited Areas".

Environmental matters are dealt with mainly by environmental agencies, rarely by sectoral ministries. An Environmental Ministry was created on 15 March, 1985. This ministry also had other responsibilities such as urban development, housing policies and sanitation. In 1988 the name of the ministry was changed to Housing and Social Welfare Ministry and environmental matters were returned to the National Affairs Ministry with SEMA (later replaced by IBAMA) and CONAMA as operating agencies. In 1990, the ministry was renamed the Environment Ministry.

There are a few cases of sectoral ministries issuing directives on environmental matters. These directives do not have the force of law but are intended to set norms and standards. Examples include:

- Directive 1832 of 1978 from the Mining and Energy Ministry: Applications for authorization to divert federal water courses must be accompanied by plans showing effluent treatment systems approved either by the federal environmental agency or by state environmental agencies.

- Directive 53 of 1979 from the National Affairs Ministry: norms and standards for treatment and disposal of solid residues. Solid toxic residues as well as residues containing inflammable, corrosive, explosive or radioactive substances and other substances considered harmful should be treated or adequately contained at the site where they are produced in conformity with requests by the state environmental agency. Monitoring, operation and maintenance of solid residues treatment systems are subject to approval by the state environmental agency. Solid residues should not be dumped into rivers, lakes and ponds except where residues are used to landfill artificial lakes with the concurrence of the state environmental agency.

- Directive 124 of 1980 from the National Affairs Ministry: norms to prevent and avoid pollution of river water. Responsibility to approve water treatment and effluent disposal systems was delegated to state environmental agencies. Any potentially pollutant industry and facilities storing hazardous substances must be located at least 200 metres away from rivers. Depositories for potentially pollutant liquids derived from industrial processing must be protected in conformity with safety norms; tanks, safety walls, barriers and containment dikes must be installed.

2. State legislation

In addition to federal legislation on the environment, the states have also legislated on this subject. In most cases, however, the state legislation is a copy of the federal laws. Exceptions are found, as in the state of Sao Paulo.

2.1 São Paulo

As São Paulo is the most developed and industrialized state of the federation and because industrialization in Brazil began in São Paulo, environmental concerns gained importance in this state sooner than in the rest of the country. In June 1973, three months before the creation of SEMA (the first federal environmental agency) the State of São Paulo created CETESB, which was initially intended to control water pollution and sanitation. In 1986 the Environmental Secretariat was created of which CETESB is now part.

In 1976, a state decree established effective measures to control pollution, and standards for water, air, and soil pollution were defined. Pollution sources were listed and a system for installation and operating permits for these sources was set up. Activities subject to environmental permits include mining, industry, and incinerators and other installations for burning solid, liquid or gaseous residues.

The São Paulo classification of waters is less complex than the federal legislation. Maximum levels of substance concentrations are the same as those in CONAMA’s Resolution 20, although fewer substances are listed. Standards for suspended solids, coliform bacteria and others follow the federal legislation. Air pollution standards for the state are the same as those in the federal legislation, although not all of the federal standards are included. The state has been divided into eleven regions where air quality is controlled. Annex II shows the state standards.

Disposal onto soil of polluting residues is forbidden. For disposal purposes, however, the soil can be used as long as residues are adequately contained and specific plans, including destination and hauling procedures, are prepared.

Directive 39 issued by the São Paulo State Power and Water Department in 1986 addresses matters of environmental concern. State waters can be diverted only with the approval of the Department. Directive 40 establishes rules for diverting state waters. Norms for specific situations are listed such as for industrial effluent disposal and for mining. Together with a description of the project, applicants must submit a signed statement affirming that they are familiar with the state environmental legislation and agree to fulfill CETESB's requests.

A subject of particular interest to bauxite mining, the recovery of mined-out areas, is addressed in Directive 18 of 1989 by the State Environmental Secretary of São Paulo. According to this directive, mine operators in São Paulo should submit, together with their EIS, a plan for recovery of mined-out areas, independently of any permit requested by other agencies.

2.2 Rio de Janeiro

In Rio de Janeiro, concern over the environment goes as far back as 1967 with the issuance of Decree 779 on air pollution control within state limits. In 1969, Decree 2721 established general guidelines for disposal of industrial residues. The state environmental agency, FEEMA, was created in 1975. Regulations concerning prevention and control of environmental pollution in the state, including definitions of pollution prevention procedures, sources of pollution and guidelines for a state policy on the environment, were established in Decree-Law 134 of 1975.

Standards for maximum concentrations of potentially pollutant substances exist for water and air. The standards are similar to the federal legislation. FEEMA has issued directives applicable to the production of primary aluminium, in particular concerning atmospheric emissions. These include:

- Directives 21 and 27 of 1978: standards for sulphur dioxide and parameters for air quality control.

- Directive 515 of 1980: concentration of gas particulates in chimneys.

- Directive 517 of 1980: stack concentration of dioxide sulphur in gas.

- Directive 648 of 1985: industrial activities emission standards.

- Directive 649 of 1985: permitting process for aluminium production with pre-baked anode and maximum concentrations of fluorides.

- Directive 650 of 1985: emission standards for primary aluminium production. Maximum emissions of particulates and fluorides per ton of aluminium produced, maximum concentrations of chloride, inorganic chlorides and opacity. Since neither federal nor other state environmental legislation sets limits for atmospheric emissions of fluorides, the standard (1.25 kg/ton aluminium) adopted in Rio de Janeiro is generally used as a guideline also in other states.

The Rio de Janeiro state laws also require the submission of environmental impact statements for polluting industrial activities and set out detailed monitoring requirements. A summary of standards adopted in Rio de Janeiro is found in annex II.

2.3 Other states

Other states where the aluminium industry is represented have included chapters on environmental issues in their Constitutions similar to those in the Federal Constitution. Environmental questions are also dealt with in laws, directives and decrees similar to those at the federal level, including CONAMA’s resolutions. Only Bahia, São Paulo, Rio de Janeiro, Minas Gerais and Maranhao have state environmental laws giving policies and operating procedures. The Maranhao Environmental Code has been issued very recently but neither water nor air standards have been defined.

In the state of Minas Gerais, the state environmental agency (COPAM) has issued two directives on the Alcan effluent treatment system. Several other directives and state laws cover water, air and soil pollution and environmental control.

Pará, where MRN mines bauxite in Oriximina, Albras produces primary aluminium and Alunorte will start producing alumina in 1995, has no environmental law to complement the general guidelines on environment in the state Constitution. A draft law is being discussed in the legislature.

2.4 Monitoring and enforcement

Environmental agencies at the state level are responsible for monitoring and enforcement of regulations, including federal regulations, since federal law delegates to these agencies the responsibility for controlling the quality of the environment within state limits. Generally, states would be expected to introduce state environmental legislation, including implementing regulations, to complement the federal regulations. Where state legislation exists and environmental agencies are effectively in command of the environmental permit process, monitoring is carried out. In states such as São Paulo which has the highest concentration of industries in the country and an environmental agency exists since the beginning of the 1970s, monitoring and control are constant. Lack of staff and equipment for monitoring is, however, a serious problem at both the federal and state levels.

IV. ASSESSMENT OF ENVIRONMENTAL POLICIES AND PRACTICES

No systematic attempt has been made at either the federal or state levels to evaluate the effectiveness of environmental policies in Brazil. Although it is theoretically one of their responsibilities, Brazilian environmental agencies have not been able to assess the evolution and impact of policies over time. After the long period of non-democratic government had delayed public dialogue on the subject of the environment, the Constitution of 1988 and the holding of the United Nations Conference on Environment and Development led to enhanced environmental awareness. The surge in activity by non-governmental organizations and local communities resulting from the wider access to information introduced by democratic government has now gathered sufficient force to influence the thinking of all citizens. It has yet, however, to reach the point where the formulation and implementation of legislation is effectively influenced by public debate.

High inflation and political instability have recently been important constraints on the Government’s ability to implement policies, partly because of the resulting strain on government finances. Environmental policies may have suffered more than other policy areas from this situation. Commitments made at the Rio Conference have not been implemented owing to budgetary constraints and political uncertainty.

As a result of the relative isolation in which policies were previously formulated, it is not unusual to find that federal government agencies still take a narrow view of their responsibilities and are relatively insensitive to the need for cooperation with industry and to the need to find solutions that satisfy both environment and development concerns. The lack of experienced and qualified staff in agencies contributes to the difficulties. Agencies are understaffed and they very seldom have experts in all the fields necessary for reviews of environmental impact statements. Accordingly, the implementation of environmental policies often consists of the mechanical application of standards which are difficult or impossible to monitor or enforce effectively. Thus, while environmental impact statements were intended to serve as a basis for negotiation and cooperation between government and industries, with a view to solving problems, in practice they have become an area for conflict between governmental personnel concerned about the strict observation of limits and standards and industries interested in proceeding with their investments as quickly as possible. Environmental agencies at the state level, such as CETESB in Sao Paulo and FEEMA in Rio de Janeiro, are often more effective, mainly because they have been in existence longer and their technical staff has had possibilities to accumulate more experience and qualifications.

As regards the influence of other policy objectives on the formulation and implementation of environmental policies, it should be kept in mind that interaction between government agencies has been minimal in the past and that sectoral policies have often been formulated in isolation from broader policy objectives, including environmental objectives. Accordingly, there has been no procedure for assessing the compatibility and possible interrelationships between environmental policies, on the one hand, and trade, fiscal and monetary policies, on the other. An examination of environmental legislation fails to detect the influence of any other policy objectives. However, other policies pursued at the federal and state levels would be expected to influence the possibilities of achieving environmental policy objectives, at least indirectly.

One example is the granting of incentives to industrial investors by state governments. Incentives such as tax exemptions for certain periods and reduced prices for acquisition of land are common. These policies are likely to have contributed to the location of industries in areas which are less suitable from the point of view of environmental protection. No examples of such policies having affected the location of installations in the aluminium sector are known, however. In the beginning of the 1970s the economic policy pursued by the military government favoured "development at any cost". An example of the results of this policy is provided by Cubatao in São Paulo State, known as the most polluted city in the world. At the time, economic advantages were granted to chemical industries located in Cubatao. These industries contaminated air, water and soil to such an extent that the state environmental agency on several occasions declared a state of alert as the health of the population was endangered. Following the 1972 United Nations Conference on Environment, the situation began to change and currently Cubatao is a good example of how state governmental action can reverse environmental damage. Pollution has been reduced to 10 per cent of the levels detected in the late 1970s. At present, the federal Government does not grant any economic or fiscal advantages to polluting industries. The consequences of the development-at-any-cost model are however still being felt in Cubatao. In the late 1960s and early 1970s, the absence of pollution control procedures allowed chemical industries to dump toxic waste into Cubatao swamps, rivers and soil. Despite attempts at identifying and cleaning up sites under an agreement between the state environment agency and the new owners of the chemical industries, it is not unusual for previously unknown sites to be discovered.

Present environmental regulation is based on the administrative enforcement of limits and standards. So far, economic incentives have not been used, although this may change in the future as a consequence of commitments made at the 1992 United Nations Conference on Environment and Development.

The lack of effective monitoring and enforcement on the part of government agencies has not resulted in non-compliance with standards and legislation in all sectors. Industry associations organizing companies within a particular branch of industry have generally been successful in promoting consistent action on environmental issues. The aluminium industry association, for instance, has an environmental committee responsible for environmental issues related to the mining of bauxite and production of alumina and aluminium. The committee holds frequent meetings to analyze and discuss industry procedures so as to comply with standards and practical actions regarding rehabilitation of mined-out areas, fluoride emissions etc.

All the companies in the aluminium sector have good environmental records, and environmental conditions at operations where the performance was below the national average have improved. As seen from the review in chapter II, the companies' performance is now generally better than that required by federal and state regulations. Most of the Brazilian aluminium sector companies have also on their own initiative instituted systems for environmental auditing at regular intervals. The objective of the environmental audits is to verify whether operations conform to the industry's environmental goals and policy.

The international companies active in the Brazilian aluminium sector - Alcan, Alcoa, Billiton/Shell - have successfully introduced environmental practices used abroad. One motivation is likely to have been the desire of these companies not to spoil the good reputation they have acquired internationally. Accordingly, they apply their own internal standards, which are usually more demanding than those defined in legislation. Domestic companies have generally been successful in introducing similar technologies. Sometimes, as in the case of Valesul, they are likely to have benefitted from transfers of technology taking place in the context of joint ventures with international companies. Cia. Vale do Rio Doce, the Brazilian government owned company, which owns Aluvale and has shares in MRN, Albras, Valesul and Alumar, is internationally acknowledged for its environmental performance, in particular with regard to its rehabilitation of mined-out areas.

The relatively good environmental performance of aluminium companies in Brazil also has to be seen in the context of the way that technological change occurs in the industry. At the smelting stage, technology and equipment are provided by only a handful of suppliers worldwide. Accordingly, new installations are standardized with regard to both processing technology *per se* and environment control technology. Furthermore, design features which are at least partly intended to increase operational efficiency, for instance recycling of fluorides back to the electrolytic cells, also yield environmental benefits. Only with difficulty could productivity enhancing features be detached from those primarily intended to improve environmental performance. As smelters modernize, or as investments are made in new plants, companies therefore automatically benefit from advances made elsewhere, since introducing modifications to the standard design in order to save on environmental control would result only in very modest savings on investment cost. It is therefore not surprising that the newer aluminium smelters in Brazil exhibit an environmental performance which is fully in line with that of modern smelters elsewhere in the world. Furthermore, it is significant that recent closures of parts of some smelters, undertaken in response to low international demand, have mainly concerned older units which, in addition to less positive environmental characteristics, have lower operating efficiency.

At the earlier processing stages of bauxite mining and alumina refining, the provision of technology as a "package" incorporating both environmental control features and processing technology is of less importance. Solutions to the main environmental problems, that is, the rehabilitation of mined-out areas in the case of bauxite mining and the disposal of red mud in the case of alumina production, have to be found on the basis of the particular characteristics of the operations and do not lend themselves as easily to standardization. It is significant that, in both these areas, the Brazilian industry has achieved good results in recent years, although it appears that the more impressive progress has been made in the parts of the industry where international companies have a strong interest, such as MRN in bauxite mining and Alumar in alumina refining.

Clearly, resources available for good environmental management depend on the general economic situation of the industry. The cost of actions to reduce negative environmental impacts in modern aluminium smelters has been estimated to represent about 10 per cent of total investment costs. This figure includes monitoring, gas washing, treatment of effluents and electrostatic precipitation. High inflation and recession in recent years combined with low international aluminium prices have led to reduced investment. In order to reduce operating costs, companies are increasingly relying on sub-contracting of certain activities. It is likely that sub-contractors' staff are less well trained in proper environmental protection procedures than the companies' own staff. It is, however, difficult to say whether this practice, which is quite recent, affects environmental management negatively.

Notes

1. The following terminology is used throughout the present report:

Aluminium sector: comprises all stages of production, including mining of bauxite, production of alumina, production of ingots and semifabricated products, processing and recycling of aluminium.

Aluminium industry: comprises the six producers of primary aluminium and about 300 transforming and recycling companies. Some of the primary producers are integrated upstream with bauxite mining and alumina production, and also downstream with the processing of ingots into sheets, foils, extruded products, cables, tubes and utensils.

2. Throughout the text, "tons" refer to metric tons.

ANNEX 1

STATISTICAL TABLES

Table 1 Production of washed and dried bauxite by state, thousand tons, 1978-1992

Year	Pará	Minas Gerais	Other states	Total
1978	-	1355	50	1405
1979	413	1171	58	1642
1980	2729	1355	68	4152
1981	3288	1368	170	4826
1982	2674	1413	100	4187
1983	3387	1741	111	5239
1984	4606	1665	162	6433
1985	3867	1809	170	5846
1986	4549	1752	145	6446
1987	4547	1878	142	6567
1988	5736	1762	230	7728
1989	5947	1756	191	7894
1990	7724	1831	321	9876
1991	8263	1941	210	10414
1992	7302	1925	239	9466

Sources: Instituto Brasileiro de Geografia e Estatistica
Suma Mineracao (review)
Associacao Brasileira do Aluminio
Departamento Nacional de Prod. Mineral

Table 2 Brazilian consumption, imports and exports of bauxite, thousand tons, 1979-1992

Year	Production	Imports	Exports	Apparent consumption	Metallurgical use
1979	1642	16	515	1143	1063
1980	4152	13	2679	1486	1197
1981	4826	15	3329	1512	1228
1982	4187	9	2991	1205	1306
1983	5239	5	3360	1884	1489
1984	6433	11	3599	2845	1689
1985	5846	8	3308	2546	2626
1986	6446	1	3052	3395	2868
1987	6567	3	2813	3757	3343
1988	7728	2	4619	3111	3176
1989	7894	129	4570	3453	3353
1990	9876	285	5378	4783	3809
1991	10414	426	5737	5103	3966
1992	9466	350	4284	5532	4216

Sources: Suma Mineracao (1979/1982) (review)
Associacao Brasileira do Aluminio
Departamento Nacional de Prod. Mineral

Table 3 Production of alumina by companies; consumption, imports and exports, thousand tons, 1980-1992

Producers	Location	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Alcan	Saramenha, Minas Gerais	124	122	136	148	147	149	150	152	146	145	144	135	150
Alcoa	Poços de Caldas, Minas Gerais	217	220	221	233	256	214	221	217	223	256	240	254	180
	Sao Luis, Maranhao(a)	-	-	-	-	135	277	369	424	434	527	567	577	539
Billiton	Sao Luis, Maranhao (a)	-	-	-	-	90	184	200	250	289	363	377	382	441
CBA	Aluminio, Sao Paulo	166	177	195	248	254	272	319	353	325	334	327	392	523
Total production		507	519	552	629	882	1096	1259	1396	1417	1625	1655	1740	1833
Imports		66	27	87	203	188	133	285	393	373	373	423	677	698
Exports		-	-	-	-	41	88	77	87	95	165	156	107	100
Apparent Consumption		573	546	639	832	1029	1141	1467	1702	1695	1833	1922	2310	2431
Real consumption		..	..	..	836	964	1134	1545	1735	1763	1806	1888	2301	2383
metallurgical uses		..	..	..	795	903	1082	1481	1651	1690	1739	1825	2264	2302
other uses			..	..	..	41	61	52	64	84	73	67	63	3780

(a) Consortium Alumar

Source: Associacao Brasileira do Alumino

Table 4 Installed primary aluminium capacity by plant, end of year, 1980-1992, thousand tons

Producers	**Location**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Albras	Belem, Pará	-	-	-	-	-	80	160	160	160	160	300	334	340
Alcan	Ouro Preto, Minas Gerais	60	60	60	60	60	60	60	60	60	60	60	55	52
	Aratu, Bahia	28	28	28	58	58	58	58	58	58	58	58	58	58
Alcoa	Poços de Caldas, Minas Gerais	90	90	90	90	90	90	90	90	90	90	90	90	90
	Sao Luis , Maranhao (a)	-	-	-	-	60	66	174	174	174	174	178	186	186
Aluvale	Santa Cruz, Rio de Janeiro(b)	-	-	-	-	-	-	-	47	47	47	51	51	55
Billiton	Sao Luis, Maranhao (a)	-	-	-	-	40	44	71	71	71	71	154	165	165
	Santa Cruz, Rio de Janeiro (b)	-	-	-	-	-	-	-	39	39	39	42	42	45
CBA	Aluminio , Sao Paulo	83	83	113	130	130	170	170	170	170	170	196	215	220
Valesul	Santa Cruz, Rio de Janeiro (c)	-	-	86	86	86	86	86	-	-	-	-	-	-
Total		261	261	377	424	524	654	869	869	869	869	1129	1196	1211

(a) Consortium ALUMAR
(b) Consortium VALESUL
(c) From 1987, capacity at valesul is shown separately for Aluvale and Billiton.

Source: Associacao Brasileira do Aluminio

Table 5 Primary aluminium production by company, thousand tons, 1960-1992

Producers	**1960**	**1965**	**1970**	**1975**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Albras	-	-	-	-	-	-	-	-	-	8.7	98.8	166.0	170.4	169.2	194.0	288.0	335.2
Alcan	7.4	15.4	25.1	55.6	87.9	87.4	88.5	107.1	119.6	120.1	120.2	112.7	117.0	115.5	115.9	113.7	102.2
Alcoa	-	-	7.9	29.9	89.3	88.5	89.7	90.2	105.9	152.5	227.2	242.7	256.4	269.6	266.1	275.9	278.3
Aluvale	-	-	-	-	-	-	-	-	-	-	-	21.0	50.7	50.8	51.4	51.0	50.6
Billiton	-	-	-	-	-	-	-	-	10.4	41.6	61.4	79.1	108.9	113.7	128.7	206.7	209.6
CBA	7.6	14.2	23.1	35.8	83.4	80.5	96.6	120.3	127.9	135.7	158.8	169.0	170.1	169.1	174.5	204.3	217.4
Valesul (a)	-	-	-	-	-	-	24.2	83.1	91.2	90.8	90.9	53.0					
Total	15.0	29.6	56.1	121.3	260.6	256.4	299.0	400.7	455.0	549.4	757.3	843.5	873.5	887.9	930.6	1139.6	1193.3

(a) Valesul's production has been partly allocated to Aluvale and Billiton in 1987, and wholly thereafter.

Source: Associacao Brasileira do Alumino

Table 6 Production, recycling, imports, exports and consumption of aluminium, thousand tons, 1980-1992

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Primary production	260.6	256.4	299.0	400.7	455.0	549.4	757.3	843.5	873.5	887.9	930.6	1139.6	1193.3
Recycling of scrap	49.6	41.8	42.9	45.0	47.2	52.7	60.6	65.9	66.8	66.6	65.0	66.4	66.9
- domestic recycling	38.5	36.5	39.2	40.9	47.0	52.0	57.5	61.0	66.0	64.0	60.0	62.0	66.0
- imported scrap	11.1	5.3	3.7	4.1	0.2	0.7	3.1	4.9	0.8	2.6	5.0	4.4	0.9
Imports	69.0	36.8	14.7	5.8	9.6	6.4	3.6	8.6	7.4	11.8	16.1	19.6	19.7
- primary aluminium and alloys	46.7	28.3	10.8	3.0	4.6	2.6	1.4	2.3	0.1	2.5	2.6	2.2	1.6
- semis and fabricated products(a)	22.3	8.5	3.9	2.8	5.0	3.8	2.2	6.3	7.3	9.3	13.5	17.4	18.1
Exports	11.5	20.8	18.4	169.6	205.3	215.1	357.0	456.9	556.5	524.8	639.4	828.7	870.6
- primary aluminium and alloys	-	2.2	6.7	116.3	148.0	179.1	323.5	430.9	514.9	470.3	592.0	787.6	816.5
- semis and fabricated products(a)	11.5	18.6	11.7	53.3	57.3	36.0	33.5	26.0	41.6	54.5	47.4	41.1	54.1
Apparent consumption	367.7	314.2	338.2	281.9	306.5	393.4	464.5	461.1	391.2	441.5	372.3	396.9	409.3
Domestic consumption(b)	356.8	293.6	317.0	289.8	286.4	355.8	428.5	411.0	382.6	392.7	317.5	338.2	314.5
Population (million)	118.6	120.9	123.3	125.6	128.1	130.5	133.1	135.6	138.3	140.9	143.7	146.4	149.2
Per capita consumption, kg	3.0	2.4	2.6	2.3	2.2	2.7	3.2	3.0	2.8	2.8	2.2	2.3	2.1

(a) aluminium content
(b) including inventory fluctations, processing losses and captive use of metal for slide bars.

Sources: Associacao Brasileira do Aluminio, Banco do Brasil (figures for foreign trade)

Table 7 Installed production capacity for fabricated aluminium products, by product, thousand tons, 1980-1991

Product	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Sheet	146.0	149.0	156.0	156.0	153.0	153.0	194.0	200.0	190.0	191.5	240.8	260.5
Foil	27.0	32.5	34.5	35.5	36.5	40.0	40.0	40.0	40.0	40.0	39.0	40.6
Cables & rods	96.0	98.0	117.0	123.0	123.0	124.0	123.0	132.0	133.0	133.0	122.0	122.0
Extruded products	104.4	108.7	113.0	115.0	115.5	113.5	124.0	131.0	139.5	144.0	143.8	138.1
Total	373.4	388.2	420.5	429.5	428.0	430.5	481.0	503.0	502.5	508.5	545.6	561.2

Source: Associacao Brasileira do Aluminio

Table 8 Uses of fabricated aluminium products, thousand tons, 1986-1992

Products	**1986**		**1987**		**1988**		**1989**		**1990**		**1991**		**1992**	
	Prod.	**Cons.**	**Prod.**	**Cons.**	**Prod.**	**Cons.**	**Prod.**	**Cons.**	**Prod**	**Cons.**	**Prod.**	**Cons.**	**Prod.**	**Cons.**
Sheets and products	113.5	105.4	105.4	103.2	92.7	83.7	107.0	101.8	90.6	91.5	95.7	103.9	86.7	88.2
Sheets	75.4	69.1	70.9	70.1	65.7	58.0	75.8	73.4	60.9	63.2	64.0	72.8	61.8	66.4
Cooking utensils	30.4	28.9	27.1	26.0	20.4	19.4	24.3	21.9	22.6	21.7	25.6	24.9	18.9	16.3
Collapsible tubes	7.7	7.4	7.4	7.1	6.6	6.3	6.9	6.5	7.1	6.6	6.1	6.2	6.0	5.5
Foil	31.0	28.6	31.2	30.5	28.9	26.2	34.6	33.5	26.4	28.1	31.3	31.1	30.1	27.2
Extruded products	106.3	100.5	102.4	99.2	93.3	89.9	113.8	109.4	73.7	75.5	76.7	78.6	72.3	71.7
Cables and rods	86.9	74.3	78.2	71.6	70.2	63.9	62.9	31.0	45.3	21.3	43.5	20.8	48.1	24.4
Castings	83.3	79.4	77.1	72.2	85.9	77.6	88.7	78.0	75.8	70.0	68.9	65.6	75.0	64.6
Powder and paste	17.0	15.6	11.0	9.9	16.1	14.4	13.3	12.2	11.1	11.2	12.5	12.6	11.4	11.4
Destructive uses	23.5	23.5	23.2	23.2	25.7	25.7	25.1	25.1	18.7	18.7	24.0	24.0	25.2	25.2
Other	1.4	1.2	1.2	1.2	1.3	1.2	1.5	1.7	0.9	1.2	1.0	1.6	1.7	1.8
Total	462.9	428.5	429.7	411.0	414.1	382.6	446.9	392.7	342.5	317.5	353.6	338.2	350.5	314.5

Source: Associacao Brasileira do Aluminio

Prod.: Production
Cons.: Consumption

Table 9 Consumption of fabricated aluminium products by sector, thousand tons, 1986 and 1991

Sector	**Civil Construction**		**Transport**		**Electrical**		**Consumer Goods**		**Packaging**		**Mechanical**		**Other**		**Total**	
Product	**1986**	**1991**	**1986**	**1991**	**1986**	**1991**	**1986**	**1991**	**1986**	**1991**	**1986**	**1991**	**1986**	**1991**	**1986**	**1991**
Sheets	24.6	24.7	13.2	15.8	4.1	1.7	40.8	31.1	13.4	23.5	3.9	2.7	5.4	4.4	105.4	103.9
Foil	0.0	0.0	1.6	1.3	1.9	1.9	4.4	3.0	20.1	21.3	0.1	2.9	0.5	0.7	28.6	31.1
Extruded products	58.4	40.7	10.7	18.3	4.7	3.7	13.7	8.7	0.0	0.0	8.7	4.1	4.3	3.1	100.5	78.6
Cables and rods	0.0	0.0	0.0	0.0	73.5	20.8	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	74.3	20.8
Castings	1.6	0.4	62.6	57.3	1.6	0.7	6.9	2.6	0.0	0.0	5.6	4.1	1.1	0.5	79.4	65.6
Powder and paste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.6	12.6	15.6	12.6
Destructive uses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5	24.0	23.5	24.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.6	1.2	1.6
Total	84.6	65.8	88.1	92.7	85.8	28.8	65.8	45.4	33.5	44.8	18.3	13.8	52.4	46.9	428.5	338.2
Sector's share (%)	19.7	19.5	20.6	27.4	20.0	8.5	15.4	13.4	7.8	13.2	4.3	4.1	12.2	13.9	100.0	100.0

Source: Associacao Brasileira do Aluminio

Table 10 Exports of the Brazilian aluminium sector, 1985-1992

Product	**Unit**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Bauxite, metallurgical use	Th tons	3308	3052	2813	4619	4570	5378	5737	4284
	US $ M	94	77	71	125	127	145	154	106
	US $/ton	28.4	25.2	25.2	27.1	27.8	27.0	26.8	24.7
Alumina	Th tons	88	77	87	95	165	156	107	100
	US $ M	24	21	24	27	62	47	28	24
	US $/ton	272.7	272.7	275.9	284.2	375.8	301.3	261.7	240.0
Primary aluminium	Th tons	159	297	397	469	419	545	757	782
	US $ M	167	350	587	1072	841	875	958	968
	US $/ton	1050.3	1178.5	1478.6	2285.7	2007.2	1605.5	1265.5	1237.9
Aluminium alloys	Th tons	20	27	34	46	51	47	30	35
	US $ M	25	35	48	109	114	82	46	47
	US $/ton	1250.0	1296.3	1411.8	2369.6	2235.3	1744.7	1533.3	1342.9
Fabricated products[a]									
Bars and rods	Th tons	14.3	9.6	4.6	4.7	16.5	19.0	17.6	18.4
Sheets	Th tons	3.1	5.3	3.2	11.4	4.6	7.7	1.9	4.3
Foil	Th tons	2.7	2.5	2.2	4.1	2.9	2.6	4.5	7.8
Pipes	Th tons	0.9	0.2	0.2	0.2	0.2	0.3	0.2	0.4
Structures	Th tons	1.4	1.7	2.7	2.5	0.7	0.2	0.2	0.1
Packaging	Th tons	0.3	0.3	0.3	0.4	0.3	0.5	0.6	0.6
Cables	Th tons	4.7	5.9	4.7	6.0	19.2	7.7	8.0	8.6
Castings	Th tons	4.3	4.0	4.7	6.2	7.4	7.5	5.9	10.4
Other	Th tons	4.3	4.5	3.4	6.5	3.2	1.5	2.1	3.5
Total fabricated products	Th tons	36	34	26	42	55	47	41	54
	US $ M	100	108	96	145	177	142	132	180
	US $/ton	2777.8	3176.5	3692.3	3452.4	3218.2	3021.3	3219.5	3327.2
Bauxite and alumina	US $ M	118	98	95	152	189	192	182	130
Primary metal and alloys	US $ M	192	385	635	1181	955	957	1004	1015
Fabricated products	US $ M	100	108	96	145	177	142	132	180
Total, aluminium sector	US $ M	410	591	826	1478	1321	1291	1318	1325
Bauxite, alumina exports as share of mining exports	%	3.3	3.9	3.4	4.9	5.5	5.5	4.0	2.3
Bauxite, alumina exports as share of metallic mining exports	%	6.5	5.6	5,5	7.3	7.7	7.2	5.2	3.0
Primary metal, alloys, fabricated products as share of metal exports	%	10.1	17.6	23.6	22.4	17.9	20.4	18.8	19.0
Aluminium sector's share of total exports	%	1.6	2.6	3.1	4.4	3.8	4.1	4.2	3.7

a/ Tonnages refer to aluminium content

Sources: Departamento Nacional Prod. Mineral (mining products)
Associacao Brasileira do Aluminio (aluminium industry)
Banco do Brasil (figures in US $)

Table 11 The Brazilian aluminium sector's influence on the trade balance, million US $, 1985-1992

	1985	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Exports								
Bauxite/alumina	118	98	95	152	189	192	182	130
Aluminium industry	292	493	731	1326	1132	1099	1136	1195
Total for sector	410	591	826	1478	1321	1291	1318	1325
Total Brazil	25639	22349	26225	33787	34383	31414	31625	36148
Aluminium sector, %	1.6	2.6	3. 1	4.4	3.8	4.1	4.2	3.7
Imports								
Bauxite/alumina	19	34	59	62	74	104	131	121
Aluminium industry	26	20	39	41	64	97	88	84
Total for sector	45	54	98	103	138	201	219	205
Total Brazil	13189	12866	15052	14696	18281	20661	21041	20578
Aluminium sector, %	0.3	0.4	0.7	0.7	0.8	1.0	1.0	1.0
Trade balance surplus								
Bauxite/alumina	99	64	36	90	115	88	51	9
Aluminium industry	266	473	692	1285	1068	1002	1048	1111
Total for sector	365	537	728	1375	1183	1090	1099	1120
Total Brazil	12450	9483	11173	19091	16102	10753	10584	15570
Aluminium sector, %	2.9	5.7	6.5	7.2	7.3	10.1	10.4	7.2

Sources: Associacao Brasileira do Aluminio (aluminium industry)
Deparlamento Nacional de Prod. Mineral (bauxite and alumina)
Coordenacao Tecnica de Intercambio Comercial do Banco do Brasil (foreign trade figures)

Table 12 Financial and profitability figures,
thousand dollars, 1992

Balance sheets	MRN	Albrás	Billiton	Alcoa	CBA	Alcan	Valesul
Assets	443,691	1,347,529	801,895	1,216,622	751,140	507,915	163,142
Current assets	36,997	98,287	76,228	176,013	205,491	99,238	50,000
Cash & trade receivables	8,214	31,171	18,004	71,405	30,091	46,075	46,044
Inventories	17,793	57,268	50,833	43,866	54,194	47,922	2,735
Others	10,990	9,848	7,391	60,742	121,206	5,242	1,221
Long-term assets	17,192	18,853	38,406	41,001	13,227	1,124	4,751
Permanent assets	389,502	1,230,389	687,261	999,608	532,422	407,553	108,392
Liabilities	443,691	1,347,529	801,895	1,216,622	751,140	507,915	163,142
Current liabilities	62,938	158,264	98,088	234,876	49,153	293,301	12,400
Loans & financing	44,163	103,245	38,377	114,765	1,451	193,299	8,372
Payables & taxes	14,590	54,295	59,711	92,777	33,935	90,364	3,337
Others	4,185	724	0	27,334	13,767	9,637	691
Non-current liabilities	5,367	1,025,173	30,000	305,462	1,994	125,084	4,653
Loans & financing	5,367	1,008,276	30,000	239,995	1,994	122,435	4,142
Others	0	16,897	0	65,467	0	2,649	511
Stockholders' equity	375,386	164,092	673,807	676,284	699,992	89,531	146,090

Statement of income	MRN	Albrás	Billiton	Alcoa	CBA	Alcan	Valesul
Sales income	174,537	410,662	302,688	634,243	618,577	410,014	69,513
Sales & other taxes	(16,210)	(21,183)	(25,390)	(77,166)	(69,581)	(68,635)	(10,719)
Net operating sales	158,327	389,479	277,298	557,077	548,996	341,379	58,794
Cost of goods sold	(109,652)	(342,674)	(227,058)	(453,412)	(285,450)	(336,546)	(55,309)
Depreciation(a)	0	(52,116)	(40,127)	0	(9,916)	0	(6,278)
Gross profit/loss	48,675	(5,311)	10,113	103,665	253,630	4,833	(2,793)
Admin. & other expenses(b)	(5,062)	(21,338)	(10,454)	(114,338)	(62,963)	(39,407)	(5,907)
Net financial income/expenses	20,771	17,934	18,464	(42,095)	367,479	2,140	5,290
Operating income	64,384	(8,715)	18,123	(52,768)	558,146	(32,434)	(3,411)
Net non-operating expenses	(2,385)	(2,316)	11,711	8,572	14,141	(4,108)	(4,939)
Currency flucttutaions	(18,832)	0	0	28,110	(466,273)	0	0
Income before tax	43,167	(11,031)	29,834	(16,086)	106,014	(36,542)	(8,349)
Income tax	(6,027)	0	4,467	20,291	(40,695)	0	0
Net income	37,140	(11,031)	34,301	4,206	65,320	(36,542)	(8,349)

Indexes	MRN	Albrás	Billiton	Alcoa	CBA	Alcan	Valesul
Liquidity	0.59	0.62	0.78	0.75	4.18	0.34	4.03
Dry liquidity	0.31	0.26	0.26	0.56	3.08	0.17	3.81
Financing/total liabilities	0.73	0.94	0.53	0.66	0.07	0.85	0.73
Debt/equity	0.18	7.21	0.19	0.80	0.07	4.67	0.12
Gross profit/net sales	30.7%	-1.4%	3.6%	18.6%	46.2%	1.4%	-4.8%
Operating income/net sales	40.7%	-2.2%	6.5%	-9.5%	101.7%	-9.5%	-5.8%
Return on assets	8.4%	-0.8%	4.3%	0.3%	8.7%	-7.2%	-5.1%
Return on equity	9.9%	-6.7%	5.1%	0.6%	9.3%	-40.8%	-5.7%

(a) When not included in "cost of goods sold"
(b) Including amortization of deferred charges

Sources: Company financial statements

ANNEX II

ENVIRONMENT STANDARDS AT FEDERAL AND STATE LEVEL

1. Federal standards

1.1 Water standards (CONAMA resolution 20)

The categories and classes of uses are as follows:

RIVER WATERS

I -	Special Class: destined for domestic consumption without previous treatment or after disinfection.
II -	Class 1: destined for domestic consumption after simple treatment, for protection of water ecosystems, for swimming, diving and water skiing, for irrigation of vegetables to be eaten raw and of fruits growing at soil level and eaten with peel, and for water species for human consumption.
III -	Class 2: destined for domestic consumption after regular treatment or for other uses included in Class 1.
IV -	Class 3: destined for domestic consumption after regular treatment, irrigation of arboreous species and cereals, for the watering of animals.
V -	Class 4: destined for navigation, harmony of landscape and less demanding uses.

SALINE WATERS

VI -	Class 5: destined for primary recreation activities, for protection of water ecosystems and for intensive cultivation of species for human consumption.
VII -	Class 6: destined for commercial navigation, the harmony of the landscape and secondary recreation activities.

BRACKISH WATERS

VIII-	Class 7: destined for primary recreation activities, for protection of water ecosystems, for cultivation of water species for human consumption.
IX -	Class 8: destined for commercial navigation, the harmony of the landscape and secondary recreation activities.

Maximum concentrations of potentially polluting substances are shown in table A. Other standards are as follows:

- Floating material, non-natural foam	Virtually absent
- Oil and grease	Virtually absent
- Substances with taste and smell	Virtually absent
- Artificial dyes	Virtually absent
- Coliforms	200 per 100 ml of water - Class 1 1000 per 100 ml of water - Class 2 4000 per 100 ml of water - Class 3
- Biological Oxygen Demand (5 days at 20ºC)	max.3 mg/l - Class 1 max.5 mg/l - Class 2 max.10 mg/l - Class 3
- Oxygen dissolved	not less than 6 mg/l- Class 1 5 mg/l - Class 2 4 mg/l - Class 3
- Turbidity (NTU - Nefelometric Turbidity Unit)	less than 40 NTU - Class 1 less than 100 NTU - Classes 2 and 3
- PH	6.0 to 9.0

Table A Maximum concentrations of substances in river waters (mg/l)

Substances	**Class 1 and 2**	**Class 3**
Aluminium	0.1	0.1
Ammonia	0.02	-
Arsenic	0.05	0.05
Barium	1.0	1.0
Beryllium	0.1	0.1
Boron	0.75	0.75
Benzene	0.01	0.01
Benzopyrene	0.00001	0.00001
Cadmium	0.001	0.01
Chloride	250	250
Chlorine residual	0.01	-
Cobalt	0.2	0.2
Copper	0.02	0.5
Chromium 3	0.5	0.5
Chromium 6	0.05	0.05
Cyanide	0.01	0.02
Dichloretene 1.1	0.00003	0.00003
Dichloretene 1.2	0.01	0.01

Table A (continued)

Fluorine	1.4	1.4
Iron	0.3	5.0
Lead	0.03	0.05
Lithium	2.5	2.5
Manganese	0.1	0.5
Mercury	0.0002	0.00002
Nickel	0.025	0.025
Nitrate	10.0	10.0
Nitrite	1.0	1.0
Nitrogen	-	1.0
Phenol	0.001	0.3
Pentachlorophenol	0.01	0.01
Selenium	0.01	0.01
Silver	0.01	-
Solids dissolved	500	500
Sulfates	250	250
Sulfates (as H_2S not dissociated)	0.003	0.3
Thallium	-	-
Tetrachlorethane	0.01	0.01
Tin	2.0	2.0
Trichloroethane	0.03	0.03
Tetrachloride of carbon	0.003	0.004
2,4,6 trichlorophenol	0.01	0.01
Uranium, total	0.02	0.02
Vanadium	0.01	0.01
Zinc	0.18	5.0
Aldrin	0.01	0.03
Chlordane (*)	0.04	0.3
DDT (*)	0.002	1.0
Dieldrin (*)	0.005	0.03
Endrin (*)	0.004	0.2
Endosulfan (*)	0.056	150
Heptachlorine epoxid (*)	0.01	0.1
Lindane (*)	0.02	3.0
Methoxychlor (*)	0.03	30.0
Dodecachlorine (*)	0.001	0.001
Polichlorinated Biphenyl (*)	0.001	0.01
Toxaphene (*)	0.01	5.0
2,4 D (*)	4.0	20.0
2,4,5 - TP (*)	10.0	10.0
2,4,5 - T (*)	2.0	2.0

* mg x 10^{-3}

1.2 Air standards (CONAMA RESOLUTION 3)

Air pollutants are defined as any type of material or energy the intensity, quantity, concentration, duration or characteristics of which are not in conformity with standards and which are capable of rendering the air:

I unwholesome, damaging or harmful to health;
II adverse to the well-being of the population;
III harmful to materials, fauna and vegetation;
IV harmful to the safety, use of property and the regular activities of communities.

For each air standard, two patterns of air quality are established:

- primary pattern: concentrations that if exceeded may affect the health of the population;

- secondary pattern: concentrations below which minimum adverse effects on the well-being of the population, the fauna, the vegetation, materials and the environment are anticipated.

Air standards are as follows:

I - Particulates in suspension

a) primary pattern
1. Average geometric yearly concentration of 80 micrograms per cubic feet of air.
2. 24-hour average concentration of 240 micrograms per cubic feet of air not to be exceeded more than once a year.

b) secondary pattern
1. Average geometric yearly concentration of 60 micrograms per cubic feet of air.
2. 24-hour average concentration of 150 micrograms per cubic feet of air not to be exceeded more than once a year.

II - Smoke

a) primary pattern
1. Average arithmetic yearly concentration of 60 micrograms per cubic feet of air.
2. The same as for secondary pattern of particulates.

b) secondary pattern
1. Average arithmetic yearly concentration of 40 micrograms per cubic feet of air.
2. 24-hour average concentration of 100 micrograms per cubic feet of air not to be exceeded more than once a year.

III - Particles that may be inhaled

a) primary and secondary pattern
1. Average arithmetic yearly concentration of 50 micrograms per cubic feet of air.
2. 24-hour average concentration of 150 micrograms per cubic feet of air not to be exceeded more than once a year.

IV - Sulphur Dioxide

a) primary pattern
1. Average arithmetic concentration of 80 micrograms per cubic feet of air.
2. 24-hour average concentration of 365 micrograms per cubic feet of air not to be exceeded more than once a year.

b) secondary pattern

1. Average arithmetic concentration of 40 micrograms per cubic feet of air.
2. 24-hour average concentration of 100 micrograms per cubic feet of air not to be exceeded more than once a year.

V - Carbon Monoxide

a) primary and secondary pattern
1. 8-hour average concentration of 10.000 micrograms per cubic feet of air (9 ppm, parts per million) not to be exceeded more than once a year.
2. 1-hour average concentration of 40.000 micrograms per cubic feet of air (35 ppm, parts per million) not to be exceeded more than once a year.

VI - Ozone

a) primary and secondary pattern
1. 1-hour average concentration of 160 micrograms per cubic feet of air not to be exceeded more than once a year.

VII - Nitrogen Dioxide

a) primary pattern
1. Average arithmetic yearly concentration of 100 micrograms per cubic feet of air.
2. 1-hour average concentration of 320 micrograms per cubic feet of air.

b) secondary pattern
1. Average arithmetic yearly concentration of 100 micrograms pr cubic feet of air.
2. 1-hour average concentration of 190 micrograms per cubic feet of air.

2. State standards

2.1 Sao Paulo water standards

Tables B, C and D show standards for river waters class 2,3 and 4 (same definitions as in the federal legislation).

Table B Maximum concentration of substances, mg/l

Substance	**Concentration**
Ammonia	0.5
Arsenic	0.1
Barium	5.0
Cadmium	0.01
Lead	0.1
Cyanide	0.2
Copper	1.0
Chromium	0.05
Fluorides	1.4
Mercury	0.002
Nitrate	10.0
Selenium	0.02
Tin	2.0
Zinc	5.0

Table C Maximum values for other parameters, mg/l unless otherwise indicated

Parameters	Class 2	Class 3	Class 4
Phenol	-	-	1.0
Dissolved Oxygen [a]	5.0	4.0	0.5
Coliforms	1000	4000	-
Biological Oxygen Demand[b]	5.0	10.0	-

[a] Minimum value
[b] 5 days at 20 degrees C.

Table D Maximum concentrations for certain effluents, mg/l

Effluent	Concentration
Barium	5.0
Boron	5.0
Cyanide	0.2
Phenol	0.5
Fluorides	10.0
Mercury	0.01
Nickel	2.0
Silver	0.02
Selenium	0.002
Zinc	5.0

2.2 Air, vegetation, water, effluents and atmospheric emission standards in Rio de Janeiro

Table E Air standards for fluorides

3.7 mg/m^3 12 consecutive hours
2.9 mg/m3 24 consecutive hours
1.7 mg/m3 7 consecutive days
0.84 mg/m3 30 days average

Table F Standards for fluoride concentrations in vegetation

40 ppm - 12 months average
60 ppm/month in more than 2 months
80 ppm more than once in 2 months

Table G Standards for river waters class 2,3 and 4 (same definitions as in the federal legislation), maximum concentration of substances, mg/l

Substance	Concentration
Arsenic, total	0.5
Lead, total	0.5
Cyanide	0.5
Copper, total	1.0
Chromium 6	0.5
Chromium 3	2.0
Fluorides	10.0
Mercury	0.01
Silver	0.1

Table H Standards for effluents, mg/l

Substance	Concentration
Cadmium	0.1
Lead, total	0.5
Cyanide	0.2
Copper, total	0.5
Chromium 6	0.5
Chromium 3	1.0
Nickel, total	1.0
Silver, total	0.1

Table I Standards for atmospheric emissions of fluorides and particulates from primary aluminium production, kg/ton aluminium

Parameter	Maximum
Fluorides (production <100,000 tons/year)	Yearly average = 1.25
Fluorides (production <100,000 tons/year)	Monthly average = 1.75
Fluorides (production >100,000 tons/year)	Yearly average = 1.00
Fluorides (production >100,000 tons/year)	Monthly average = 1.50
Particulates (production <100,000 tons/year)	Yearly average = 5.00
Particulates (production <100,000 tons/year)	Monthly average = 6.50
Particulates (production >100,000 tons/year)	Monthly average = 6.00
Particulates (production>100,000 tons/year)	Yearly average = 4.50