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**ENVIRONMENTAL MANAGEMENT
IN THE ALUMINIUM INDUSTRY OF
BRAZIL, GUYANA, JAMAICA, SURINAME AND VENEZUELA**

(NC/RLA/92/057)

Final Report

Prepared under UNDP - financed TSS-1 facility

V.95-51954



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1. EXECUTIVE SUMMARY

1.1 Introduction

The bauxite, alumina and aluminium industries are very important sectors in several countries of the Latin American and Caribbean Region, and vice versa the development of the sector in this countries has a major influence on the status of the aluminium industry and trade world wide. The stage of development of the sector varies from country to country, depending mainly on the availability of good quality bauxite, cheap hydro-energy resources and market potential. The international role of the major producing countries of the region is well illustrated on the following Figures 1.1 - 1.6 reflecting production data for 1991. (Source: UNCTAD Commodity Yearbook,1993).

Figure 1.1 Bauxite Production by Region

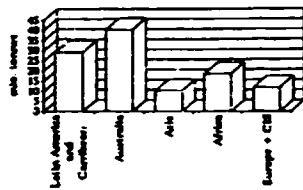


Figure 1.2 Alumina Production by Region

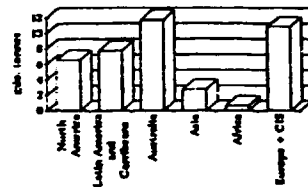


Figure 1.3 Production of Primary Aluminium by Region

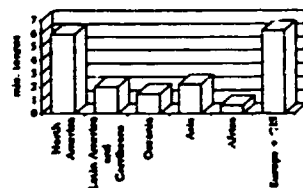


Figure 1.4 Bauxite Production by Countries

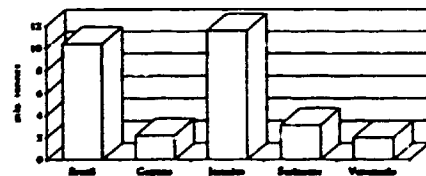


Figure 1.5 Alumina Production by Countries

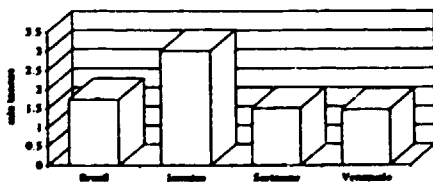
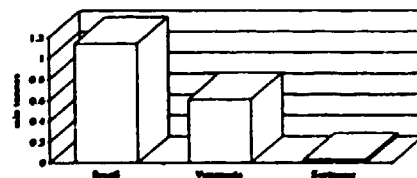


Figure 1.6 Primary Aluminium Production by Countries





The dynamic growth of the aluminium industry could result in serious environmental problems. Introduction of cleaner technologies and energy saving measures would effectively improve the ecological conditions. In light of the above, in 1993 UNIDO was appointed by UNDP to undertake a study under the TSSI scheme with the aim to address the problem of ecologically sustainable development of the aluminium sector in Brazil, Guyana, Jamaica, Suriname and Venezuela.

From 29 August to 10 October 1993 a team of experts (Mr. T Gróf, team leader, UNIDO; Mr. C. E. Chanduvi Suarez, UNIDO; Mr. J.D. Hamilton, international consultant on primary aluminium production; Mr. P. Siklósi, international consultant on alumina production and Mr. R.O. Williams, UNIDO) has undertaken a fact finding mission to the selected five countries to assess the technical and environmental situation of the aluminium industry and formulate recommendations for appropriate technical, legislative and social measures to be taken.

This report is the result of the work of the Team. It takes into consideration the observations and recommendations of those local authorities and companies, who deemed necessary to comment on the findings incorporated in the draft of the report.

The authors of the report take this opportunity to convey their appreciation to the governments and officials of Brazil, Jamaica, Guyana, Suriname and Venezuela, the UNDP and UNIDO offices in the respective countries as well as to the institutions and companies visited and experts met for their support and assistance in the data collection work.

It is sincerely hoped that the findings of the report will be used by the governments and industry for the improvement of the efficiency and environmental situation of the sector. The report could provide basis for the formulation of a programme for the strengthening of economy and ecological situation of the selected countries with the assistance of international organizations and the donor community.



1.2 Major findings

In the following pages of this Chapter the major findings of the Team is summarized country by country. The detailed description of the industry and of the environmental legislation as well as recommendations concerning the improvement of the situation are contained in Chapters 2 - 6.

BRAZIL

In Brazil mining, refining and smelting operations are undertaken in several states employing technologies, procedures and processes which vary considerably in scale, complexity and age. The UNIDO team visited facilities located in the northern states, but only one smelter in the south. The standards of environmental management observed by the team were exemplary and equivalent to the best practice applied elsewhere in the world. This can be attributed to:

- A highly responsible attitude to environmental concerns on the part of company management;
- A high level of environmental awareness on the part of all levels of the work force; and
- Functioning regulatory programmes based on cooperation and negotiated compliance between regulators and the industry.

The sensitivity of the environment and the high profile of operations in the northern states of Brazil have exerted considerable influence on management's concern for environmental impacts. Furthermore, technologies and processes in the north are modern and efficient. With the exception of the Valesul smelter, the UNIDO team did not visit any of the older facilities, (of which there are mines, refineries and smelters), in the southern part of the country and can only report the favourable observations of individuals and organizations with whom discussions were held.

While it was possible for the UNIDO team to make some recommendations concerning the introduction of cleaner production and waste reduction measures by industry and also suggestions as to how there could be promoted by regulatory means, the state of environmental management in Brazil is such that the other countries in the Region could benefit from access to Brazilian experience and expertise.



GUYANA

The environmental impacts of bauxite mining and processing at Linden in Guyana are a consequence of 60 years of neglect for any kind of environmental management on the part of the industry and the complete absence of an effective, national environmental regulatory programme. Both the health and well-being of the local community and the flora/fauna associated with the surrounding vegetation are affected. Although there are technical problems, particularly in respect of mine rehabilitation, some of the most serious pollution, including dust emissions from the calciners, could have been reduced using pollution control equipment accepted as the norm by industry elsewhere. Government interventions in the industry's operations were, in general, not successful and unable to address environmental damage. Current recovery efforts, aimed at privatization and involving international companies in the management of the industry, are hampered by the poor financial situation of the company and the large budgetary deficit at state level.

Installed bauxite processing plant is old, pollution and energy intensive and in serious need of proper maintenance. The future of the industry in Guyana is dependent on decisions to be made by the Government and the interest shown by potential investors/buyers. This is largely a function of the market for Guyana's bauxite products and the direct and indirect income they generate for the country.

National efforts to introduce an environmental regulatory programme are at a very early stage and moving slowly. Improvements in operating practice by the industry will be in response to corporate or institutional policy on the part of potential investors and operating companies rather than as a result of regulation enforced by the Government. Opportunities were identified for improved housekeeping and improved control of energy consumption, savings from which could offset costs, but the scale of the environmental damage to date and the vintage of the installed plant and its poor state of repair suggest that bringing plant operations into line with internationally accepted environmental standards will be prohibitively expensive.

JAMAICA

As a result of the geological features of its bauxite formations and their close proximity to residential, agricultural and tourist areas, the current and potential future impact on the environment of Jamaica's bauxite industry is unique in the Region. Bauxite is mined and transported by small scale methods corresponding to the special features - small pockets in a limestone matrix - of the deposits. Environmental impacts are limited to dust, noise and general disturbance and disfigured landscape remaining after partial reclamation. In economic terms these effects are not currently significant but further encroachment of activities into tourist areas could affect tourist income. However, compared to world standards environmental performance of mining and reclamation could be considerably improved, which would be appreciated by residents and farmers affected by mining operations.



The Jamaican alumina refining plants are pollution- and energy-intensive and also out-of-date, as a result of limited investment over two decades. Of critical concern is groundwater contamination resulting from caustic leakage from old red mud ponds. Opportunities for improved operational practice to reduce waste exist, but internationally acceptable standards of environmental management cannot be achieved without considerable investment in new procedures, plant and equipment.

Both, the multinational aluminium companies and the Government, are participants in the industry, however, relations between the two parties resulted in minimum concern by either side for environmental protection. Independent, cohesive regulatory machinery is at an early stage of being put in place and the new Natural Resources Conservation Authority will need considerable external support in respect of both ambient and compliance monitoring to be effective. Focusing on regulatory and economic instruments which promote cleaner production will avoid potential conflicts with either government or industry.

SURINAME

In Suriname Bauxite mining began already in 1916. Based on the local bauxite resources, which especially in the early days of the aluminium industry was considered rich and good quality, gradually a substantial bauxite mining, alumina refining and aluminium smelting industry was created. This industry has remained the backbone of the country's economy. During the last three decades, due to the difficulties of the Suriname's economy and as a result of emerging some new and very efficient producers in other countries of the world, the international significance of Suriname as an aluminium producer has substantially decreased. There were no major capital investments during the recent decades and the signs of decay are becoming more and more visible.

Nevertheless the environmental situation of the industry has not deteriorated as fast as e.g. in Guyana. The company operators are aware of the hazards and several measures were taken by them to offset the deleterious effect of their operations. Housekeeping, maintenance and worker safety is good at all production facilities even though there are no environmental laws and adequate safety regulations in Suriname. This is a major evidence of the commitment of plant management and personnel.

Efficient and innovative technologies are applied in the mines. There is no restoration of the original marshlands, but some mined out areas serve very well as mud lakes of the alumina plant and others are transformed into lakes with the intention to be converted in the future into recreational areas. The alumina refinery is operated well and with acceptable technical parameters taking into consideration the raw material quality and the age of the plant. Even though the lime burning kiln generates large amount of dust, it is used also to incinerate toxic wastes collected in the country. The environmental management of the smelter is not adequate and the age of the technology is one of the major reason for that. Measures were taken to stop hazardous disposal of spent pot linings and water pollution. The resolution of the air pollution problems would require costly large scale reconstruction of the smelter. The company is in the decision making process concerning this issue, which



will influence the fate of the whole sector and will have a major impact on the economy of the country.

VENEZUELA

A congruence of several factors could effectively contribute to the creation of the world's most competitive aluminium industry in Venezuela. They are:

- extensive and good quality bauxite reserves;
- inexpensive and reliable energy supply;
- efficient transportation facilities;
- well-trained work force; and
- modern and efficient installed technologies.

The industry already contributes substantial foreign exchange income although this is still modest compared with earnings from the oil industry. Since 1991 low metal prices have reduced the pace of expansion but Venezuela maintains its goal of eventually achieving 2 million tonnes/year of primary aluminium capacity.

Apart from the unavoidable disturbance caused by mining, the recent vintage and high efficiency of the processes and equipment have, to date, resulted in controllable environmental impacts. However, the scale of operations is such, that the discharges and emissions of polluting waste identified by the UNIDO team, could rapidly escalate to the level of major environmental damage.

In particular, the following concerns need to be addressed:

- Accumulation of a large quantity of caustic red mud next to natural, (fishing), lagoons and at the Orinoco river with attendant leakage through the retention dikes and risk of catastrophic failure;
- Unmonitored accumulation of spent pot linings, pitch and other hazardous waste in landfills with potential to contaminate groundwater;
- Unacceptable fluoride discharges from the smelters due to poor maintenance and slack operating practice; and
- Limited diversity of the new vegetation introduced to rehabilitate mined-out areas of bauxite.

Mining, refining and smelting operations are supervised by the state-owned CVG, the principal entity responsible for promotion and coordination of the development of the Guyana region where the aluminium industry is located. Even though mining operations are in a remote area where they need not interfere with residences or farming and the refinery and smelters are located a few miles away from residential areas in the city of Puerto Ordaz, CVG are aware of the environmental risks listed above and are actively



seeking solution. An environmental Vice-Presidency exists at the corporate level and all the operating entities are equipped with functioning risk assessment /safety/ environment units. The existence of the above problems, however, indicates inadequacies in the integration of environmental concerns into CVG's development planning. The emphasis appears to be on production, and environmental staff are pre-occupied with developing new ambitious projects which do not address the most processing problems.

Training and awareness programmes for personnel at all managerial and production levels in environmental management, particularly cleaner production and waste minimization, are required to ensure a wider participation in efforts to reduce pollution at source. This applies particularly to smelting operations.

Greater visibility on the part of the regulatory authorities would enable the national environmental authorities to exert more influence over CVG's development planning to avoid problems of the type listed above. Voluntary agreements between industry and regulators to implement the opportunities identified by the UNIDO team for cleaner production would be an appropriate starting point for improved cooperation.



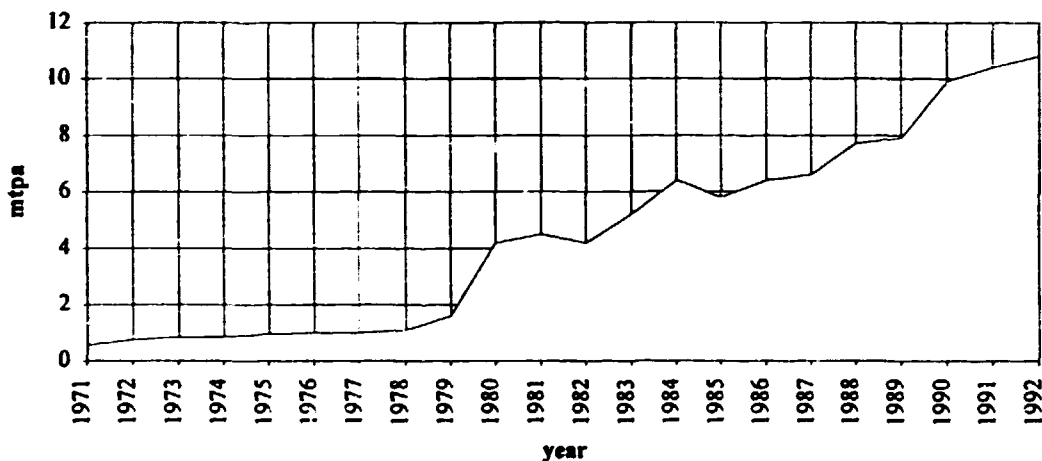
2. BRAZIL

2.1. Introduction

Development of the aluminium sector in Brazil is the result of concentrated efforts by the Government. It is largely being carried out in the framework of the development programme of the Amazon region and is based on the vast bauxite resources and hydroelectric power potential of the region. The success of the programme is documented in the chapter below.

Brazil is currently the fourth largest *bauxite* producing country of the world, with a share in total world bauxite production of about 10%. Since 1970 annual production increased from 0.5 to over 10 million tonnes which represents an average annual growth rate of over 15% (Figure 2.1.1). Further development of mine capacities and opening of new mines are on the agenda. This could boost production yet further in the second half of 1990s.

Figure 2.1.1 Bauxite production of Brazil



The only mine visited by the Team was Mineração Rio do Norte's (MRN) Trombetas mine in Pará State, Oriximiná County. Nearly 80 % of Brazil's current bauxite production comes from this single mining operation which is located near to the Trombetas River, a tributary of the Amazon. MRN is a joint venture of seven companies. Its capital structure has changed several times since it was constituted in 1974 and is presently as follows (ordinary and preferred shares):

Aluvale (Vale do Rio Doce Alumínio S.A.) (Brazil)	40.0 %
Shell/Billiton (The Netherlands)	14.8 %
ALCOA (U.S.A.)	13.2 %
ALCAN (Canada)	12.0 %
C.B.A. (Companhia Brasileira de Alumínio) (Brazil)	10.0 %
Reynolds Metals (U.S.A.)	5.0 %
Norsk Hydro (Norway)	5.0 %



The two Brazilian companies ALUVALE and C.B.A. together have a majority interest (52.5 % of the ordinary shares).

Other significant metallurgical grade bauxite mining operations are in the South, in Minas Gerais state, in Pocos de Caldas, Cataguases and Ouro Preto, which supply the three metallurgical grade alumina plants of ALCAN Alumínio do Brasil S.A., ALCOA Alumínio S.A. and Cia. Brasileira de Alumínio (CBA). A few minor independent mining companies are also active in the region serving mainly the non-metallurgical sector.

The growth pattern of *alumina* manufacturing is similar to that of bauxite production. Alumina output increased from 119,000 tonnes in 1970 to 1,833,000 tonnes in 1992 (Figure 2.1.2) with an average annual growth rate of about 14%. The alumina output of Brazil represents about 5% of the world total.

The present level of alumina production is unable to absorb all the bauxite produced in the country. On the other hand it is insufficient to fully feed the smelters with alumina. Thus, Brazil is a major exporter of bauxite and a net importer of alumina (Figures 2.1.3 and 2.1.4). In 1992 the alumina import reached already 698,000 tonnes (Source: ABAL). Further increase of alumina capacity to about 3 million tpa is expected still in this decade which will make Brazil self-sufficient in alumina, but maintain her status of major bauxite exporter.

Figure 2.1.2 Alumina production of Brazil

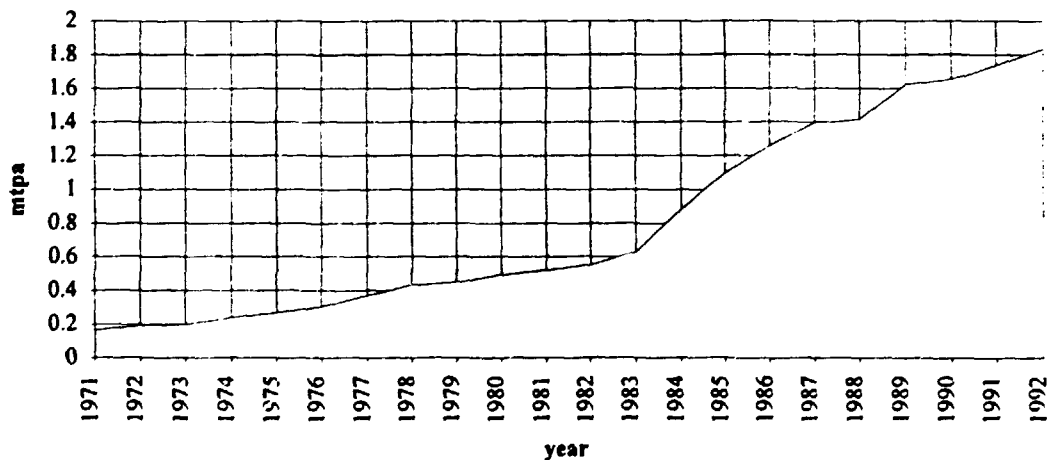




Figure 2.1.3 Net export of bauxite from Brazil

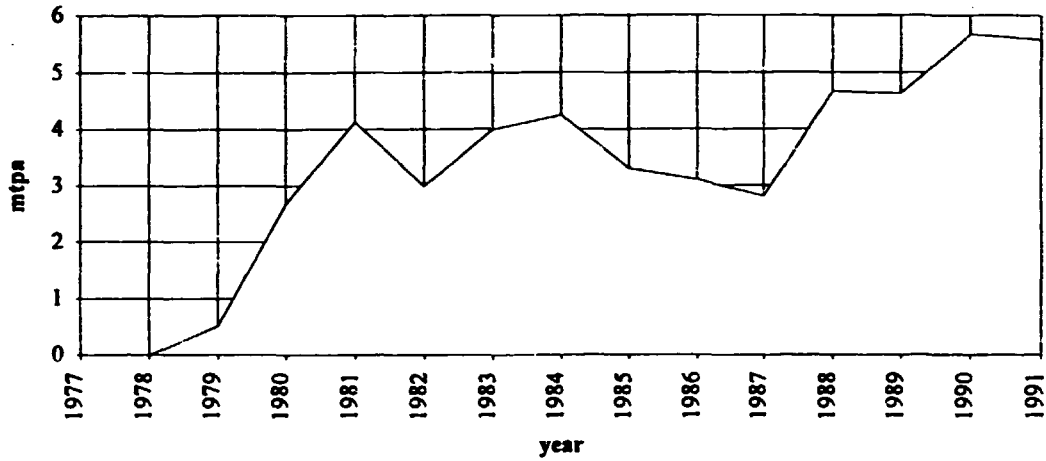
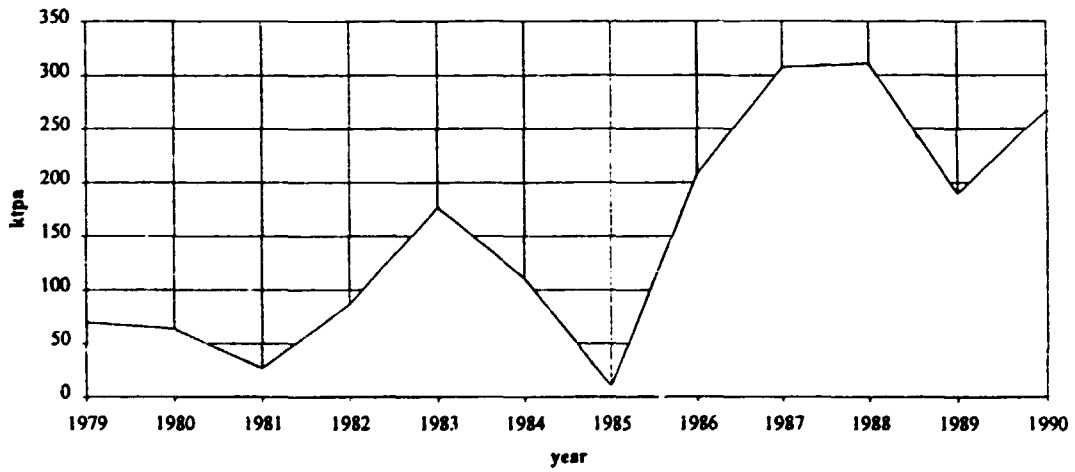


Figure 2.1.4 Net import of alumina to Brazil



Source: The Economics of Bauxite & Alumina 1993, Roskill



Four metallurgical grade alumina plants are currently operating in Brazil (Table 2.1.1). The three plants in the South are older and smaller, whereas the largest and most modern (ALUMAR), is in the North-East. A fifth alumina plant, also in the North-East, is under construction (ALUNORTE). The team visited only the latter two as indicated in Table 2.1.1 below.

Table 2.1.1 Alumina plants in Brazil (metallurgical grade only)

Name, location	Start up date	Ownership	Capacity, tpa	Remarks
ALCAN Alumínio do Brasil, S.A., Saramenha	1944	ALCAN Alumínio do Brasil S.A.	160,000	Not visited
CBA, Alumínio (Mairinque)	1954	Industria Votorantim	440,000	Not visited
ALCOA Alumínio S.A., Pocos de Caldas	1972	ALCOA Alumínio S.A.	270,000	Not visited
ALUMAR Consortium, São Luís	1984	54 % ALCOA Alumínio S.A.; 36 % Billiton Metais S.A.; 10 % ALCAN Alumínio do Brasil S.A.	1,000,000	<u>Visited</u>
ALUNORTE, Barcarena near Belem	1996	30 % CVRD 30 % MRN 40% ALCAN, NAAC, CBA	1,100,000	<u>Visited</u>

The principal customers of the alumina refineries (for at least two thirds of their production) are associated smelters in Saramenha, Sorocaba, Pocos de Caldas and São Luís (Alcoa Alumínio also produces chemical grade alumina; Alumar supplies the VALESUL smelter near Rio de Janeiro).

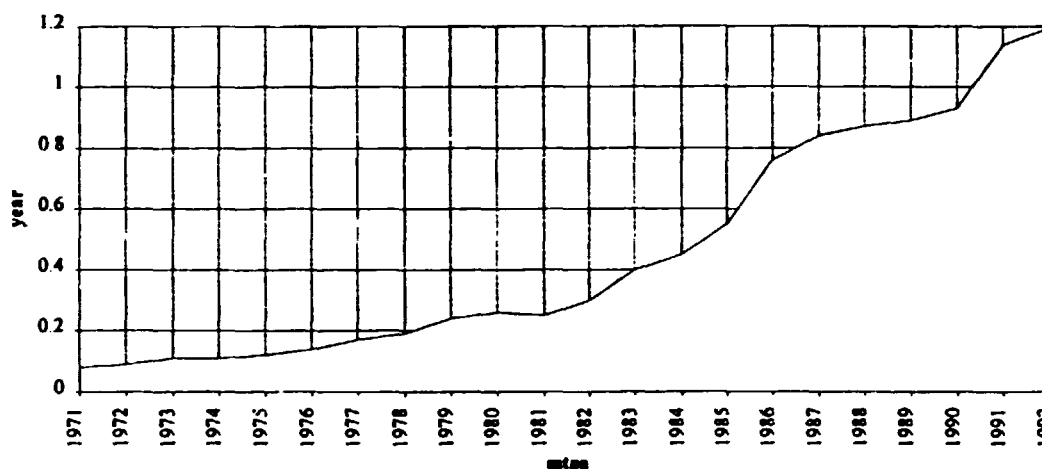
With the present power crisis developing in the South of Brazil some of the smelters operating in this region may not only reduce their output but even completely shut down. This, in turn could lead to a partial or complete shut-down of some of the Southern refineries and earlier expansion projects here will probably be shelved. On the other hand, there is a potential to double or even treble the capacity of the ALUMAR refinery in the North.



There is also a considerable production of non-metallurgical grade bauxite and alumina products in Brazil, the main products being refractory materials and fused aluminas for grinding purposes (abrasives), alumina sulphate for water treatment, etc. Due to the small amounts produced by this sector in comparison with the metallurgical grade products these operations were not studied.

The Brazilian primary *aluminium* production (Figure 2.1.5) increased from 81,000 tonnes in 1971 to 1,193,300 tonnes in 1992 (14 times). In 1992 Brazil was the fifth largest aluminium producer of the world after the USA, CIS, Canada and Australia. Aluminium exports reached a record for the country, amounting to 872,600 tonnes.

Figure 2.1.5 Aluminium production of Brazil



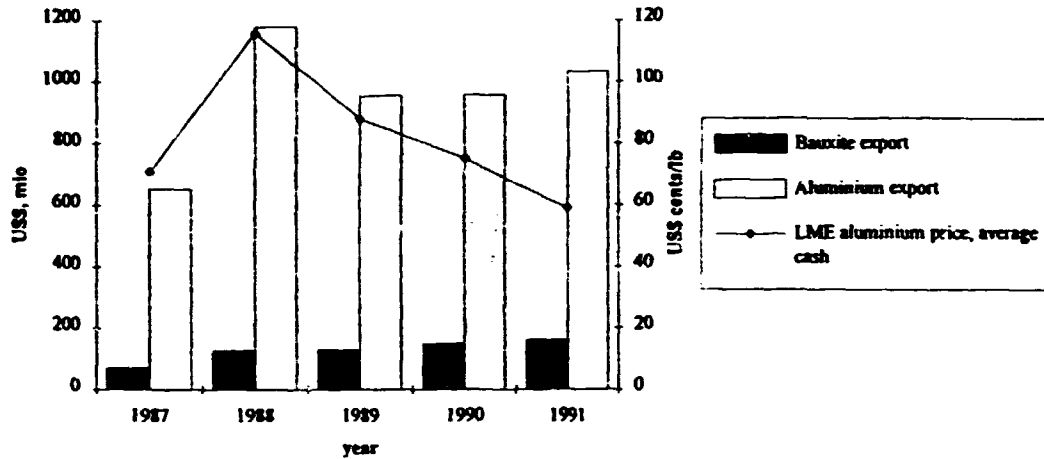
Sources: Yearbook of International Commodity Statistics, 1985 and 1993, UNCTAD

As a result of the dynamic growth of production the foreign exchange revenues from the bauxite and aluminium exports remained around the US\$1.2 billion level even though the average London Metal Exchange aluminium cash prices have been falling sharply (Figure 2.1.6).

The Brazilian smelters are listed in Table 2.1.2.



Figure 2.1.6 Export of bauxite and aluminium from Brazil



Sources: Yearbook of International Commodity Statistics, 1993, UNCTAD

Table 2.1.2 Aluminium smelters in Brazil

Name, location	Start up date	Ownership	Capacity, tpa	Remarks
ALCAN Alumínio do Brasil, S.A., Saramenha	1945	ALCAN Alumínio do Brasil S.A.	51,000	Not visited
CBA, Alumínio (Mairinque)	1955	Industria Votorantim	217,000	Not visited
ALCAN Alumínio do Brasil S.A., Aratu	1971	ALCAN Alumínio do Brasil S.A.	58,000	Not visited
ALCOA Alumínio S.A., Pocos de Caldas	1970	ALCOA Alumínio S.A.	90,000	Not visited
VALESUL Alumínio S.A., Santa Cruz, near Rio de Janeiro	1982	49% Aluvale (CVRD) 41% Billiton Metais S.A. 8.8% Cataguazes Leopoldina 1.2% Other small	93,000	Visited



Name, location	Start up date	Ownership	Capacity, tpa	Remarks
ALUMAR Consortium, São Luís	1984	54% ALCOA Alumínio S.A.; 46% Billiton Metais S.A.;	356,000	<u>Visited</u>
ALBRAS, Alumínio Brasileiro, S.A, Barcarena near Belem	1985	51% ALUVALE, Vale do Rio Doce Alumínio, S.A 49 % NAAC, Nippon Amazon Aluminium Co. Ltd. (Japanese consortium)	345,000	<u>Visited</u>



2.2. Description of the industry

a. Bauxite Mining

Geography, Geology

Brazil's bauxites are of lateritic origin, most deposits are of the blanket type, capping plateaus of moderate altitudes. Total (proven+probable+possible) reserves exceed 3 billion tonnes (ranking third in the world behind Australia and Guinea). More than 83 % of these reserves are in Par  State, in the Amazon region, some 14 % in Minas Gerais state, in the South-East, and less than 3 % in the rest of the Country.

Quality

The average composition of the *Trombetas* bauxite is:

AA (available Al_2O_3) :	.....	49 %
RS (reactive SiO_2):	.....	5 %
Fe_2O_3:	.....	11 %
TiO_2:	.....	1 %
L.O.I. (loss on ignition):	.....	28 %
Moisture:	.....	14 %

Trombetas bauxite is appreciated because of its low levels of contaminants (V_2O_5 , P_2O_5 and especially organic carbon).

Mineralogy: Gibbsite 78%, Boehmite 1%+, Goethite 7%, Kaolinite 7%.

Mining Operations

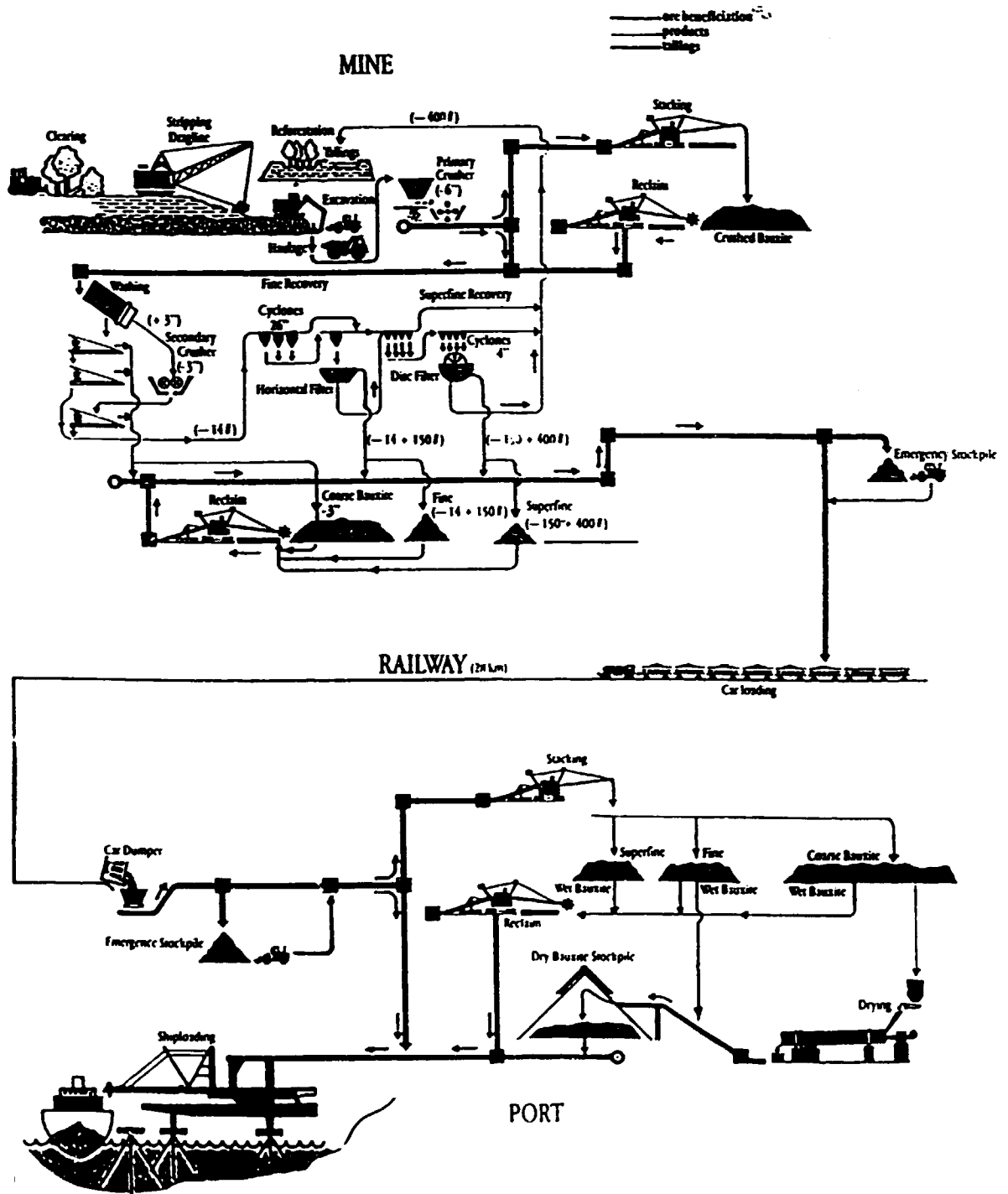
The mining operation of MRN at Trombetas started in 1979 and by 1992 68 million tonnes of bauxite had been produced (an average of 5 million tonnes per year over 14 years). The present capacity of the operation is about 3.5 million tpa. The total proven reserves of MRN properties were estimated at 780 million tonnes in 1992, of which 200 million tonnes are on the presently mined Sarac  and the nearby Almeidas and Aviso plateaux.

The typical mining profile consists of about 0.5 m organic topsoil (originally covered by native rainforest), 8 m overburden (clay, nodular bauxite in clay matrix and ferruginous laterite) and 4.5 m massive and blocky bauxite. After clearance of vegetation the topsoil is scraped away and stored for later reuse and the overburden is stripped by walking draglines into the nearby mined-out area (1 electric dragline with a 20 m³ and 2 diesel draglines with 13 m³ buckets). After occasional blasting the bauxite is loaded by backhoes or front-end

Bauxite Deposits, Mining Operations and Producers of the World

MINING OPERATIONS

BENEFICATION PLANT (Courtesy of MRN)



February, 1991

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loaders into dumper trucks or motor-tractors. These transport it to the primary impact crushers (95 % < 150 mm).

The crushed bauxite is stockpiled or immediately transported to the beneficiation plant. Here it is first washed in a rotary screen with 75 mm openings. The +75 mm fraction is crushed in a secondary hammermill to 75 mm. After these all bauxite goes to 14 mesh (about 1 mm) vibrating screens, where it is further washed. The oversize of these is Coarse Commercial Bauxite (50-60 % of the total). The undersize is pumped to the first set of cyclones (dia 65 cm) which cut it at about 150 mesh (100 μ m). The 0.1 to 1 mm fraction (some 10 to 15 % of the total) is filtered on a horizontal filter and constitutes the Commercial Fines. The overflow of the first cyclones is pumped to a second set of dia 10 cm ones cutting it at about 400 mesh (40 μ m). The 40 to 100 μ m fraction (some 5 to 10 % of the total) is filtered on disc filters and constitutes the Commercial Superfines. The three fractions are stored and transported separately by standard gauge railroad to the port area (28 km from the mine) on the Trombetas River.

The slime obtained as the overflow of the second stage of cyclones undergoes settling and compaction in an elaborate system of ponds which recover most of the water used for bauxite washing for reuse, thus minimizing the freshwater requirement of the washing plant. The compacted tailings (some 20 to 30 % of the original bauxite) are pumped to ponds on the mined-out areas and allowed to dry prior start of revegetation.

At the port area the rail cars are discharged by a wagon-tippler and the three sorts of bauxite (Coarse, Fine and Superfine) are stored in three separate open-air stockpiles (total capacity about 700 kt). Two 27 m long, dia 4 m rotary kilns serve for the drying of Coarse Bauxite (typically from 12-15 % moisture to 3-4 %) and the dried material is stockpiled in a covered silo (capacity 170 kt). Both dried and wet material are shipped (dried usually for export to overseas, first of all Canada and U.S.A., wet mainly to ALUMAR), with Fines and Superfines mixed to them according to requirements. Shipping is done in vessels with capacities up to 60,000 tonnes. Maximum shiploading capacity is 6,000 t/h.

Typical composition of the shipments is the following:

TA (total Al ₂ O ₃):	.....	54 %
AA :	.....	50 %
TS (total SiO ₂):	.....	4 %
RS:	.....	3.5 %
Fe ₂ O ₃:	.....	13 %
TiO ₂:	.....	1.2 %
L.O.I.:	.....	28 %

Up to 1989 the bauxite washing plant was also located in the port area, where unlimited amount of water was readily available. The tailings were pumped into the Batata Lake, a lagoon parallel to the Trombetas River.



Rehabilitation

MRN's mine rehabilitation program goes on parallel to the mining activity. Some 600 hectares have already been re-afforested out of the total of about 2,000 hectares of cleared rainforest. The filling of the mined-out area with overburden and tailings is part of the mining operation. Native plants are grown in the mine's nursery (located in the township area near the Trombetas River) for planting on the areas being rehabilitated.

Another focus of the environmental program of MRN is the rehabilitation of the Batata Lake contaminated by the tailings of the first ten years of operation. An in-depth research effort is under way (with the help of the University of Rio de Janeiro) to find the best solution for the rehabilitation. This research work (restoring a tropical lake) is unique in its scope.

b. Alumina Production

Of the four metallurgical grade alumina plants operating in Brazil the Team visited ALUMAR and, briefly, the ALUNORTE plant which is under construction. ALUMAR is described below. This plant cannot be regarded as typical; it is, however the largest refinery in Brazil and demonstrates excellent solutions which could be taken by other producers within Brazil and in the Region. It appeared that environmental impacts were adequately addressed during the design and erection of ALUNORTE.

Processing Features

The ALUMAR refinery is located at the southern end of the island of São Luís, about 30 km from the city of São Luís in the State of Maranhão.

Presently the ALUMAR refinery runs 100 % on Trombetas bauxite shipped down the Amazon river. (A few years ago they also processed some Sierra Leone bauxite.) The plant was originally designed for the classical low-concentration American Bayer process for an initial capacity of 500 ktpa, with expansion possibilities up to 3,000 ktpa. However, instead of expanding the plant with the addition of new equipment the process was intensified by increasing the liquor concentration (to about 270 gpl caustic Na_2CO_3 , i.e. about 160 g/l caustic Na_2O in precipitation) and the liquor productivity (above 80 kg $\text{Al}_2\text{O}_3/\text{cu.m}$) so that the refinery's output increased to 1,000 ktpa for very little new investment. The process applied involves a conventional wet bauxite grinding followed by a double-stream low-temperature digestion (around 150°C), settling and 6-stage counter-current mud washing in large single-tray thickeners; short, intensive precipitation (about 30-40 hours) with interstage cooling and three-stage hydrate classification; fluid-flash calcining in Alcoa Mark III calciners. The plant is highly automated and computer controlled.



Material and Energy Consumption

ALUMAR consumes about 2.1 t of Trombetas bauxite (dry basis) per tonne of alumina. Caustic soda consumption of ALUMAR is also relatively low, about 80 kg/t (as 100 % NaOH). The energy consumption of ALUMAR is probably the lowest in the world: 7.1 GJ/t, including 0.6 GJ/t of electric energy.

c. Aluminium smelting, carbon making

There are seven aluminium smelters in Brazil with a total capacity of 1,209,000 tpa. The Team visited only the three prebake smelters (ALBRAS, ALUMAR and VALESUL), which, however, represent 66% of the total Brazilian primary aluminium production.

ALBRAS

The plant is located about 40 km by river and road to the southwest of the city of Belem in the State of Para. Following the retrofitting of Line 1 and expansion to four potlines, the plant is producing 345,000 tonnes of aluminium each year. Only remelt products are made in the casthouse.

Description of Process Technology and Equipment

The first potline of 240 pots was installed in 1985. A side fed 135 kA prebake unhooded pot was used. The potroom roof discharge was water scrubbed.

A second potline was installed in 1986, a centre fed 150 kA prebake fully hooded pot with point feeders was used.

In 1988 Line 1 was hooded and in 1990 the pot was converted to point feeding and the operating current was raised to 150 kA.

In 1990, two further potlines of hooded point fed 150 kA prebake pots were added to the plant. All potlines are equipped with dry scrubbers.

The plant has two identical carbon plants, the first constructed in 1985, the second in 1990. Solid pitch is used in pencil form. The coke is stored in coke silos and the pitch in a well constructed pitch bay. The four bake furnaces are open furnaces one with a 54 section and three 36 section rings. Large 4 stub hole anodes are produced and rodded with cast iron.



Material and Energy Consumption

Table 2.2.1 *Main technical parameters of ALBRAS, Lines 1,2,3&4*

Line Amps, kA	Current Efficiency, %	Energy Consump. kWh /kg	Net Carbon Consumption t/t Al	Bath Ratio	Pot Life, days	Anode Effects /Pot-day
150	92+	14.3	0.425	1.12	2,200	0.7

These cells do not have the latest distributive control systems but despite this limitation their performance is excellent.

Net carbon at 0.425 tonnes/tonne of aluminium produced is low indicating good carbon quality and good pot operating conditions. The current efficiency of 92%+ and the specific energy requirement of 14.3 kWh/kg of metal produced indicates excellent performance for a cell of this type. Good pot life is being achieved. The anode effect frequency of 0.7 per pot day is on the high side and could be reduced if more modern control equipment were to be installed.

ALUMAR

The Smelter is adjacent to the ALUMAR alumina refinery described above. The plant was developed in three phases. Following operating improvements the efficiency and output of each phase has been substantially increased since start-up.

Table 2.2.2 *Upgrading of ALUMAR potlines*

	Year	Number of cells	Original Capacity, tpy	Current Capacity, tpy
Phase 1	1985	208	100,000	120,000
Phase 2	1986	250	135,000	146,000
Phase 3	1990	154	83,000	91,000
TOTAL		612	318,000	357,000

The product is standard 22 kg remelt ingots.



Description of Process Technology and Equipment

A 216 kA pot is used throughout the plant. The cells are point fed prebakes with 24 anodes per cell. Alumina is fed directly to the pot via dry scrubbers by a dense phase piped conveying system.

The cells are controlled by a central computer. The hooding design, condition and placement are excellent. The cells have a facility to increase gas flow from the cell to the scrubbing system whenever it is necessary to open an end door or remove a hood.

The carbon plant uses seven batch mixers and operates on petroleum coke and solid pitch. There is no pitch melting facility. Aggregate is heated and mixed with solid pitch on admission to the mixer. A large two stub hole green anode is formed, cooled and transferred to one of the three open bake furnaces. Furnace 1 has 76 sections, Furnace 2 has 68 sections and Furnace 3 has 40 sections. These furnaces operate without cyclones or scrubbers to three stacks of about 40 m height.

Material and Energy Consumption

Table 2.2.3 Main technical parameters of ALUMAR, Lines 1,2&3

Lines	Line Amps, kA	Current Efficiency, %	Energy Consump. kWh/kg	Net Carbon Consump., t/t Al	Bath Ratio	Anode Effects /Pot-day
1,2 &3	216	93.8	14.06	0.403	1.11	0.6

The net carbon consumption of 0.406 tonnes per tonne of aluminium, the low alumina usage of 1.92 tonnes per tonne of aluminium and the AlF_3 usage of 14 kg per tonne of aluminium and a current efficiency of almost 94%, all reflect the high quality of this operation.

The specific energy requirements of 14.06 kWh/kg is appropriate for a cell of this vintage. This might be improved by the introduction of a more sophisticated control system with a microprocessor controlling the performance of each pot. Anode effects of 0.6 per pot day should also be reduced by the use of such equipment. Since the lines are operating so well with central computers, it may be difficult to justify the installation of a new control system on the grounds of cost reduction.

VALESUL ALUMINIO S.A.

The plant is located 70 km south of the centre of Rio de Janeiro at Santa Cruz and is 25 km from the harbour of Sepetiba. The plant was originally commissioned in 1982 to produce 86,000 tonnes of metal each year. Improved operating practices raised output to 93,000 tonnes each year. Recently, due to extremely high energy costs during the evening peak demand period (19:00 hours to 22:00 hours) combined with the historically low



aluminium prices, it has been necessary to modulate the line current. Current has been reduced by 37% during the peak period with consequent loss of production and a fall in current efficiency of about 2%. Because of the low metal price and high cost of power production is about to be cut by 25% to 68,000 tonnes per year for the foreseeable future. Fifty-four pots will be shut down.

Description of Process Technology and Equipment

The plant was commissioned in 1982.

The potline consists of 216 cells. The normal line current is 162 kA but this is now reduced to 102 kA for the three-hour evening energy usage peak.

The cell is a centre worked pre-baked unit with a bar breaker. The cell uses 18 two-stub, aluminium sprayed anodes. The electrolyte is maintained at an NaF/AlF₃ ratio of 1.40 and contains lithium. Alumina is fed to the cells from the crane hopper. The potline is controlled by a central computer.

Pot fume is collected and fed to Mikropul dry scrubbers located in the courtyard between the lines.

The carbon plant produces about 65,000 tonnes of green anodes each year using continuous mixers and a vibratory former. Anode baking is carried out in a 48-section Riedhammer closed furnace. The exhaust from this furnace passes to a scrubber consisting of a water spray pre-cooler and electrostatic precipitator.

In the rodding room, spent anodes are rough cleaned in a machine that is effectively ventilated to a large baghouse.

The cast house contains six holding furnaces to supply metal to a pig caster, a continuous caster and a direct chill casting pit. 22 kg remelt ingot, continuously cast plate, extrusion billet and 500 kg sow are produced at the plant. A small amount of chlorine is used with argon to degas some metal before casting.

Material and Energy Consumption

a. Without current modulation

Table 2.2.4 Main technical parameters of VALESUL potline

Line Amps, kA	Current Efficiency, %	Energy Consump kWh/kg	Net Carbon Consumption t/t Al	Bath Ratio	Pot Life, days	Anode Effects /Pot-day
162	90.4	15.2	0.45	1.40	2,000	0.8



The specific energy consumption is as would be expected for a cell of this design and vintage and with this bath chemistry. The net carbon is on the high side. Pot life is excellent.

b. With current modulation

Line Amps, kA:	162-102
Current Efficiency, %:	88.5

As would be expected, the current efficiency has fallen due to the unstable operating conditions that follow major changes in line current.

PRIMARY SMELTERS IN BRAZIL VISITED BY THE TEAM

NAME	START DATE	LAST MAJOR MODIFIC.	NO. OF POTS	POT TYPE	FEED TYPE	LINE AMPS., kA	CURRENT EFFICIENCY, %	SPECIFIC ENERGY kWh/Kg	ANODE EFFECTS PER POT DAY	NET CARBON, %	BATH RATIO	CONTROL SYSTEM	POT LIFE, days	SCRUBBER TYPE
ALBRAS, 1	1985	1990	240	CWPB	PF	150	>92.0	14.3	0.7	0.425	1.12	Central Computer	2,200	Dry
ALBRAS, 2	1986		208	CWPB	PF	150	>92.0	14.3	0.7	0.425	1.12	Central Computer	2,200	Dry
ALBRAS, 3	1990		208	CWPB	PF	150	>92.0	14.3	0.7	0.425	1.12	Central Computer	2,200	Dry
ALBRAS, 4	1990		208	CWPB	PF	150	>92.0	14.3	0.7	0.425	1.12	Central Computer	2,200	Dry
ALUMAR, 1	1984		204	CWPB	PF	216	93.8	14.06	0.6	0.403	1.11	Central Computer	1,700	Dry
ALUMAR, 2	1986		250	CWPB	PF	216	93.8	14.06	0.6	0.403	1.11	Central Computer	1,700	Dry
ALUMAR, 3	1990		154	CWPB	PF	216	93.8	14.06	0.6	0.403	1.11	Central Computer	1,700	Dry
VALESUL	1982		216	CWPB	CB	162	88.5*	15.2	>1	0.45	1.4 plus Li	Central Computer	2,000	Dry

CWPB - Centre Worked Prebake

PF - Point Feed

CB - Central Bar Breaker Feed

* - This line operates at 90.4 without current modulation.



2.3 Environmental Impact of the Bauxite Mining, Alumina and Aluminium Industry

a. Mining

MRN

Apart from the pollution of the Batata Lake the main environmental concern at MRN is *dust*. The possible sources of dust are the transportation, unloading and drying of the bauxite. Since the bauxite is transported in a wet state from the mine to the port area the first two of the above sources are not too significant. Wet scrubbers are installed at the drying kilns to keep the third one under control. The efficiency of the wet scrubbers is above 98%.

Some 7-8 kg/t of fuel oil are consumed by the drying kilns resulting in an estimated output of 2 ktpa of SO₂ and 100 ktpa of CO₂. These figures are quite negligible.

Regarding mine rehabilitation the only remark of the team is, that although natural habitat demands more than 1,000 tree species in the endemic primary rainforest, only 80 can be successfully grown in the harsh mining conditions. Final success of the rehabilitation programme can only be judged when all industrial activity has moved to another plateau, and sufficient time has elapsed to enable the natural renewal of biological diversity.

Maintenance and housekeeping practices in bauxite mining are good at MRN. Worker's safety is also good. Safety and environmental awareness is high.

General assessment of the performance of the mining operations visited

Apart from the aforementioned remarks it can be stated that both the technical level and the environmental performance of the MRN operation in the Trombetas area are good, the best seen by the Team in the region and ranking among the best in the world.

b. Alumina plants

ALUMAR

Red mud disposal is the main environmental concern of the alumina plants. This problem is solved in an exemplary way at ALUMAR. Next to the plant sealed lakes (40 cm of clay at the bottom; plastic foil on the top of the clay layer) were constructed with drainage pipes laid in a 40 cm thick sand layer above the plastic foil. Two such lakes (21 and 30 hectares) have already been established, the third one is under design and planned to be constructed in 1996. The pond area has not been decided yet. The first lake is already filled up with 18 m of mud, the second one can be operated until 1997 with the present production rate, when some 0.7 t/t i.e. some 700 ktpa of red mud (dry basis) is produced. A large amount of water is recycled from the active mud lake to the alumina plant (some 900 m³/ph) and some seepage is also collected from the oldest lake. Since most of the rainwater falling on these lakes seeps downward, any soluble caustic still present in the (dried and compacted)



mud will be slowly washed out making the rehabilitation feasible, without compromising the environment. Despite of this, such kind of rehabilitation work requires expertise and technology. A large number of experimental plots have been established on the top of the oldest mud lake, some with a soil cover with or without chicken manure others without it. Ash of the coal fired in the boilers of the alumina plant is also used for this purpose. It seems that some plants thrive not only on the soil-covered surface of the filled-up mud lake, but also on the uncovered mud surface. The areas cleared for clay and sand mining are also re-afforested.

ALUMAR consumes some 76 ktpa of fuel oil for calcining and some 106 ktpa of high quality coal for steam generation. This gives rise to a total emission estimated to 10 ktpa of SO₂ and 500 ktpa of CO₂ - figures not negligible, but relatively low and acceptable.

Particulate emission (dusting) figures of the plant are quite good. Almost no bauxite or alumina dust can be seen in the plant area and in its surrounding. The amount of dust is low in the flue gases (less than 50 mg/cu.m. in the stack gas of the boilers, less than 100 mg/cu.m. in the flue gas of the calciners).

Maintenance and housekeeping practices are excellent at the ALUMAR alumina refinery. The plant is kept very clean, no spillages or seepages could be seen. Workers' safety seems also very good.

General assessment of the performance of the refineries visited

Based on the site visits undertaken by the UNIDO team, it can be stated that both the technical level, bauxite, soda and energy consumption data and the environmental performance of ALUMAR are outstanding and there is a good chance for ALUNORTE to achieve very good technical and environmental performance upon its completion.

c. Aluminium smelters

ALBRAS

Air pollution

■ POTROOM

This plant operates under a license that defines the levels of fluoride, and particulate that may be discharged and at present it operates comfortably within the licensing conditions. This situation is the result of series of technical measures and vigorous management efforts:

- All pots are hooded and the hooding standards are high. Potroom housekeeping is good with few spillages.
- All potlines are equipped with dry scrubbers. Line 1 was installed without hoods on the pots and the roof discharges were scrubbed. After few years of operation the



original design was changed, hoods were installed and presently instead of the roof the pot fumes are collected and scrubbed.

- The company operates an extensive pollution monitoring system, which includes 8 roof and 11 stack pollution measuring points. There are several ambient air analysis stations around the plant measuring fluorides, oxides of sulphur and particulate material. Nine staff work full time on environmental monitoring and the results for recent years confirm the excellence of the pollution control exercised by the production departments. The current level of fluoride discharge from the plant is 0.7 kg of fluoride per tonne of metal produced.

The official guardians of amenity of the State of Pará have some capability of making their own measurements to ensure compliance with the operating license. These technicians have had training from the ALBRAS staff and it is interesting that some ex-ALBRAS employees are now employed by the State in the capacity of pollution control monitors.

Despite the great attention given to pollution control at this plant, some damage to vegetation has been reported. This is being investigated by EMBRAPA (Empresa Brasileira de Pesquisas Agropecuárias) and a well known international specialist botanists Dr. L Weinstein from Cornell University is providing consultation to the Company.

▪ CARBON PLANT

The exhaust from the older bake furnaces is wet scrubbed and gives rise to a sludge of pitch condensate and solids. The newer bake furnace is dry scrubbed.

Water pollution

The water from the bake furnace wet scrubber is conducted to a settling pond for treatment prior to discharge. This pond was also once used to treat water from the old potroom roof scrubbers. The carbonaceous residues collected from this water are collected and disposed of to a controlled sealed hazardous waste tip some kilometres from the plant site. The treated water is run to drain. The plant process drain once ran into a stream that passed through a nearby village on its way to the Para river. This flow has been diverted to discharge towards the sea, away from the village.

Solid waste

The storage conditions for spent potlinings are excellent with ventilated walled buildings and controlled drainage to collect water should this ever become necessary. The spent pot linings will remain in the buildings until they can be rendered harmless. Currently, research is being undertaken to add the spent pot linings to the raw material of brick making in Para. Local bricks are of low quality and it appears that the addition of spent pot linings containing sodium and fluoride improve product quality and reduce the energy required to bake the brick. Since wood is used to fire brick kilns this technology could be an environmentally friendly way to dispose of spent potlinings and save the forests of Brazil.



Maintenance and housekeeping practices

The plant looked well maintained and in an excellent condition. Although we were informed that recent powercuts had led to some damage to hoods and lowering of hooding standards, the rooms we were shown had very clear atmospheres and hoods appeared to be in a good condition and in place. General housekeeping of roads and work areas was excellent.

Worker safety

There was a very high safety awareness on the plant. Safety clothing, hard hats, safety footwear and eye protection was worn in the work areas. Part of the potrooms have on several occasions achieved more than one million manhours worked between lost time accidents. Traffic on site moved slowly and carefully. Drivers wore safety belts.

General assessment of the technical performance of the plant

Although ALBRAS is equipped with quite small pots by modern standards they were being operated very well. The low levels of energy and material consumption are evidence of good operation. Environmental and safety awareness and performance is good.

Albras is a well managed, efficient operation.

ALUMAR

Air pollution

There is a very comprehensive monitoring programme in operation at this facility. This was the only smelter we have seen during the mission using the EPA method of potroom roof louvre sampling. This involves the installation of anemometers and two isokinetic sampling systems in each potroom. Samples are taken over a twenty-four hour period once each month. Discharges from all stacks and scrubbers are measured but discharges from the butt cooling bay are not yet measured on a routine basis. This discharge is about 0.15 kg of fluoride per tonne of aluminium produced.

Two outplant monitoring stations capable of measuring SO₂, particulates and fluorides are in operation. Vegetation is regularly examined and analysed and the services of an expert botanist from Cornell University are used on a consulting basis to advise on the status of local vegetation. In the past, some damage to the leaves of some sensitive plants has been observed.

The plant is operating well within the conditions of its operating license by which on an annual basis, fluoride discharges must be below 1.25 kg per tonne of aluminium produced and particulates must be below 5.0 kg per tonne of aluminium produced. We were advised that future licensing conditions might refer to the concentration of pollutants in ambient air at certain locations rather than to permitted discharges which are related to production. Thus the work now being carried out using ambient air stations is of great importance.



▪ **POTROOM**

All pots are hooded with well maintained properly located hoods and the facility to increase gas flow to the scrubber when end doors need to be opened or hoods removed.

Potroom housekeeping was excellent and there was no evidence of alumina or bath spillages. The air slide alumina conveying system virtually eliminates the discharge of alumina particulates into the atmosphere. Pot fumes are conducted to dry scrubbers located in the courtyards.

▪ **CARBON PLANT**

Fumes in the green carbon plant are collected and discharged to the atmosphere via fibre glass filters.

Very high standards of operation of the bake furnaces, plus excellent flue maintenance, result in almost clear stack discharges even though scrubbers are not used. 0.15 kg of fluoride per tonne of metal produced is released here and, if it is ever necessary, this could be reduced by the use of dry scrubbers. The opacity of bake furnace stack gases in 1992-1993 was well below 10% which favourably compares with the legal limit of 20%.

Reduction in the discharge of fluoride from the plant achieved through consistent implementation of above measures is shown in the Table 2.3.1 below.

Table 2.3.1 Fluoride discharge (kg F/t Al) of ALUMAR

Year	1989	1990	1991	1992	1993
Potrooms	0.56	0.60	0.40	0.25	0.24
Scrubbers	0.086	0.025	0.051	0.020	0.014
Bake Furnace	0.65	0.64	0.25	0.27	0.16
TOTAL (Legal limit = 1.25)	1.30	1.20	0.70	0.54	0.41

Thus, very high standards are being achieved in the minimization of fluoride discharges into the atmosphere.

Water pollution

There were no problems of water pollution reported at the Smelter site.



Solid waste

The storage of spent pot linings is excellent. It is done in enclosed buildings until they can be rendered harmless in accordance with the best practices of the industry. Twenty-five thousand tonnes are presently stored on site and there is still room in the buildings for a further two years arisings.

The plant is involved with another smelter in the investigation of procedures to dispose of this material via the brick making industry.

Maintenance and housekeeping practices

The condition of the plant and all the equipment seen was excellent. A very high standard of housekeeping is maintained in all work areas and on roads and open spaces. Grass and trees are being planted on parts of the site.

Worker safety

High standards of industrial hygiene and safety are achieved in this plant. Safety clothing was worn whenever required and active safety programmes managed by a safety specialist are ongoing. Traffic moves slowly and parks carefully.

General assessment of the performance of the plant

The plant is operating very well by any standards. The safety of employees, the protection of the environment and the attainment of quality in all aspects of the operation are major concerns of the people of this plant at all levels. Ongoing programmes are in place to continually improve all aspects of the operation.

The equipment installed in the plant is being used efficiently and the steadily improving performance over the past few years is an indication of the capability and commitment of employees. It was stated that 80% of the improvements were due to people and 20% due to technology.

ALUMAR is well managed and well operated and could serve as an example to other smelters in the Region which have yet to solve their problems of environmental protection.



VALESUL

The environmental, industrial, hygiene and safety management of this plant is of a high standard. Plans for continuing improvement extend to several years ahead. Problems have been identified and solutions are being sought and tested vigorously. The monitoring programme ensures that no discharge goes unmonitored and that the plant remains in compliance with its licensing conditions.

Air pollution

The plant has an excellent environmental monitoring programme. There are two offsite monitoring stations selected in compliance with the environmental authority (FEEMA) at the nearby schools, one 3 km north of the plant and one 2 km south of the plant which measure fluoride, particulates and SO₂. Recent results show that compliance with official standards is being comfortably achieved.

Table 2.3.2 Air pollution standards and actual data for recent years at VALESUL

	Standard, $\mu\text{g}/\text{m}^3$	Actual, $\mu\text{g}/\text{m}^3$
Fluoride	0.84	0.1
Particulate	80	40-70
SO ₂	80	6

▪ POTROOM

In the potrooms all pots are fully hooded and fitted with end doors. Potroom atmospheres are clear. Pot fume is efficiently collected and conducted to two dry scrubbers located in the courtyards.

There are facilities on site to sample all stacks and to sample the roof louvres of the potrooms. The latter are sampled weekly using a Reynolds technique at one point in each potroom. Results lie well within the licence conditions for the plant but particulate discharges sometimes exceed the more stringent standard the plant sets for itself and, therefore to reduce particulate discharges, the life of bags in the dry scrubbers has been halved from four to two years.

The licence permits 1.25 kg of fluoride to be discharged per tonne of aluminium produced. The plant standard presently is set at 0.47 kg. In June 1993, the total fluoride released from the plant was 0.39 kg/tonne of aluminium. Of this, 0.17 kg came from the scrubbers, 0.11 kg came from the roof louvres and 0.01 kg came from the bake furnace stack. These are excellent figures.



■ CARBON PLANT

Pitch fume in the green carbon plant is collected and discharged to atmosphere via a baghouse.

The bake furnace exhaust is discharged to stack via an electrostatic precipitator after water spray pre-cooling.

As with all such scrubbers when used on a closed ring furnace, 14 to 15 tons of condensed pitch fume are collected monthly. Since the smelter is near to the pitch producer, this material can be returned and consumed in the tar distillation process and thus is not a problem at this plant.

The butt cleaning facility in the rodding room is effectively hooded and fume is collected in a large baghouse.

There are no scrubbers in the cast house to collect chlorine and hydrochloric acid after metal fluxing since only small quantities of chlorine are used.

The general housekeeping and handling of raw materials is good and dust generation is low. Liquid pitch is used, thus eliminating pitch dust from the site entirely.

Water pollution

Green anodes are water-cooled in large troughs and the water becomes contaminated with pitch condensate and particulates.

Closed circuit cooling water for the casting shop becomes contaminated with casting lubricants and hydraulic fluids over a period of time. Oil disperser is used to inhibit the contaminants and allow chemical treatment.

Solid waste

Spent pot linings are presently stored on roofed concrete pads with facilities to collect any water runoff that may occur. The buildings are not walled and some wind-blown dust may arise from this area.

Considerable efforts are being made to find an environmentally acceptable way to dispose of spent pot linings. Tests are being carried out to check its suitability for use as a deoxidizer and slag former in a process to make ferro-alloys. If successful, 400 tonnes per month of spent pot linings could be consumed. Further tests are to be undertaken to find out if it can be used in cement kilns. It is not expected to use the material in brick manufacture in this area, since here this is an old and small-scale industry with no experience of handling potentially hazardous materials.

For all other solid wastes from the process, a commercial environmentally acceptable destination has been found.



Maintenance and housekeeping practices

The plant appeared to be generally well-maintained. The green carbon fume collecting system was discharging to atmosphere and required attention. The horizontal bath removing chisels on the butt cleaner were not working at the time of the visit and some manual cleaning was being carried out.

The plant housekeeping was of a high standard, and there was no evidence of alumina or bath pillages.

Worker safety

High standards of industrial hygiene and safety are in place in this plant. Regular urinary fluoride analysis takes place. Safety clothing is worn wherever it is required. Traffic moves carefully. The plant regularly works one million manhours without a lost time accident.

General assessment of the performance of the plant

The plant is operating the equipment it has reasonably well but, in view of the very high price of energy, modernization of the potlines is an urgent requirement. It is expected to achieve a current efficiency of 93%, a reduced anode effect frequency and a reduced specific energy requirement following the introduction of point feeders, modified buswork changed bath chemistry and single cell micro-processor control. Environmental awareness and performance is good. An amazing feature of this plant is the large number of trees growing on the plant site alongside potrooms, carbon plant etc. These are generally thriving.

Brazilian facilities not visited

According to data of the technical literature¹ *Alcan Alumínio* mine some 0.4 million tpa of relatively low quality (Al_2O_3 38-39 %) bauxite in their Ouro Preto mines and transport it by trucks over a distance of some 65 km to their Saramenha refinery.

Alcoa Alumínio produces some 0.6 million tpa of medium quality (TA 55 %; AA 46 %; TS 5 %; RS 4.5 %) bauxite in their Pocos de Caldas mines and truck it over a distance of about 22 km to their Pocos de Caldas alumina plant.

CBA mine some 0.8-0.9 million tpa (1.3 million tpa according to another source) of similar quality bauxite at their Pocos de Caldas mines and transport it by road or rail over a distance of about 350 km to their Sorocaba (Mairinque) alumina plant. As a result of the depletion of the latter reserves CBA plan to reduce the output of the Pocos de Caldas mines to about 0.5 million tpa and to start up another mine at Cataguases with an initial output of 0.5 million tpa (to be increased to 1.0 million tpa). The ore (AA 41 %; RS 3 % after washing) will be transported by rail over a distance of 170+670 km (with a transfer at Tres Rios) to the Sorocaba plant

¹Bauxite Deposits, Mining Operations and Producers of the World, Aluminium Verlag Düsseldorf, 1992



According to the discussion with Mr. José Eugênio Rosa Júnior Chairman of Environmental Committee of ABAL, the mined-out areas in the South of the country are properly rehabilitated.

Based on the information obtained from the literature² it would appear that the older alumina plants use one or another variant of the conventional American Bayer process including low-temperature digestion. Two have fluid-flash calciners (Sorocaba since 1986, Pocos de Caldas since start-up), Saramenha uses rotary kilns. Due to the lower quality of their feedstock - these plants run with substantially higher than ALUMAR bauxite consumption, e.g. Saramenha consumes 3.25 t/t against 2.1 t/t at ALUMAR. The energy consumption figures of these plants (9 to 12 GJ/t) are also fairly good, especially for their age and capacity.

For the environmental effects of the alumina plants in the South the Team again had to rely on second-hand information from the literature and ABAL. According to these red mud disposal sites are usually dammed-off valleys, which does not provide for a complete safety against caustic leaks, however, Saramenha plant neutralizes the red mud before pumping it to the red mud pond. We could not obtain data about atmospheric (SO₂, CO₂, particulate) emissions.

It was not possible to visit any of the older Söderberg smelters which may have more environmental problems than the modern plants but in discussion with Mr. José Eugênio Rosa Júnior of ABAL, we were told that these plants were operating efficiently when the age and type of technology employed is taken into consideration. All are subject to licensing conditions imposed by the State Authorities. The ABAL Environmental Committee, which consists of representatives of each of the seven primary smelters in Brazil, discusses the environmental control performance of the smelter of the member companies from time to time.

The following facility descriptions were obtained by reference to the technical literature³:

CIA Brasileira de Alumínio (CBA) is located in Aluminio. The first pots were installed in 1955 using 32 kA Montecatini vertical stud Söderberg (V.S.S.) technology. The second line using Elken 86 kA VSS technology was started up in 1960. The 32 kA pots have been shut down in 1970, and were replaced by 64 kA pots of VSS Montecatini technology. Four newer potlines, the last of which was installed in 1990, use Pechiney 120 kA V.S.S. technology.

Pot fume is collected and scrubbed by dry scrubbers on two pot lines and wet scrubbers on the others. The plant does not yet use dry paste technology. The plant produces about 218,000 tonnes per year.

² Alumina Refineries and Producers of the World, Aluminium Verlag Düsseldorf, 1992

³ Primary Aluminium Smelters and Producers of the World, Aluminium Verlag Düsseldorf, 1992



ALCOMINAS is located at Pocos de Caldas and began operation in 1970. Three lines each of 96 V.S.S. pots are operated to produce 90,000 tonnes of aluminium per year. Dry scrubbers are used and licence conditions limit the discharge of fluorides to 1.25 kg per tonne of metal produced and particulate discharge to 5.00 kg per tonne of metal produced.

ALCAN Alumínio do Brasil is located at Aratu. One line of 176 horizontal stud Söderberg (H.S.S.) pots using N.K.K. technology was installed in 1971 and operates at 62 kA. This is presently shut down. A second line of 96 V.S.S. pots, based upon Sumitomo technology, was installed in 1983 and operates at 120 kA. This line has a dry scrubbing system. The plant produces 60,000 tonnes per year.

ALCAN Alumínio do Brasil operates also a plant at Saramenha. The first potline of ELCHEM H.S.S. pots was installed in 1945 and has now been shut down. The second line of 142, 65 kA pots using ALCAN Arvida technology was started in 1958. The third line of 168, 66 kA pots using N.K.K. technology was started in 1978. The output of the two operating lines is 52,000 tonnes per year. The pots are hooded and wet scrubbers are used. Working conditions are good. A programme for retrofitting for dry scrubbers is under way.



2.4 Barriers to Sustainable Development

a. Structure and Profile of the Industry in Brazil

The aluminium sector in Brazil consists of eleven bauxite mines, four alumina refineries, seven primary aluminium smelters, 300 large and medium size transforming companies, and 35,000 small and micro companies. These enterprises operate under various types of ownership structure. Despite of its large size and diversity of ownership, the Brazilian aluminium sector seems to have a coordinated and uniform environmental approach. The plants are mutually benefitting from the variety of experiences and expertise in the field of cleaner technologies and practices available in the country.

Transnational aluminium companies are direct participants in Brazil's aluminium industry at several locations, (see section 2.1., Table 2.1.1). Most, if not all, of the world's technical expertise on mine rehabilitation, dry stacking of red mud, fluoride emission control, safe disposal of pot linings and other environmental management aspects of the industry, resides within the transnational firms. They have been able to apply their wide experience, substantial resources and technical capability in environmentally sound operating practice to the Brazilian operations with which they are associated.

An instrumental role in attaining of this common environmental approach has also been played by the Brazilian Aluminium Association (ABAL). The Association has created an Environmental Committee constituted of representatives from all the Brazilian alumina and aluminium plants. The Committee promotes exchange of information on cleaner technologies and approaches among its member companies. Mutual environmental assessments, environmental audits, workshops on common problems are some of the activities executed by the Committee.

In the given conditions the transfer of advanced technologies and operating practices to the well trained Brazilian engineers is a real success story.

Unlike the situation in other countries covered in this report, the structure and profile of the industry are not barriers to sustainable development.

b. Status of regulatory programme

In Brazil, authority to control the environmental impacts of the aluminium industry is exercised by bodies at both the Federal and State levels. At the Federal level the main forum for discussion of national environmental issues is the National Council for Environment, (CONAMA), on which all concerned parties, including Government, Industry and Non-governmental organizations, are represented. CONAMA is chaired by the Minister of Environment.

The Brazilian Institute of Environment, (IBAMA), is the executive and technical branch of the Federal Ministry of Environment. IBAMA's normative functions include establishing standards (maximum allowable concentrations of selected pollutants), for atmospheric



emissions and also discharges to natural watercourses. Standards established by IBAMA are based on those employed by the US EPA. The following general approaches to standards would apply to the aluminium industry:

In the case of water, Federal standards for fluorides, chlorides, pH and aluminium ions vary according to the class of water body into which the industry is discharging, (potable, class 1,2 or 3 and salt water). Daily maxima and annual average standards are applied to atmospheric emissions of SO₂, particulates and CO₂. IBAMA is also responsible for issuing, operating licenses for industrial facilities located in environmentally sensitive areas (this would apply in the case of bauxite mining operations in the northern states).

Standards are also established by State Authorities. These must be equivalent to, or more stringent than, Federal standards. Pará, Maranhão, Rio de Janeiro and São Paulo states, where aluminium industry operations are concentrated, all have comprehensive regulatory programmes in operation.

The State Environment Secretariat of São Paulo for instance includes several agencies. One such agency, The Environment and Sanitation Technology Office, (CETESB), coordinates environmental quality control for water, air and soil. As such it has primary responsibility for regulating the environmental impacts of the aluminium industry. Among other duties, CETESB is responsible for licensing polluting activities, compliance monitoring (inspection) and enforcement. CETESB has the authority to close operations for persistent non-compliance. Corrective action is triggered by complaints, and through inspections. Enforcement is applied through warnings, fines and cessation orders. CETESB's approval is required for all new industrial projects/expansions, which would include aluminium industry activities, and the approval of licenses of which there are two types:

- Installation Licenses, which establish technical requirements for pollution control;
- Operation (includes evaluation of the performance of pollution control plants).

CETESB maintains an inventory of major sources of pollution and also undertakes its own ambient monitoring in the vicinity of industrial facilities which, in principle, would facilitate detection of any adverse impacts on receptors of emissions (such as fluorides or caustic soda) from bauxite/alumina/aluminium operations.

In Rio de Janeiro, the State Secretariat for the Environment and Special Projects (SEMAM), is the central office among the State's several environmental authorities. The State Environmental Engineering Foundation (FEEMA) is one of several decision making agencies which support SEMAM. FEEMA is responsible for implementing environmental protection policy in Rio de Janeiro State. Among its other responsibilities, FEEMA issues licenses and undertakes inspections. The State Environmental Protection Commission (CECA) also has certain regulatory functions. It can levy fines and enforce regulatory compliance. Aluminium industries must be licensed by FEEMA.

The UNIDO team was provided with a copy of an operating license issued by FEEMA to Valesul Alumínio S/A in Rio de Janeiro State. The licence authorizes the smelting



operations of Valesul for the production of aluminium metal. Details of the environmental impacts of Valesul operations are given in section 2.3 of this report. The licence establishes maximum allowable concentrations of pollutants (fluorides, "organics" and "non-organics") per ton of aluminum produced, which are equivalent to the highest standards used elsewhere in the world. Monitoring procedures for gaseous and particulate fluoride emissions and for ambient concentrations of particulates, fluorides and SO₂ at appropriate locations are established. Valesul is required to undertake the monitoring programme and to report results regularly to FEEMA. The licence also establishes maximum concentrations of pollutants in liquid discharges and makes general provision for hazardous wastes management.

In the State of Pará the State Secretariat for Science, Technology and Environmental Protection (SECTAM) is responsible for issuing operating licenses and implementing inspection programmes in the industry. IBAMA is responsible here mainly for the agriculture and forests. Before a license is issued an environmental impact assessment is prepared by independent consultants, a study is made on the social aspects of the project and a public hearing takes place. The second phase is to issue a license for the installation and, finally, in the third phase the operation is licensed. SECTAM has the right to close companies in case of continuous breach of regulations and/or unauthorized use of environmentally hazardous substances. Multinational plant owners report through their Brazilian partner (e.g. CVRD in the case of ALUNORTE). Here the environmental department has been operating already eight years with about 200 technical in a laboratory, which was set up with assistance from Japan.

In Maranhão the environmental policies are implemented jointly by the local IBAMA representation and the State Secretariat for Environment Protection and Tourism, SEMATUR. SEMATUR is not well equipped and relies heavily on the assistance of FEEMA from Rio de Janeiro and CETESB from São Paulo. Licenses in complex cases are issued by SEMATUR in consultation with the aforementioned more experienced institutions. In some cases consultants are hired and their cost is charged to the company concerned. Monitoring is implemented by ALUMAR itself.

Observations made by the UNIDO team of the environmental impacts of plant operations and of environmental management at the plant were very favourable and indicated a serious commitment on the part of plant authorities to comply with if not to exceed the license provisions. As such, the development of regulatory programmes in Brazil cannot be viewed as a barrier to sustainable development.

c. Attitude of Plant Management

The general impression of the members of the Team based on their site visits is that the Brazilian aluminium operations are well managed. The high performance of the plants can be attributed in many respects to good management practices. The staff is committed to their work and large emphasis is placed on improvement of the environmental performance of the plants. The companies implement modern and ambitious environment management programmes based on strict environmental policies and with full participation of the staff at each level. Regular training of staff is an integral part of these programmes. All plants



have strong cooperation with the environment protection authorities, maintain close contact with the local communities and run several public relation programmes.

In the mining sector MRN had spent in excess of US\$ 91 million by end 1992 for environment protection at the Trombetas operation. Selection of proper rehabilitation procedures was of utmost importance because the mine is situated in the Amazon region. Thus, revegetation with native species was selected as the most appropriate (however by far not the least cost) solution, which facilitates most effectively the restoration of the original rainforest.

An agreement with IBAMA (Brazilian Institute for the Environment and Renewable Natural Resources) aims at the protection of the Trombetas Biological Reserves (385,000 ha) and the Saracá-Taquera National Forest (429,600 ha). MRN provides technical, scientific and financial support to the programme in this sensitive area of Amazonia. Further agreements with Brazilian and renowned international scientists assists the company to restore the damage to the natural environment.

ALBRAS is also located in the Amazon region. The environmental policy of the plant includes:

1. *Strive for integration of the Company with the community and the inhabitants of the Amazon Region within the area of influence of ALBRAS, thus respecting their way of life and culture as much as possible.*
2. *Avoid and control the emissions from the Company with a determined effort obeying the current legislation and always trying to attain the best possible standards.*
3. *Catalyze and stimulate the preservationist conscience of the local community and employees through educational campaigns.*
4. *Give those responsible for pollution control the necessary equipment and training to operate it at optimum performance.*
5. *Develop and implant techniques in the operation of the ALBRAS smelter to improve the quality of the air, water and soil.*
6. *Emphasize that the project as a whole has Man and his well-being as its main objective."*

The above statement is well demonstrated in the every day practice of the Company. Apart from the technical pollution abatement measures described in Chapter 2.2 ALBRAS also maintains a horticultural nursery and a 3,500 ha forest reservation around the plant. During the recent years 600,000 native tree seedlings have been planted here. Cooperation agreements with various universities and R&D institutions aim at improvement of the environmental impact of the region and the image of the Company.

In case of ALUMAR the excellent environmental programme of the Company deserves special attention. Brief description of the programme is attached to the report.

At VALESUL the large number of trees planted in the Company next to the production bays shows not only the commitment of the staff towards environment protection but these plants act also as permanent and sensitive natural indicators of pollution levels.



d. Site specific and technical barriers

The majority of the aluminium operations in Brazil are situated in environmentally sensitive areas. This requires special efforts and constant attention of the plant management. However, with the presently applied and constantly improved rehabilitation and environmental protection procedures there are no site specific or technical barriers to sustainable development of bauxite mining, alumina and aluminium manufacturing in the Northern/North-Eastern region of Brazil. Only a limited world market demand and limited investment funds may act as barriers.

One of the most important technical barriers to the general development of the aluminium industry in the South could be the availability and price of electric power for smelting. With a possible shut-down of the Southern aluminium smelters the fate of the bauxite mines and alumina refineries would be sealed.

Another (longer-term) site specific barrier in the South could be the availability of bauxite, which seems to be secured from the immediate vicinity for only a few decades at the present production level. These alumina plants - being landlocked - could hardly survive on overseas bauxites.

The aforementioned technical barriers in the South are aggravated by the lower efficiency and greater pollution intensity of the older mine and plant facilities.



2.5 Strategy for Sustainable Development in the Bauxite/Alumina/Aluminium Industry

The mine, alumina plant and the three prebake smelters we visited in Brazil were all commissioned in the last fifteen years and have all kept abreast of technological developments to improve efficiency and to minimize their impact on the environment. They are all well managed with a continuing managerial emphasis on operational improvements and environmental protection.

All the operations have impressive self-monitoring programmes and all of them operate under formal licenses which clearly specify the levels of containment of pollutants which are required. All these plants are comfortably exceeding the license requirements and could meet EPA Standards to operate anywhere in the World today.

In the light of the sharply increasing cost of energy and the introduction of stricter environmental legislation however, parts of some of the older plants may be shut down or about to be shut down.

There are some areas for technical improvement for the newer plants as well which are detailed in the following part of the report.

The high performance of the bulk of the industry indicates that not only appropriate equipment and technology, but well trained and motivated staff are also available. In addition to this Brazil has very large deposits of good quality bauxite. The hydroelectric power potential is tremendous. These factors provide excellent preconditions for Brazil to strengthen her position among the leading aluminium producers of the World. The export revenues of the industry even at the present historically low prices already exceed one billion US\$. To continue the dynamic growth of the industry settlement of power price disputes between the aluminium and power producers would be necessary. In this regard linking the power and metal prices, which is widely used in other parts of the world should be considered. Restriction of production through power modulation as exercised e.g. by VALESUL due to disproportionate power price increase, will lead to operating inefficiencies and undesirable consequences.

a. Strengthening Policy and Regulatory Programmes

Comprehensive regulatory programmes and legislation are in place in all states in Brazil where aluminium operations are located. Compliance with licenses (permits) was found to be enforced in both São Paulo and Rio de Janeiro states and in the northern states of Pará and Maranhão.

The UNIDO team was able to observe first hand the environmental impacts of mining, refining and smelting operations in the northern states. These are discussed in detail in section 2.3. The industry's efforts to minimize negative environmental impacts are at a level equivalent to those found anywhere else in the world.



Visits to operations in São Paulo and Rio de Janeiro included only the Valesul Smelter in Rio de Janeiro state. Consequently it is not possible, in this report, to evaluate the regulatory programmes in São Paulo (CETESB) to see the extent that they minimize the negative environmental impacts of the aluminium industry. The UNIDO team was assured by industry representatives (ABAL), that the smelters not visited were operating efficiently when the age and type of technology is taken into account. Authorities from all states visited also assured the UNIDO team that licenses were enforced and companies reprimanded for violations. As described in section 2.3 the environmental record of the Valesul Smelter in Rio state is exemplary.

The high level of concern for the environmental impacts of mining, refining and smelting operations exhibited by the aluminium industry, particularly in Pará and Maranhão states, can be attributed to several factors, in addition to State and Federal regulatory programmes.

The high profile of the transnationals and the sensitivity of the unique environments, where mines, refineries and smelters are located, particularly in the northern states, have contributed to fostering a highly responsible attitude towards environmental management on the part of the operating companies.

Given the size of the industry and the importance of its contribution to national and state economies, regulatory authorities will want to maintain their good working relationship with the operating companies. It is probable that, particularly in the northern states, regulatory bodies will depend on the industry to "self-monitor" its environmental performance for some considerable time to come. Currently, any new policies to improve the environmental performance of the aluminium industry in Brazil should offer further encouragement to the operating companies to continue to deploy the most modern environmental management techniques available.

The command and control (CAC) approach can effectively control polluting emissions where a few large operations dominate the industry (since monitoring and enforcement are easier). In the case of Brazil's aluminium industry, however, the incremental benefits of stricter regulations would probably not justify the additional resources required, particularly in Pará and Maranhão, or the risk of souring the goodwill which exists between the authorities and industry. As stated above, the regulators depend on the industry for much of their information on ambient pollutant concentrations and the state of receptors as well as the industry's commitment to sound environmental practice.

As a result of both reasonably effective regulations and also external pressures, the environmental impacts of Brazil's aluminium industry are maintained at a level (at least in respect of those sites visited by the UNIDO team), which can be considered acceptable to most concerned parties. They are considerably less damaging than those observed by the team in other countries of the Latin America/Caribbean Region.

With the foregoing observation in mind, the Brazilian Authorities may wish to consider the following suggestions based on the team's field observations.



- To continue their policy of negotiated compliance, which, in the long term, will be more effective than either stricter regulations or taxes and charges in promoting management strategies which introduce waste minimization, pollution prevention and cleaner production. Flexible guidelines such as technology-based standards could be incorporated in licenses. The objective would be to accommodate both the sensitivity of receptors and the vintage of the installed plant. Such arrangements would, for example, give operators of the older Söderberg plants time to introduce the retrofit technologies.

Given the long anticipated working life of capital facilities employed in most of the aluminium industry, over which statutory environmental objectives are likely to vary, voluntary agreements are more likely to favour efforts to recycle rather than the installation of end-of-pipe solutions which may, with time, become inadequate. Spent pot linings (SPLs), for example are a worldwide problem for which the best solution is currently storage in a manner which prevents both contamination of water and wind blown dust. SPLs are the subject of intense international research to identify appropriate means for their safe recycling. When a solution is found it will rapidly be adopted as the industry norm, to which authorities will expect all plants to adhere. At this stage, voluntary agreements with the regulators, allowing temporary but safe storage, would enable the smelters to rapidly adapt to new recycling opportunities when they become available.

- Single medium permitting, as is currently the case in Brazil, can transfer pollutants from one medium to another. Bake furnace flue gas wet scrubbers, for example, generate sludges containing toxic aromatic condensates which are a disposal problem. Coordinating the issuing of licenses for air, water and hazardous waste emissions is a useful first step towards integrated, multi-media permitting which would treat smelters and refineries as whole entities. Under such an arrangement one integrated permit could be issued for the entire regulated facility so as to eliminate opportunities to transfer pollutants across media. This would encourage waste minimisation through, for example, the use of dry scrubbers on bake furnaces or simply higher standards of bake furnace maintenance and operation (see environmental evaluation of the ALUMAR smelter), to minimize bake furnace flue gas.
- Regulations which call for the gathering and reporting of information on releases to the environment have the effect of stimulating efforts to reduce wastes. Such an approach would be applicable to fluoride emissions from smelters.

b. Institution and Human Resource Development to Implement Regulatory Programmes

To ensure that environmental considerations are fully integrated into development of the aluminium industry it may be necessary to strengthen capability in environmental impact assessment for application to new developments and expansions of existing facilities.

The team observed that Regulatory authorities in Rio de Janeiro and São Paulo states are equipped with the necessary resources to exercise effective control over the environmental



impacts of the aluminium industry. Resources available to the authorities in Para and Maranhão states are more limited. As discussed in paragraph 2.4.b the regulators in these states depend heavily on the industry to undertake self-monitoring. Such technical staff that are available were trained in the industry.

c. Environmental Management at Plant Level

Environmental management at the mines and plants visited by the Team are of high standard and serve as good examples for other producers in the Region. These management programmes incorporate major elements of the same of multinational companies e.g. at ALUMAR experience of ALCOA is taken into consideration. International experience is regularly transferred through a scheme of exchange of information between the subsidiaries of multinational companies. However, transfer of foreign know how would not have been successful without active participation of Brazilian managers and experts. The know-how was adapted to local conditions and enriched with local experience. This approach should be further encouraged and disseminated.

d. Opportunities for the Introduction of Pollution Prevention and Cleaner Technologies

- Very little can be done either at the Trombetas mines or at the Alumar refinery to further improve their environmental performance.
- According to second hand information collected by the UNIDO team, red mud disposal sites of the alumina plants in the South are usually dammed-off valleys, which do not adequately safeguard against caustic leaks. Saramenha plant neutralizes the red mud before pumping it to the red mud pond. In this plant 95% of the steam required for the alumina plant is produced by electrical boiler. The positive experience of ALUMAR in handling the red mud problem should be studied and gradually taken over by these plants to avoid contamination of ground water.

The Team did not obtain data about atmospheric (SO₂, CO₂, particulate) emissions of the alumina plants in the South. Nevertheless this issue doesn't seem to be a major one and in case of any problem solutions can be found locally.

- It is not possible without spending some time at the considerably older, Söderberg plants in Brazil to comment upon the degree of modernization that has been undertaken. Several major aluminium producers offer retrofit technology to improve the efficiency of Söderberg cells and to provide better working conditions and reduce environmental impact⁴. The technology includes, where appropriate, the use of dry anode paste, the introduction of point feeders, cell automation, fume collection improvements and the use of dry scrubbers. Such retrofitting has been necessary at a number of locations around the world to achieve conformance with increasingly strict licensing requirements and to keep the facilities commercially competitive.

⁴Light Metal Age, Vol. 51, February 1993



- Proper management of spent pot linings represent a major problem all over the world. All three smelters visited by the Team in Brazil are carrying out large scale experiments to resolve utilization of spent pot linings. The orientation and results reported by the companies appear promising. It is strongly encouraged to finalize the tests, select the most appropriate technology and disseminate it among the producers in the Region.

- **ALBRAS**

To eradicate the only pollution source not tackled yet the wet scrubber on the older bake furnace is to be replaced by a dry scrubber and thus the problem of generating the carbonaceous sludge will be eliminated. Until that time, the sludge should be disposed of safely to a sealed hazardous waste tip according to the present practice.

- **ALUMAR**

Very high standards of operation of the bake furnaces, plus excellent flue maintenance, result in almost clear stack discharges even though scrubbers are not used. 0.27 kg of fluoride per tonne of metal produced is released from the bake furnaces and, if it is ever necessary, this could be reduced by the use of dry scrubbers.

Apart from the possibility of scrubbing the exhaust from the bake furnaces the only places where significant improvement is clearly possible is in the butt cooling area where butts stand after removal from the pot and the butt cleaning area where butts are cleaned manually and butt materials accumulate. Both these areas are receiving consideration from Management and will shortly be improved.

- **VALESUL**

To increase efficiency of the potlines, point feeders, modified buswork and single cell microprocessor control could be installed and the bath chemistry could be modernized. The upgrading has already been started, however the present low metal and high current prices might hinder the project.



e. Cost of new, cleaner technologies

Neither the Trombetas mine nor the ALUMAR refinery and the smelters visited appear to need large funds for new, cleaner technologies apart from those programmes which have already been started. At MRN an increase of the present 0.25 M US\$ yearly environmental fund to 0.5 to 1 million US\$ per year could mean a further improvement of the rehabilitation programme. (The International Primary Aluminium Institute in its Bauxite Mine Rehabilitation Survey prepared in December 1992 found that various bauxite producers are spending for mine rehabilitation US\$ 0.12 - 0.55 per dry tonne of bauxite delivered. (In 1992 MRN produced 7.3 million tonnes of bauxite.)

As far as the other mines, refineries and smelters are concerned, we can not give any estimate of the funds required.

- ALUMAR - ENVIRONMENTAL MANAGEMENT

- Line Management Responsibility

- Operational Plan Deployment

- Standard Operating Practices Enforcement

- Awareness Training

- Cooperation between Operating and Environmental Areas

- Audits - Communication - Feedback

2. ENVIRONMENTAL MANAGEMENT PROCESS

- . DEPARTMENT ORGANIZATION
 - TECHNOLOGY
 - MONITORING
 - INDUSTRIAL WASTES
 - LAND MANAGEMENT

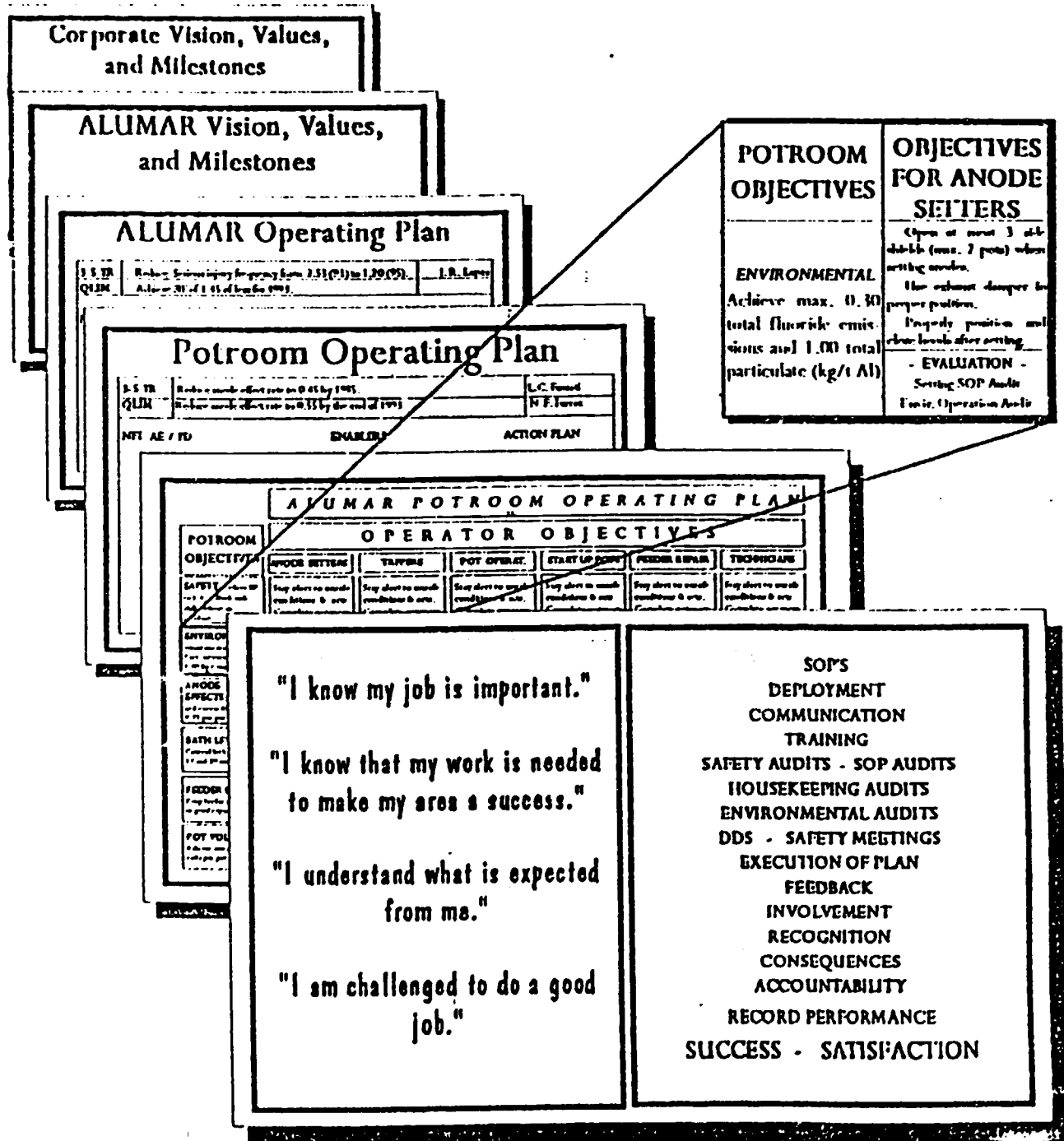
- . ENVIRONMENTAL POLICY - LINE MANAGEMENT

- . OPERATIONAL PLAN - ATTACHMENT I
 - VALUES
 - LONG TERM DIRECTION
 - 3-5 YEARS MILESTONES & QUANTUM LEAP
 - CONTINUOUS IMPROVEMENT MILESTONES

- . ENVIRONMENTAL OPERATIONAL PLAN

- . MANAGEMENT PROCESS
 - ENVIRONMENTAL MONITORING
 - ENVIRONMENTAL CONTROL
 - ENVIRONMENTAL EDUCATION
 - WASTES MANAGEMENT
 - ENVIRONMENTAL ENGINEERING
 - LICENSING
 - LAND CONSERVATION AND LANDSCAPING
 - EXTERNAL RELATIONSHIP
 - HUMAN RESOURCES DEVELOPMENT

DEPLOYMENT OF OPERATING PLAN



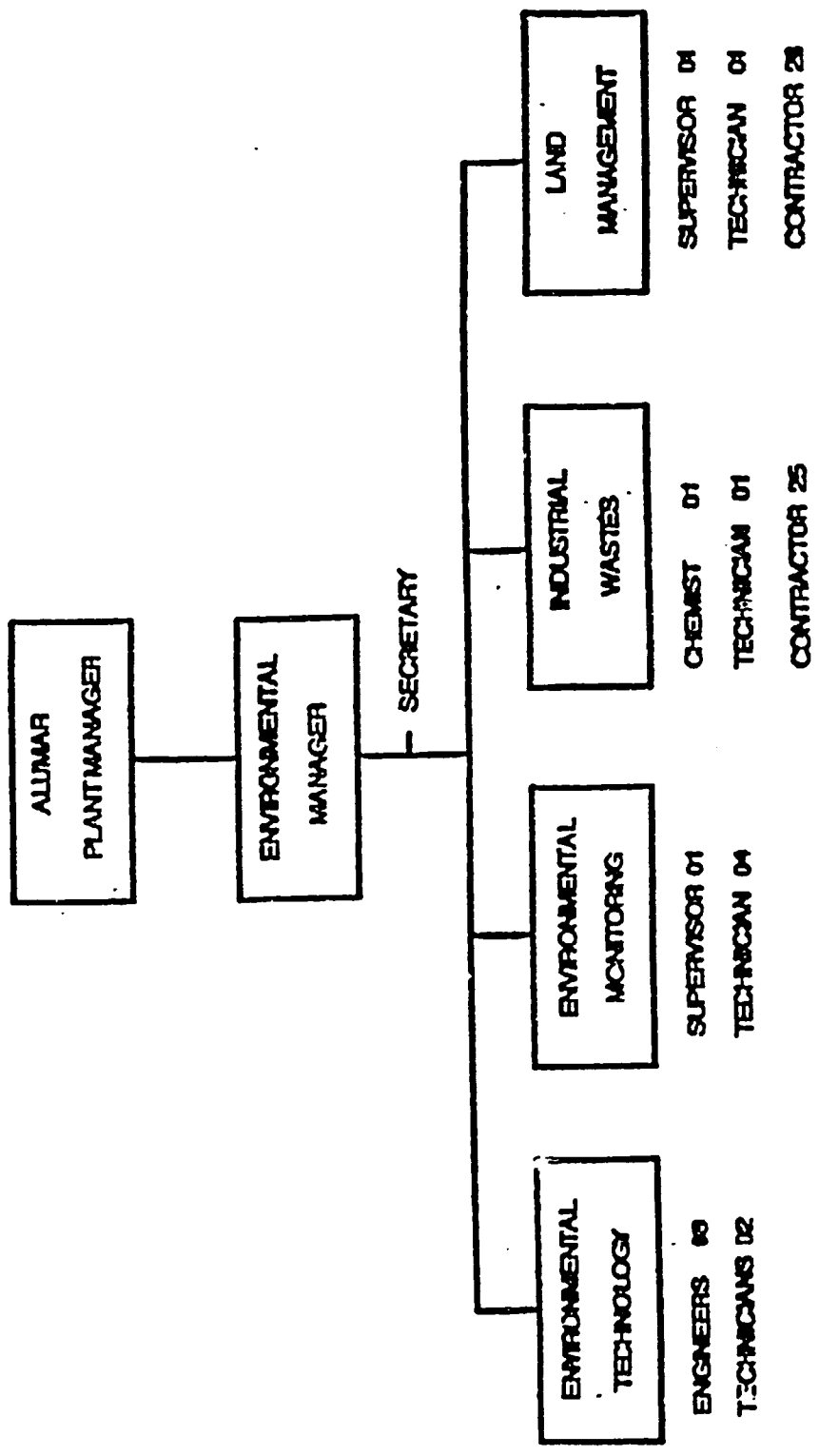
OPERATIONAL PLAN - 1992 (ATTACHMENT.1)

LONG TERM DIRECTION:
ELIMINATE OR RECYCLE ALL PRODUCTS THAT OFFER RISKS
TO THE ENVIRONMENT

3 - 5 MILESTONES:
CORRECT OR ELIMINATE ALL CONDITIONS THAT EXCEED
ESTABLISHED LEGAL OR ALUMAR ENVIRONMENTAL STANDARD
WHICHEVER IS MORE RESTRICTIVE (96)

- . REDUCE AVERAGE NUMBER OF ANODE EFFECT FROM 0.88
TO 0.75 (92) AND 0.65 (93)
- . POT LIFE - ACHIEVE 2000 DAYS POT LIFE (94)
- . REDUCE TOTAL F EMISSION FROM 0.75 TO 0.60 Kg/tAl (4Q 92)
- . ACHIEVE STACK OPACITY BELOW 20%, 90% OF THE TIME
- . MAINTAIN AVG PARTICULATE EMISSIONS AS FOLLOWS:
 - < 50 mg/m³ - BOILERS
 - < 100 mg/m³ - CALCINERS
- . REDUCE GOOD STORM LAKE WATER pH FROM 10.5 TO 5.0 - 9.0
RANGE
- . SURFACE REHABILITATION OF THE BAUXITE RESIDUE LAKE # 1
(92 - 95)
- . SPL RECYCLING DEVELOPMENT ON CERAMIC INDUSTRY (92)
- . REHABILITATE 70ha OF DEGRADED AREAS (92 - 93)

ENVIRONMENTAL ORGANIZATION





3. GUYANA

3.1 *Introduction*¹

Guyana is situated on the north-east coast of South America, with its southern half forming part of the Amazon Basin. Most of the Population live along the flat coastal plain. Its landmass of 215,000 square kilometres includes extensive areas of agricultural land and tropical hardwood forests.

Bauxite is the country's dominant mineral product with large proven reserves. Bauxite is the second largest foreign exchange earner, accounting for about a third of total export earnings (Table 3.1.1).

Table 3.1.1 Main exports of Guyana, G\$ mn

	1986	1987	1988	1989	1990	1991
Sugar	356.2	910.8	712.2	2,342.0	3,219.6	10,474.2
Bauxite	351.4	841.0	820.5	2,021.5	3,172.1	8,952.9
Rice	57.2	155.2	139.1	367.4	513.2	2,102.6
Shrimp	23.9	265.8	231.1	608.9	906.1	2,026.2
Rum	32.4	94.5	82.5	209.7	393.7	308.7
Gold	62.3	165.8	184.0	193.1	993.5	2,308.2
Timber	17.7	43.7	28.2	89.1	181.4	456.8

The Demerara Bauxite Company (Demba), the local branch of the Canadian company Alcan, started mining bauxite in Guyana (then British Guyana) in 1916. The main mining centre is at Linden, 120 km south of Georgetown. An industrial complex was established in association with the mining operations, for the beneficiation and drying of the mineral, with one factory producing calcined bauxite and another alumina. At the end of the 1960s these operations produced 75% of the ore mined, as well as all the calcined bauxite, and had a work-force of 4,500. The lack of a major electricity supply prevented the production of the final product, aluminium. At the beginning of the 1990s Guyana was no nearer to solving its power problems. Government plans for a 750 MW hydroelectric project, on the Upper Mazaruni River, were suspended.

¹Source: The Economist Intelligence Unit Country Profile 1992-93



The US company, Reynolds, began mining bauxite around Kwakwani after the Second World War, and, in 1965, was producing 15% of the total bauxite mined, with the proportion rising to 25% by 1975.

Demba and Reynolds were nationalized, in 1971 and 1974 respectively. From 1974 the industry was beset by management problems, lack of finance and a fall in demand. In 1977 the two nationalized companies were amalgamated, to form Guyana Mining Enterprises Ltd. (Guymine), but were again split, in 1992.

Not only were alumina production targets not achieved, but the actual revenues from bauxite declined. Production, in 1970, exceeded 4.4 million metric tons and even in 1974 it was 3.6 million metric tons. By 1980 a 50% reduction had taken place and further declines, to 1.43 million tons, by 1982, followed. In 1982 the industry incurred a financial loss of US\$ 22 million and the country's alumina plant was temporarily closed, in June. In 1983 industrial problems and the closure of the country's only alumina refinery reduced production to 1.09 million tons, while losses rose to US\$ 35 million. Production rose to 1.55 million tons in 1984, but this was considerably below total capacity. The problems of the bauxite-alumina industry created pressure on the Government to return the industry to private management. In 1985 the Reynolds company was invited back to Guyana, in order to provide managerial and technical assistance, to help to return the bauxite industry to profitability. Output increased slightly, in 1985, to 1.59 million tons, but fell to 1.50 million tons in 1986. In that year US\$ 8 million-worth of equipment for the bauxite industry was contributed by US and Japanese firms. Plans were announced for the revitalization of the industry and for an increase of 44% in the annual output of bauxite, by 1989.

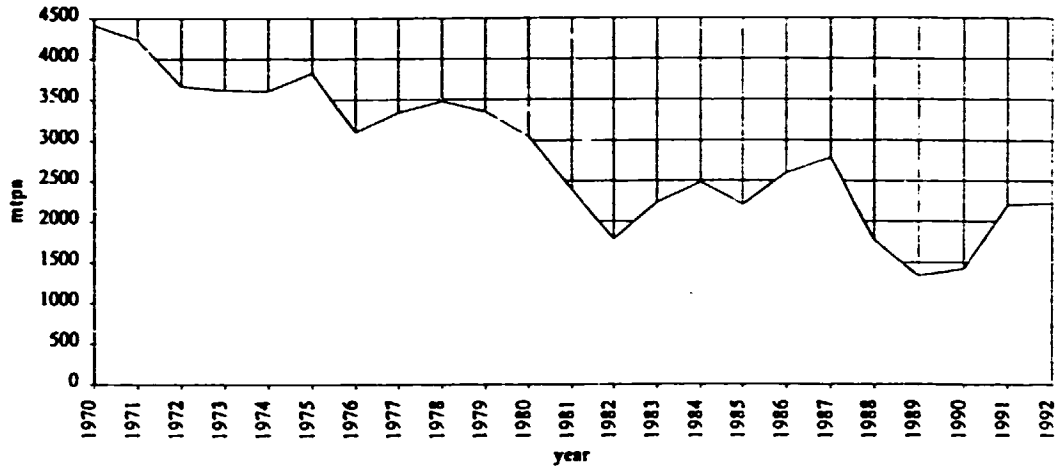
In February 1989, the Government announced a US\$ 25 million joint venture with Reynolds International, a subsidiary of Reynolds Metals, to exploit the Aroaima mine near Kwakwani, with projected deposits of 30-35 million metric tons of bauxite and possible production of 2.6 million tons per year. The newly formed Aroaima Bauxite Company began operations in mid 1991 and, by the end of the year, had produced 800,000 metric tons of bauxite. The joint venture projects an annual production of 1.5 million metric tons, equivalent to the 1986 production for the whole country. All of the bauxite was to be exported, to be refined into alumina in Venezuela, Canada and the USA. Also, with the help of Commonwealth Development Corporation funding of US\$ 8 million to the Aroaima Bauxite Co., goals to mine 2 million or more tons of bauxite per year seemed within reach.

In Linden the production is picking up since a management contract was awarded in 1992 to Minproc, Sydney, Australia.

The historical data of bauxite and alumina production are shown in the following exhibits (Figures 3.1.1 and 3.1.2).

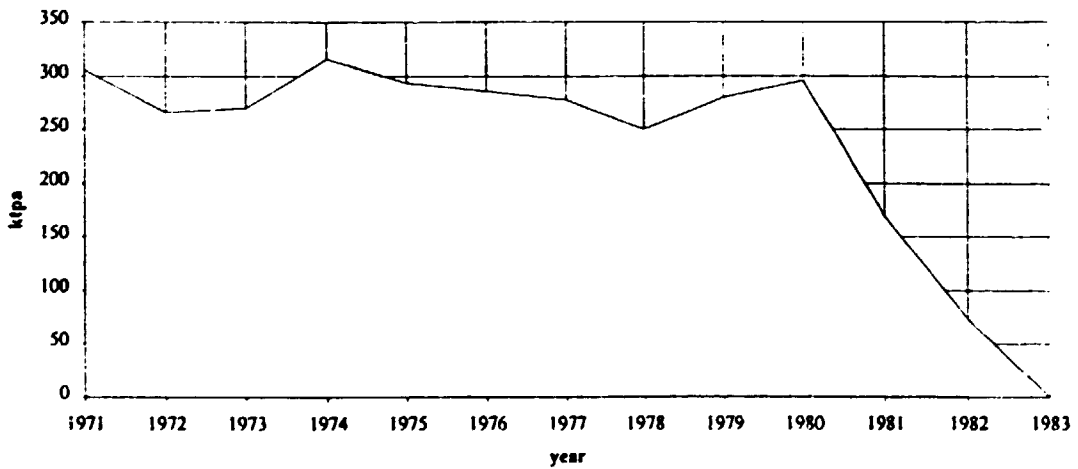


Figure 3.1.1 Bauxite production of Guyana



Source: *The Economics of Bauxite & Alumina 1993, Roskill*

Figure 3.1.2 Alumina production of Guyana



Source: *Yearbook of International Commodity Statistics, 1985 and 1993 UNCTAD*



3.2. Description of the industry

a. Bauxite Mining

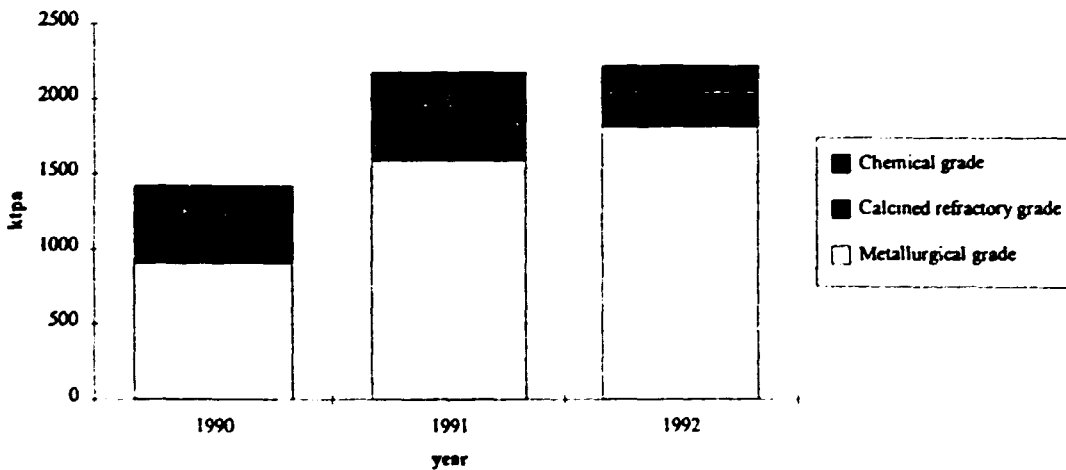
Geography, Geology

Guyana's bauxite deposits can be found in a 325 km long and 30 km wide belt running parallel to the coastline at a distance of about 120 km. Their total reserves is estimated to about 500 million t, however, some other guesses speak about several billion tonnes. The reserves lie under thick layers of overburden (sand, soft and hard clay, occasional laterite hard cap). The few outcrops of bauxite and the reserves with less thick overburden have already been mined.

Quality

Guyana's bauxites are typically high in Al_2O_3 (54 to 60 %), relatively high in SiO_2 (5 to 8 %) and low to extremely low in Fe_2O_3 (1 to 8 %). Some with the lowest Fe_2O_3 contents are well suited for calcining to refractory grade material. (Guyana used to be practically the only supplier of the world of this type of bauxite; recently China has overtaken it.) As far as mineralogy is concerned, they are of purely gibbsitic type.

Figure 3.2.1 Production of different types of bauxite in Guyana



Source: Mining Journal, Annual Review, 1993



Mining Operations

Presently bauxite mining and processing operations are undertaken at the following locations:

- **Bermine**

Located at Kwakwani 180 miles upstream on the Berbice river, annual capacity 1.5 million tonnes.

- **Linden Mining Enterprise (Linmine)**

Located at Linden 60 miles upstream on the Demerara river, annual capacity 1.5 million tonnes.

- **Aroaima**

Located 126 km up the Berbice River, not far from the Bermine operation. Bauxite mining and drying activity here started recently.

The two former operations belong to Guymine, a subsidiary of Bidco, which is government-owned. Aroaima Bauxite Co. is a 50-50 % joint venture between the Government of Guyana and Reynolds International Inc.

The Team had no opportunity to visit the Bermine and Aroaima operations, so our information on them are less extensive and reliable.

Mining Procedures

Bauxite is strip mined in large scale operations requiring the removal of up to 60 m of overburden.

Bauxite mining in the *Linden area* was started by Alcan in 1916 at an outcrop on the Demerara river. Since that, mining went on to ore-bodies lying deeper and deeper underground.

The total amount of bauxite mined in the Linden area used to be well over 2 million tpa around the time of nationalization. Poor management, lack of funds, etc. led to a gradual drop to about 600 ktpa production. Overburden removal dropped even more, threatening even this low production level. Since April, 1992 Minproc Engineering (Sydney, Australia) is responsible for mining, processing and marketing under a management contract. By 1993, the production level has already picked up a little. (Expected: about 700 ktpa raw ore.)

Presently, a mine called East Montgomery is operated. All available equipment is concentrated here. Because of the 50 to 60 m thick overburden huge stripping efforts are needed before the bauxite (9 m thick in the average) can be mined. The typical mining sequence is as follows:



A bucket wheel excavator removes the upper 20 m of white sand feeding a belt conveyor system; another 15 m of (more compacted) sand is removed by scrapers; the last 20 m of sandy clay is excavated by Bucyrus Erie draglines and thrown into the mined-out part of the pit. The mining face is about 1.5 km long. The ore itself is blasted, loaded by draglines and trucked to nearby stockpiles. From here it is transported by rail to the Linden plant.

In the *Berbice area* mining was started by Reynolds in 1940. This operation was nationalized in 1975. Presently it produces some 1 million tpa of raw ore. Here the overburden is much less thick, 20 to 25 m, however, the bauxite layer is also thinner (about 3 m in the average). The overburden is removed by a bucket wheel excavator and/or scrapers. The ore is transported by trucks to stockpiles on the Berbice river and from here barged to the Everton plant located some 225 km downstream at the mouth of the same.

The *Aroaima mine* has similar overburden and ore thicknesses (20-25 m and 3 m, respectively). This mine produces about 2 million tpa of metallurgical grade bauxite (it started in 1991 with an output of 800 ktpa). The bauxite is exported as raw ore, with some 7 to 8 % moisture content.

Rehabilitation

There is practically no rehabilitation at the Linden mine. Stockpiles and waste cover the mine site, excavations fill with water and several square miles of forest are completely denuded. Topsoil is very thin in this area, only a few centimetres of black-tainted sand on the top of the white sand. So there is nothing to cover any mined-out area with. Pits themselves are also not filled up, only some of the stripped overburden is placed in the mined-out areas of the mines.

According to our information the situation is similar in the Bermine mines.

The Aroaima mine has just begun its operation, so there was little scope for rehabilitation up to now. But there are promises that the environmental concerns will get more attention by them.

b. Bauxite Processing

In Linden, the bauxite is crushed by hammer mills and washed on a series of screens, the finest being 10 mesh (retaining + 1.4 mm material). Between 1961 and 1982 the slurry passing the finest screens was further classified by cyclones and rake classifiers and the resulting sand-like bauxite fraction was refined to alumina in the nearby alumina plant. Before 1961 and since 1982 this material goes to waste, together with the high-silica slime consisting mainly of kaolinite. 40-50 percent of the raw bauxite is lost during this washing step, however, the SiO₂ content of the oversize material is about 30 relative percents lower than that of the raw ore. There are two washing lines installed, the present low production level can be handled by one operating line. There are also 10 rotary kilns of various sizes installed; 8 are for calcining refractory and abrasive grade bauxite, 2 for drying metallurgical grade one.



Since no metallurgical grade bauxite is currently produced, the dryers are idle, and the present low production rate (expected production 240 ktpa in 1993) can be handled by 2 of the calciners. Calcining is carried out at a temperature of about 1540 °C. During calcination 30 percent of the feed is lost as loss on ignition (water bound mainly in gibbsite). Nearly 30 percent of the rest (*close to 100.000 tpa*) are lost as dust with the flue gases, due to the absence of proper dust collection equipment. The problem is that the composition of the dust particles is poorer than that of the calcined product and it does not meet specification, so there is little incentive to collect it.

According to information obtained from Bidco the Everton plant presently produces only negligible amounts of calcined products. Its output consists of about 80 % metallurgical and 20 % chemical grade bauxite (chemical grade may contain more silica, metallurgical grade more iron oxide). Both grades are dried to a moisture content of about 5 % in rotary kilns.

The Berbice bauxite contains too much fines to be washed, so its processing is restricted to crushing and drying.

Transportation

The product(s) leaving the bauxite processing plant are loaded into bulk vessels (typically about 10,000 tonnes per vessel) and shipped down the Demerara river. In earlier times these relatively small ships carried the bauxite to a transshipment point in Trinidad, from where it was carried on in larger bulk carriers. Presently the transshipment is carried out at a leased 30,000 tonnes bulk carrier anchored near the mouth of the Demerara river, but outside the sandbank which prevents larger ships navigating up the river. Shiploading and transshipment is carried out with relatively little dusting.

The ships loaded in Everton can also carry only about 10,000 t of bauxite, but these can be topped up or transloaded at the Demerara transfer terminal referred to above.

Maintenance and Housekeeping

At Linden, during the last twenty years, maintenance of the equipment and housekeeping of the plants have been neglected. The whole area is littered with broken-down, rusting equipment. Some of the idle equipment has been cannibalized for spare parts. The inner roads of the bauxite plant are muddy, at one place litter was stamped into the ground, just a few meters away the same happened to a lot of electrical cables. Under such circumstances, worker's safety can not be very good.

General assessment of the technical performance of the bauxite operations

The extremely high overburden to ore ratio characterizing Guyana's presently operated bauxite mines make their products relatively uncompetitive in the world market. Factors mentioned above (shipping problems, lack of foreign currency for spare parts, managerial shortcomings, workers' attitudes) have made this situation even worse. Under these conditions the government has to decide (after a thorough studying of all economic factors), whether it is worthwhile maintaining this industry, or it would be better to shut it down.



This thought was also expressed to our team by the Hon. Prime Minister of Guyana. The latter solution would also prevent further environmental damages.

c. Alumina Production

An alumina refinery operated between 1961 and 1982 in the vicinity of the bauxite processing plant in Linden. It was installed by Alcan to utilize the high quality fine bauxite fraction (between 10 and 325 mesh, i.e. about 0.044 and 1.4 mm) which previously was discarded in the washing phase. The refinery had a nominal capacity of 350 ktpa. It was well managed and operated up to the nationalization and even a few years beyond that.

From the late 1970s on the disadvantages of government management (general neglect, low worker morale, etc) started to show.

Though a new, up-to-date Lurgi stationary calciner was installed just at this time, the rest of the equipment was neglected and even the new calciner broke down because of careless operation. The problems were compounded by the fact that Linden alumina had always had a relatively high Fe_2O_3 content. The latter disadvantage could be compensated within the worldwide Alcan system by mixing it with other (e.g. low iron Jamaican) aluminas. However, it was difficult for the government to market this alumina independently, especially at times of worldwide oversupply. This led to the 1982 closure of the refinery, originally intended to be temporary, but, with the passing of time, it became permanent. Recent studies have shown that to restart the refinery would cost about US\$ 200 million, which would be sufficient to expand other alumina plants of the world with similar or even larger extra capacities, operating at more favourable conditions. Thus, the closure of the Linden alumina refinery can be considered as final and permanent.

Neither the company nor the government has the necessary funds required for environmentally safe demolition of the facilities. The abandoned refinery could remain for decades. There is also little chance for the rehabilitation of the old red mud disposal area. Fortunately, the natural ground water in this area is quite acidic (pH 4 to 5), so it can neutralize any caustic seeping from the plant area or the mud disposal lake.



3.3. Environmental impact of the bauxite and alumina industry

Mine restoration in Guyana is mainly limited to some backfilling, following overburden removal and ore extraction. On completion of mining, excavated areas remain filled with unconsolidated sand and clay. This way the original relatively low growth rainforest is turned into a moonscape of barren heaps and pits.

Environmental impacts of bauxite mining operations have hitherto not been addressed resulting in serious environmental deterioration. It will take hundreds (or even thousands) of years for the rainforest to reclaim these areas, if it will ever be able to do so.

At the Linmine site financial constraints currently inhibit any efforts to landscape and revegetate exploited areas. Restoring mined out areas is complicated by the lack of top soil which is only a few cm thick above the sand overburden. The situation could be similar at Bermine. There is scope for more attention to be devoted to environmental issues at the new Aroaima mine site.

Processing and calcining of Linden bauxite prior to shipment induces severe pollution. The environmental impacts of these operations include gaseous and particulate emissions from calciners, tailings disposal from wet screening, fugitive fuel oil leaks, surface run off, atmospheric emissions from fuel-oil based power generation, and direct discharge of process water. As of now, no significant measures have been taken to control either air emissions or waste discharges.

Hundreds of tonnes of grey, abrasive dust settle daily on the surroundings of the bauxite processing plant, including the township of Linden. Dust emissions are the most harmful environmental effect of the Linden bauxite processing plant. CO₂, SO₂ and NO_x emissions are relatively insignificant when compared to the deleterious effect of dust. There are continuous complaints from the community regarding the health hazard and daily nuisance caused by dust emission of the plant.

Another nuisance in Linden is the bauxite slurry formed in the washing plant, which is disposed of in large, dammed settling ponds. Since this slurry is neutral, any water seeping from the ponds does not affect the environment. Plans exist for pumping this material in nearby exhausted mining pits.

The Linden operation accounts for a major portion of Guyana's fuel oil consumption. The design, operation and maintenance of the kilns lag far behind of the up to date practices and represent a further pollution source.

An ongoing feasibility study, coordinated by the Bauxite Industry Development Company (Bidco), includes a detailed investigation into the current level of environmental damage caused by Linden operations. This will be the first comprehensive determination of the environmental impacts of mining and processing in the Linden area. As indicated previously a red mud lagoon still exists along with cannibalized process equipment which contains caustic soda. Contamination of surface or ground water has not been investigated.



Although the environmental impact assessment will include an assessment of liquid effluent and groundwater contamination, no specific mention is made in the TOR of possible caustic contamination from the abandoned alumina plant.

The team was given to understand that dusting is also a problem at the Berbice bauxite drying operation but to a lesser degree than in Linden.

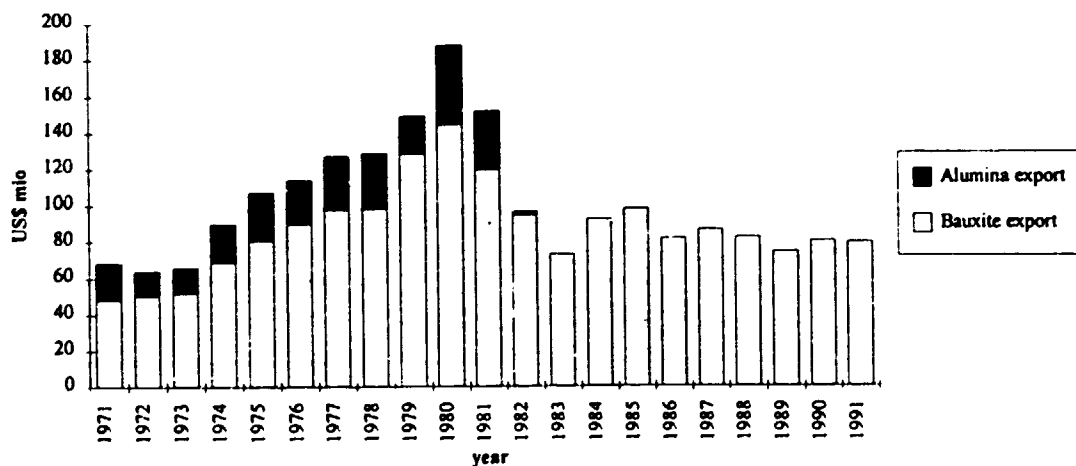


3.4. *Barriers to Sustainable Development*

a. Structure and Profile of the Industry in Guyana

Bauxite has been the most important industrially utilized mineral resource and revenue earner of the country for several decades (Figure 3.4.1). Mining and processing of bauxite has been providing direct and indirect employment to large number of qualified work force. Consequently, the sector has been attracting special attention of the Government. The nationalization process, however, was not successful and, instead of improving, it substantially reduced the technical and financial capacity of the mines and plants. The income generated by the industry diminished fast and instead of profit the companies started to make losses. The deteriorating financial situation of the companies, combined with the large budgetary deficit on state level, prevented the development of mine and plant technologies, and replacement of worn out equipment and proper execution of everyday maintenance and housekeeping. The environmental situation has not been a focus of management. Privatization and involvement of well-known international companies in the management of the industry may change the situation to maintain the company image and comply with the company policies.

Figure 3.4.1 Bauxite and Alumina Export of Guyana



Source: Yearbook of International Commodity Statistics, 1985 and 1993, UNCTAD



b. Status of Regulatory Programme

An Environmental Bill, drafted initially in 1990, establishes an agency with authority to prevent or control environmental pollution in Guyana. The role of this new agency will include the submission of proposals to the Minister of drafting regulations, undertaking surveys into the causes, nature and extent of pollution, promoting research and information dissemination, evaluating EIA's, compilation of resource inventories and the authority to inspect authorised industrial activities for compliance with the regulations. The Bill has yet to be enacted by the government, however, so establishment of the new agency remains in abeyance and there is no regulatory programme in place to effectively control pollution caused by the bauxite industry or its use of natural resources.

In Guyana the following institutions have some authority to regulate the activities of the bauxite mining and processing industries with respect to environmental impact. The Guyana Agency for Health Sciences, Education, Environmental and Food Policy (GAHEF) have primary responsibility for regulating the bauxite industry. The Guyana Natural Resources Agency (GNRA) provides policy advice on natural resource development including energy, mining and forestry. GNRA also proposes projects in natural resources development. The Guyana Geology and Mines Commission (GGMC) inspects mining operations, primarily for occupational health and safety, but also undertakes some environmental monitoring. GGMC carries out assessments of mineral reserves and issues prospecting and mining license. The Commission can request environment impact assessments (EIA) for proposed mining operations.

In Guyana the bauxite industry operates with a high level of autonomy. Accountability for its performance is at Cabinet level. Consequently the institutions mentioned above currently exert only limited influence on the environmental impacts of the industry.

The Bauxite Industry Development Company Ltd. (BIDCO) a shareholder in two of Guyana's three bauxite operations, have certain responsibilities concerning implementation of the EIA for the Linden Mining Enterprise, (Linmine). This EIA constitutes part of the feasibility study (see paragraph 3.3) considered necessary prior to proposed privatisation of Linmine operations.

The new Environmental Bill does incorporate important environmental considerations into a coherent regulatory framework. It makes provision for drafting regulations in which potentially polluting processes and substances will be prescribed. Standards and permits (authorizations) for atmospheric emissions and waste discharges can be granted by the new agency. Industry will be required to introduce best available technologies in connection with prescribed processes. The new agency will have authority to prohibit polluting activity and to request EIA's for public and private sector development projects.

When the Environmental Bill becomes law an important step will have been taken towards providing for sustainable industrial development including potential expansion of the bauxite industry in Guyana. Currently several institutions have overlapping responsibilities and none have, historically, been able to control the industry's environmental damage.



c. Attitude of Plant Management

The operations visited at Linden reflect the result of previous long lasting neglect - lack of proper housekeeping and regular plant maintenance. As it is described in the previous chapters the safety and environmental record of the plants is the worst seen by the Team during their tour in the Region. The current management has started to take certain actions to revitalize the Company, however it will need prolonged and vigorous efforts to improve the situation.

d. Site Specific and Technical Barriers

Bauxite Mining

The main barriers to sustainable development are the high overburden to ore ratios of the remaining bauxite deposits of Guyana and the high production costs of Guyanese bauxite mainly resulting of this. Twenty years of government ownership and transportation problems (coastal sandbanks) contribute to the barriers. The high production costs prevent the funding of a proper rehabilitation work. The soil conditions (a thick, barren layer of white sand covered by a very thin layer of quite poor soil) make any rehabilitation even more difficult. As far as the dust emissions of the bauxite processing plants are concerned, it seems that electrostatic precipitators are not very much suited for removing bauxite dust from the flue gases of the calciners and driers. But other solutions like wet scrubbers could solve the problem. It would be very important to find a profitable use for the dust caught in this way, because this would provide an incentive for gas cleaning and would pay for its costs.

Alumina Manufacturing

The problems described in Chapter 3.2. made it impossible to sustain alumina production in Guyana, not to speak about development. The resurrection of the alumina refinery closed down more than a decade ago would involve prohibitive costs. Further, in the present state of bauxite mining the quantity of the by-product of the bauxite washing operation would be insufficient as raw material for the refinery.



3.5. Strategy for Sustainable Development of the Bauxite Industry

a. Strengthening policy and regulatory programmes

Legislation covered in the Environmental Bill drafted in 1990 provides a framework for controlling environmental impacts of bauxite mining and processing. Regulations need to be drafted which restrict emissions of particulate matter from bauxite calcining operations to acceptable levels and which make provisions for reclamation and/or vegetation of old stockpiles and mined-out areas. Regulations should address permitting procedures (authorizations) and licensing requirements for mining and processing (calcining) activities and tailings disposal. Fugitive discharges of fuel oil and safe disposal of engine oils also require adequate control. Policy measures which foster the "pollution prevention" approach, including cleaner production and energy efficiency are more likely to encourage the mining and processing operating companies to reduce atmospheric emissions and liquid discharges than laws which establish maximum concentrations of pollutants in wastes discharged to the environment.

b. Institution and human resource development to implement regulatory programmes

The new Agency to be established under the Environment Bill will initially need to rely on the capacity of the institutions referred to in paragraph 3.4.b, particularly GAHEF. It will need to be strengthened in order to effectively carry out its regulatory functions. During the first few years of its existence this Agency will have to serve in an advisory and planning role; assisting rather than policing. In order to draft regulations covering the environmental impact of the bauxite industry it will need to rely on the industry itself for technical information. Monitoring will have to be undertaken by organizations with access to laboratory facilities, possibly GGMC, academic institutions or NGOs. Self-monitoring by the bauxite companies, for example, environmental audits, will need to be requested.

For Linmine operations, the EIA currently being undertaken (paragraph 3.3) will establish baseline data on the extent of environmental damage. It will also draft an environmental management plan for any proposed new development. The EIA should provide basic data and proposals which could be of valuable assistance in drafting regulations covering the bauxite industry.

c. Opportunities for the introduction of pollution prevention and cleaner production at plant level

The most important environmental problem to be solved is reduction of dust emission of the bauxite calciners and driers. This could be addressed by installing wet scrubbers to treat the exhaust gases. At Linden, slurries formed from bauxite washing and at the wet scrubbers (should the latter be installed) could be pumped into abandoned, exhausted mining pits thus preventing the further increase of the areas covered by disposal lakes.



Rehabilitation of calciners and dryers with the aim to save operating costs through substantial reduction of the energy consumption will also result in improved environmental performance.

Further improvement could also be expected from improved management and housekeeping practices.

Training and strengthening the environmental awareness of the staff on all levels are of high importance.

d. Cost of New, Cleaner Technologies

Rehabilitation of kilns and installation of wet scrubber would cost hundred thousands of US dollars per kiln, depending on the size of the same, i.e. how much flue gas the given scrubber has to handle.



4. JAMAICA

4.1 Introduction

Jamaica is host to both bauxite mining and alumina refining operations. Bauxite and alumina are both exported, bauxite primarily to the USA and alumina to USA, Canada, Norway, the Netherlands, U.K., Ghana etc. Multinational aluminium companies and the Jamaican Government are the major participants in Jamaica's bauxite/alumina industry.

The international significance of the industry in Jamaica has changed substantially over the past twenty five years (Figures 4.1.1 and 4.1.2). Between 1957 and 1970 the country was the world's largest bauxite producer. As a result of fast growth of bauxite production in Australia, Jamaica lost its leading position. In the beginning of the eighties Guinea, the producer of the world's highest grade bauxite, also overtook Jamaica leaving it in third place.

Output of the bauxite industry in Jamaica has passed through a long period of crisis. Production fell steadily from the 1974 peak of 15.2 million tons per annum to 6.2 million tons per annum by 1985. By 1991, after about three years stagnation, production recovered to 11.6 million tons per annum and stabilised at this level. Jamaica's share of the world's bauxite production has declined from 18.1% in 1974 to 7% in 1985 recovering to 10.5% by 1991. The decline of the industry resulted in reduced foreign exchange inflows and loss of about 2,000 jobs.

The international recession had a severe impact also on the alumina production of Jamaica (Figure 4.1.3). Outputs of all plants sharply declined and moreover the American company Revere permanently shut down their refinery in Magotty in 1975.

Figure 4.1.1 Jamaica's Bauxite Production

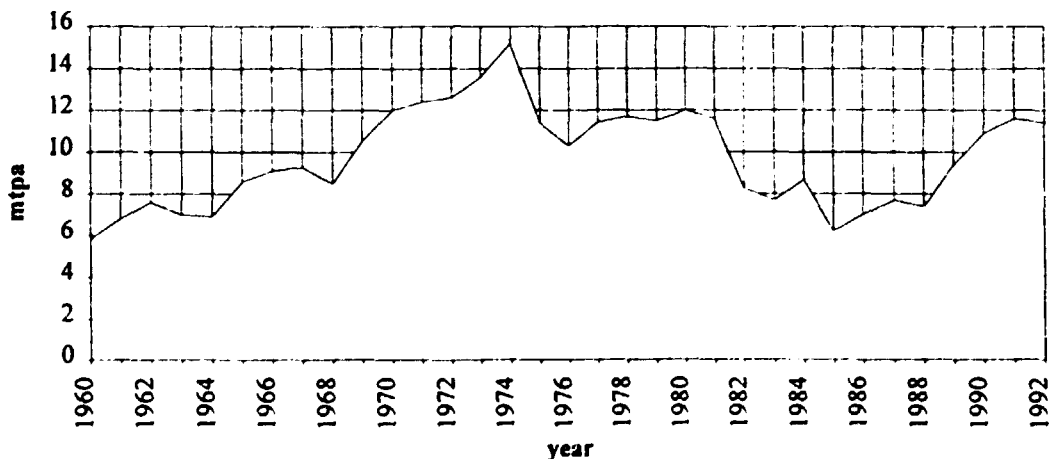




Figure 4.1.2 Jamaica's Share of World's Bauxite Production

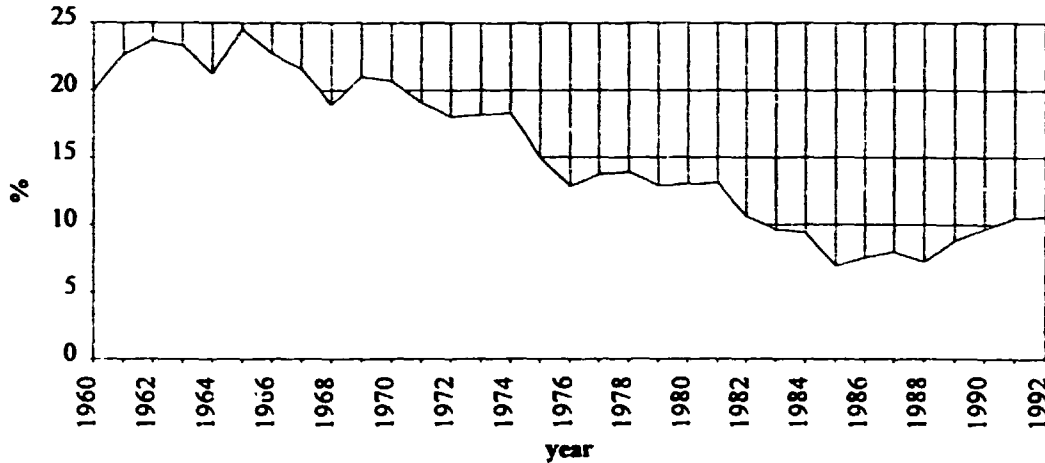
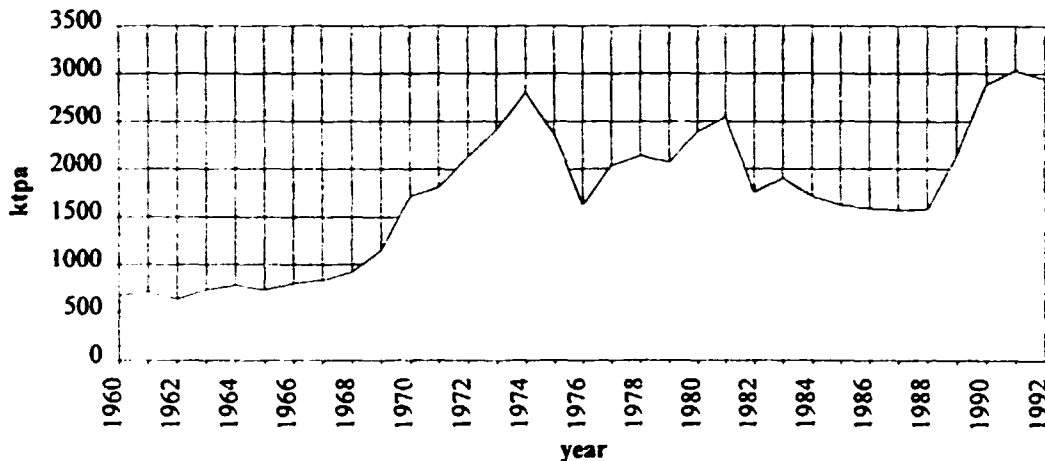


Figure 4.1.3 Jamaica's Alumina Production



Since bauxite is currently exported only by Kaiser Jamaica Bauxite Co. and all the other producers process their ore in their local alumina refineries, difficulties affecting the local alumina industry had further negative impacts on domestic bauxite production. The decline of bauxite and alumina production after 1974 was the result of several factors. The dramatic increase in the price of oil was followed by an economic recession which severely affected the alumina and aluminium industry worldwide, including its production costs.

In addition to external factors, the competitiveness of the Jamaican bauxite industry was affected by internal financial measures. Due partially to the global economic crisis, Government revenues from the bauxite/alumina sector dropped sharply, while taxes were



assessed on declared income of companies. As a countermeasure, in 1974 the Jamaican Government changed the taxation of foreign bauxite producers by replacing income taxes and royalties by a levy. The intention of the Government was to avoid low transfer prices between the local and foreign subsidiaries of multinational companies (the ore was seldom traded to third parties). The new levy was based on the actual realised ingot price as revealed in the returns to the US Securities and Exchange Commission.

The timing of the introduction of the levy and its magnitude however was not appropriate since, at that time, new, low-cost, high capacity bauxite and alumina production facilities went on stream elsewhere in the world and US companies became less dependent on Jamaican bauxite and alumina.

Despite discounts and concessions in the levy system, production remained on its reduced level until the end of 1970's even though the world economy improved and global bauxite production increased. The next global downturn in the aluminium industry in the beginning of 1980's resulted in the closure of the small bauxite industry in both Haiti and the Dominican Republic. This crisis also affected Jamaica. The major customers of Jamaican bauxite and alumina - the refineries and smelters on the US Gulf Coast - substantially reduced their production and US companies started to shift their smelters to the vicinity of cheap energy sources. The decline continued to the late 1980's. Reynolds closed their Lydford mine in 1984 and Kaiser reduced their bauxite production near Port Rhodes, Discovery Bay to almost 50% after the closure of their Baton Rouge refinery in Louisiana, USA. In 1985 ALCOA closed their refinery at Clarendon and ALPART their refinery at Nain after longer periods of operation at 50% capacity. Jamaican alumina output fell from 2.6 million tons 1981 to 1.5 million tons in 1988.

After several revisions of the fiscal regime in 1988 the Government replaced the previous bauxite levy system. The new agreement comprises a basic levy linked to the average realized price (ARP) of metal and escalating in proportion to any increase in the ARP; an income tax component of 33½ % and a royalty. The new arrangement in combination with the global recovery of the industry and high prices paid for alumina renewed the interest in the Jamaican bauxite industry. The Alpart bauxite mine and refinery at Nain were reopened in 1988 and the production of alumina reached 1.3 million tons per annum by 1991.

The ownership structure of the Jamaican bauxite/alumina industry is shown in Table 4.1.1.



Table 4.1.1 Ownership structure of the Jamaican bauxite and alumina companies

<u>Company</u>	<u>Established</u>	<u>Capacity (ton/annum)</u>	<u>Ownership</u>	<u>Remarks</u>
Kaiser Jamaica Bauxite Co. Ltd., Discovery Bay	1952	4.5 million bauxite	Kaiser - 49% Govt. - 51%	Expansion in 1988 from 3.8 mill.tpa to 4.5 mill. tpa, can be expanded further to 5.5 mill. tpa.
Jamaica Bauxite Mining (JBM) Lydford Mines, Lydford	1952	2.5 million bauxite	JBM - 100% (Govt.)	Formerly Jamaica Reynolds Bauxite Partners, closed in 1984.
Jamaican, Ewarton	1959	450,000 alumina	Alcan - 93% Govt. - 7%	To be expanded to 550,000 tpa.
Jamaican, Kirkvine	1952	550,000 alumina	Alcan - 93% Govt. - 7%	
Jamalco, Halse Hall, Clarendon	1963 (bauxite), 1972 (alumina)	800,000 alumina	Alcoa - 50% C.A.P - 50% (Govt.)	Joint venture with Clarendon Alumina Prod. Ltd. (C.A.P) since 1988. To be expanded to 1 million tpa in short term. Can be expanded to 2 mill. tpa.
Alpart, Nain	1969	1.45 mill. alumina	Kaiser - 65% Hydro - 35%	Closed in 1985, reopened in 1988 after change in ownership structure. Can be expanded to 2 mill. tpa.
Revere, Magotty	1971	200,000 alumina		Closed in 1975

The UNIDO team could visit only the Kaiser Jamaica Bauxite Co. and the alumina plant of JAMALCAN in Ewarton.



4.2. Description of the industry

a. Bauxite Mining

Geography, Geology

Jamaica's bauxite occurs in a series of deposits across the middle of the island, north to south. The biggest deposits are in the parishes of St. Ann, Manchester, St. Elizabeth and Trelawny with smaller deposits in Clarendon and St. Catherine. Most of the ore is found in the highlands at about 500 m above sea level and lies in pockets and bowls in the limestone which forms two-thirds of the island's bed rock. Proven reserves presently exceed 2,500 million tonnes of bauxite. The ore lies right on the surface and there is no overburden covering the bauxite as is the case in most other countries. Mining Regulation (1947) Sec.53(1)(a) obliges the mining companies to scrape off and stack the top six inches of soil for respreading after a deposit is mined. Since it is not compacted under overburden, Jamaican bauxite is soft and relatively easy and inexpensive to mine.

Quality

As far as the percentages of total and available Al_2O_3 are concerned, Jamaican bauxites can be considered as medium quality (48-50 % total alumina, 42-46 % available alumina), as a result of the diluting effect of iron minerals present in a relatively high concentration (18-19% as Fe_2O_3). However, their reactive silica content is among the lowest in the world (1-2%). Most Jamaican bauxites are purely gibbsitic or contain only negligible amounts of boehmite (1-2% as Al_2O_3), however, some of them may contain higher quantities (up to 15% Al_2O_3 in boehmite). The adhesive moisture content of the Jamaican bauxites is perhaps the highest in the world (18-25% depending on site and season) and it can not be significantly reduced by drying because of excessive dusting.

As a result of the above factors most of the Jamaican bauxites can be very profitably processed to alumina within Jamaica. Their transportation to overseas customers is less economic, since it takes nearly 3 t of Jamaican bauxite (dried to a moisture content of 17.5%) to produce 1 t alumina compared to less than 2 t of Boké (Guinea) bauxite, the present favourite. Of course, in the case of the alumina plants on the Gulf Coast of the USA (Gramercy, Corpus Christi, Point Comfort) the much shorter distances compensate this disadvantage.

Mining Operations

There are altogether five active bauxite mining operations in Jamaica. Four of them (Jamalcan Ewarton; Jamalcan Kirkvine; Jamalco Clarendon and Manchester Plateau operated by Alpart) are designated to serve the respective alumina plants; the fifth (Kaiser Jamaica Bauxite Company), supplies the bauxite drying and shipping plant in Port Rhoades, Discovery Bay. A sixth operation (the export-oriented Jamaica Bauxite Ltd, in Lydford, formerly belonging to Reynolds) is presently inactive. Two more (Malvern Ridge and Essex Valley) act as reserves for Alpart. The capacity of Kaiser Jamaica Bauxite Company's



operation is estimated to be 4.5 million tonnes of crude bauxite per annum, that of Jamaica Bauxite Mining Ltd could reach 2.5 million tpa in a few years after restarting. The capacities of the other mines correspond to those of the respective alumina plants.

Production

The observations of the Team are based on the site visit to Kaiser Jamaica Bauxite Co., which is the largest bauxite mine in the country.

The latest available production figures are the following:

Table 4.2.1 Bauxite production

<u>Operation</u>	<u>Year</u>	<u>Production</u>
Kaiser Jamaica Bauxite Co.	1992	4150 kt/a (Crude; dried to 17-18% moisture)
Jamalcan Ewarton	1991	1316 kt/a (Crude, 22-25% moisture)
Jamalcan Kirkvine	1990	1635 kt/a (Crude, 19-21% moisture)
Jamalco Clarendon	1992	2200 kt/a (Estimate for dry; 22-25% moisture)
Alpart Manchester Plateau	1991	3100 kt/a (Estimate for dry; 18-22% moisture)

Mining Procedures

Corresponding to the geomorphology of the Jamaican bauxite reserves indicated above, bauxite is mined from individual pockets and lenses containing some 30,000 to 1,000,000 tonnes of ore each. Overburden removal means the scraping off the upper 15 to 45 centimeters of bauxite and setting it aside for land reclamation. Relatively small individual equipment (shovel, loader and/or dragline) is used to mine the bauxite and load it onto dumper trucks which carry it to some relatively close storage area, where it can be blended to obtain the desired composition. At these places the bauxite is loaded into railway cars or on belt conveyors to take it to the bauxite or alumina plants. The bauxite contains various sizes of limestone boulders. The biggest ones can be left in the mine itself, the next size (e.g. above 30 cm in diameter) is removed by large screens before loading.

Several pockets are mined simultaneously and the product is usually blended since available alumina and total silica content in the bauxite varies between deposits. Networks of haulage roads are established over the mining area to connect pockets being worked to a central blending and loading area.



Rehabilitation

Mining operations are located in hilly areas where the vegetation consists of grass and low bushes. Agriculture, that either co-exists with, or has been displaced by the bauxite/ alumina industry, involves small-scale animal husbandry or fruit tree cultivation. Individual rural dwellings and smallholdings are frequently located in the immediate vicinity of mining operations.

Regulations require land to be returned to at least the level of agricultural or pastoral productivity previously existing or for utilization for afforestation. Landscaping is required and top soil must be replaced. In practice limestone formations close to mined-out pockets are backfilled into the pits and covered by the topsoil set aside before mining. Deeper pits are reduced in depth, but can remain with one near-vertical side. After seeding it with grass the terrain is usually transformed into pasture land.

It seems that the individual mines declared to be exhausted still contain significant amounts of residual bauxite, which would be difficult to reclaim by the usual heavy equipment but could perhaps be recovered by cheap contract labour. After the mined-out area is refilled and replanted, these amounts are lost forever.

Transportation, drying

The bauxite is transported by a 25 km long standard gauge railway to the drying plant in Port Rhoades and is tippled from the cars and beltconveyed to an open air stockpile. After the removal of further limestone lumps (reject) its moisture content is reduced in parallel (direct) current rotary drying kilns from about 22% to 17-18% at a temperature of about 115 °C. (In this state it is much easier to handle it, but it is still not extremely dusting.) Fuel (Bunker C) consumption is relatively minor, 1 to 1.5 US gallons/tonne (4 to 6 litres/t) depending on the original moisture content. The dried bauxite is conveyed on a belt to a 125,000 t capacity dome shaped silo. From the bottom of the latter it is conveyed to the shiploader.



b. Alumina Production

Jamalcan operates two alumina plants: Ewarton (start-up in 1959, capacity originally 550 ktpa, presently about 450 ktpa) and Kirkvine (start-up in 1952, capacity 550 ktpa) with a total output for the two ranging 964 to 975 ktpa during the last three years (1990 to 1992). Alpart's alumina plant in Nain started production in 1969 with a capacity of 1,200 ktpa (expanded recently to 1,450 ktpa). It was stopped in 1985 and restarted in 1989, with production figures between 1,188 and 1,300 ktpa for the last three years. Jamalco's Halse Hall alumina plant started up in 1972 with a capacity of 800 ktpa and production figures between 705 and 752 ktpa for the last three years. Further expansions are planned for Ewarton (550 ktpa), Nain (up to 2,000 ktpa in stages) and Halse Hall (1,000 ktpa).

Processing Features

Our observations are based on the visit to ALCAN, Ewarton refinery. Access to the other plants was not granted to the UNIDO team.

Due to the softness of Jamaican bauxites they require relatively little grinding. On the other hand, they usually contain a lot of limestone lumps, which have to be separated from the bauxite partly before, partly after grinding. Those lumps separated after grinding have to be washed to prevent the loss of significant amounts of caustic soda. In the Ewarton plant these rejects form a huge heap within the fenced area.

Because of the thixotropic character of the Jamaican bauxites it is impossible to obtain ground slurries with solids contents exceeding 50% by weight. The typical figures are closer to 35-40%. This fact has adverse effects on the heat economy of the digestion process, especially if a high temperature double stream digestion is applied (as at Alpart).

Three of the alumina plants (Ewarton, Kirkvine and Halse Hall) have low temperature digestion facilities (operating around 140-150 °C) and only one (Nain) a high temperature one (about 250 °C). The latter can extract the monohydrate (boehmite and/or diaspore) content of the bauxite. The Halse Hall plant had originally both a high- and a low-temperature digester train installed, however, the high-temperature one exploded in the late '70s and has not been reconstructed ever since. Jamalcan is in the process of modifying the digestion facilities of their Ewarton works to introduce the so-called double digestion technology.

Because of the high iron content of Jamaican bauxites a relatively large amount (nearly 1 t per t of alumina) of digestion residue (red mud) has to be separated and washed. The settling and compaction characteristics of Jamaican muds are quite poor. This is the reason why Jamaican alumina plants have to apply an unusually large number of relatively large-size red mud settling equipment. Jamalco has recently installed two so-called deep thickeners at the end of their Ewarton red mud washing line, in connection with the dry stacking of red mud (see later).

As far as calcination is concerned, three of the alumina plants (Ewarton, Kirkvine and Nain) have originally got rotary calciners (three of them each), whereas Halse Hall has three Alcoa



Mark III fluid flash ones. Alpart (as part of its expansion programme) has recently installed two Lurgi circulating fluid bed calciners with the capacity of 1,400 tpd each. The latter are capable to calcine about 1,000 ktpa of alumina, only the rest will have to be handled by the old rotary type kilns.

As a summary it can be stated that most of the processes and equipment of Jamaican alumina plants are fairly old and outdated (at least 20 and in some cases 30 to 40 years old), with a few exceptions like the calciners at Alpart.

Material and Energy Consumption Data

According to the Team's information, the bauxite consumption of the alumina plants is not really measured but only calculated on the basis of the alumina output with a factor of 2.4 dmt per t of alumina. This system can lead to some wasteful practices. The caustic consumption figures (Table 4.2.2) the team has obtained from JBI are extraordinary high and can be true only if they (or most of them) are expressed as 50% NaOH solution. Even if so, the figures for the Jamaican plants are still too high, indicating larger than usual physical losses. (The figures obtained do not allow for an in-dept analysis.)

As far as fuel consumption is concerned, that of Jamalco is fairly good (about 1.7 bbls of fuel oil i.e. some 10 GJ per t of alumina), the average of the Jamaican plants (about 2.25 bbls of fuel oil i.e. 13-14 GJ per t of alumina) still acceptable when considering the relatively small size and the age of the alumina plants and that of Alpart (3.0 to 3.3 bbls of fuel oil, i.e. 18 to 20 GJ per t of alumina) very high, probably the worst in the world for its size and among those processing bauxite by the Bayer process.



Table 4.2.2 Alumina sector - caustic soda & fuel consumption 1989 - 1992

<u>Year</u>	<u>Company</u>	<u>Alumina output</u> (tonnes)	<u>Caustic consumption</u> (tonnes)	<u>Fuel oil consumption</u> (bbls)
1989	Jamalcan	925,603	169,845	2,033,995
	Jamalco	647,460	80,002	1,130,486
	Alpart	648,002	95,112	2,264,339
	<i>Total</i>	2,221,065	344,959	5,508,233
1990	Jamalcan	975,126	151,451	2,142,139
	Jamalco	705,515	104,251	1,188,815
	Alpart	1,188,203	117,858	3,583,680
	<i>Total</i>	2,868,844	373,560	6,914,634
1991	Jamalcan	974,746	162,951	2,170,676
	Jamalco	740,163	61,897	1,271,826
	Alpart	1,299,676	128,158	3,925,148
	<i>Total</i>	3,014,585	353,006	7,367,650
1992	Jamalcan	963,769	148,892	2,209,938
	Jamalco	751,693	61,929	1,299,141
	Alpart	1,201,700	157,001	3,953,739
	<i>Total</i>	2,917,162	367,822	7,462,818

¹ Source: Reg. 58, Economics Division, JBI, 1 September 1993



4.3 Environmental impact of the bauxite and alumina industry

Mining operations have the following negative effects on the environment:

The original vegetation is usually transformed into pastureland after concluding the rehabilitation. However, the areas in question are relatively small, and the relatively dense population of Jamaica would in any case require the transformation of a certain amount of forests into farmland, so this problem can be considered relatively minor.

Bauxite haulage roads crisscross the mining areas and their construction also requires the removal of the vegetation. More often than not they are not rehabilitated after finishing the mining operation.

Dusting of the bauxite during mining, transportation and storage can be a nuisance, especially during dry weather, however, it is not known, that bauxite dust would have deleterious health effect. Spraying of the haulage roads by water and occasionally by Bunker C fuel oil or calcium chloride can reduce the problem.

Transportation and drying operation has the following negative effects on the environment:

- dusting during transportation and handling;
 - SO₂ and CO₂ content of the flue gases of the drying kilns;
 - huge reject dumps formed around the drying plant;
 - visual contamination.
- a. The dusting problem has recently been practically eliminated by installing dust collectors at every critical point of the process and installing wet scrubbers to the drying kilns. (According to informations obtained at the site the originally installed electrostatic precipitators did not perform properly.) It is very important to maintain (or even further improve) this favourable situation.
 - b. The amounts of SO₂ and CO₂ are relatively minor compared to those formed in the alumina plants.
 - c. The question of rejects should be solved, probably by transporting them back into the mined-out areas. Technically this can not cause any unsolvable problems, of course, some extra costs would have to be absorbed. The rejects already accumulated around the drying plant should also be eliminated over the next few years.
 - d. The bauxite handling, drying and storage facilities are all visible from the tourist areas around Discovery Bay; the shiploading facility protrudes into the Bay itself; large cargo ships call at the latter from time to time. As far as the "visual contamination" is concerned, very little can be done without completely shutting down the operation, which would clearly not be in the interest of Jamaica.



Should the Lydford mining, drying and shiploading operation ever be resurrected, it would be even more important to solve the above problems, since it is located in a turistically even more exposed area, in the immediate vicinity of Ocho Rios.

The other active mining operations use a 7 km aerial ropeway (Jamalcan Ewarton), a 5 and a 14 km cable belt conveyor (Jamalcan Kirkvine and Alpart, resp.) and a railway line (Jamalco Clarendon) to transport the bauxite from a central loading station to the respective alumina plant. The group had no opportunity to visit these mining operations, however, the informations received from JBI indicate that both the problems and the solutions are more or less similar to those seen at Kaiser Jamaica Bauxite Co.

Maintenance and Housekeeping practices in bauxite mining, transportation and drying - as far as we could judge on the basis of our short visit to Kaiser Jamaica Bauxite Co. - are acceptable (except for the large open-air pond of spent engine lubricants we saw). Workers' safety seems also good (hard hats, steel caps on the shoes, etc).

General assessment of the technical performance of the mines

As a general remark it can be stated that both the technical level and the environmental performance of the visited Jamaican bauxite mining operation (including handling and transportation) correspond to the special features of the Jamaican bauxite deposits, however, they lag far behind the best available practices of the world.

Alumina plants are polluting in several ways. The major source of pollution is red mud. Up to 1986 all red mud produced in the Jamaican alumina plants was impounded in dammed mud lakes, only Jamalco's lake being sealed at the bottom. In that year Jamalcan introduced the dry stacking system in their Ewarton plant after preparing five gently sloping fields (4.3%) with a total area of about 100 ha by covering them first with a 1.5 m thick clay layer to prevent the seepage of the caustic liquor into the ground. Since that, a thick red mud slurry (27 to 30% by weight) is spread over them periodically to dry on their surface. The five fields are used alternately, after a short period of mud spreading (4 or 5 days, some 7-8 cm at a time) a four times longer period (about three weeks) of drying follows. Any supernatant liquor is collected at the lower edge of the fields and pumped back to the alumina plant for mud washing. In this way the caustic soda content of the disposed red mud is kept to a minimum and its leaking to the aquifer is prevented. Unfortunately, this system is used only in one alumina plant (in the smallest of all of them). It would be very important to introduce similar solutions to the other alumina plants, first of all to the Kirkvine and Nain ones. (According to some unconfirmed information Alpart is working on the problem.) Another problem is that - because of the lack of sufficient buffer capacity - the Ewarton plant uses the old mud lake for storing excess supernatant liquor, first of all during the rainy season, so the mud stored in it can not dry and it can not be rehabilitated properly. Some seepage of caustic liquor from it towards the aquifer can also not be excluded.

Another source of pollution is connected with the unnecessarily high energy consumption of the alumina plants. The boilers and calciners of the four Jamaican alumina plants consume a total of more than 1 million t of fuel oil per year. With a (supposed) average



sulfur content of 3% this results in some 60 ktpa of SO₂ and in more than 3 Mtpa of CO₂ being emitted to the atmosphere, the former resulting in acid deposition, the latter (ultimately) in global warming. Fortunately, acid deposition does little harm to the soils of Jamaica because the underlying limestone neutralizes it.

Particulate emissions (dusting) is a relative minor problem, at least at the Ewarton works visited by the team. Most of the bauxite arrives by a covered belt conveyor and the few trucks hauling directly into the plant from nearby mines are covered by canvass. Alumina dusting is kept under control by electrostatic precipitators at the calciners.

Maintenance and housekeeping practices at the alumina plants seem more or less adequate at the Ewarton works. Except for a few liquor spills seen in the wet section (first of all in the mud settling and washing areas) and the moderate amount of alumina dust in the calcination area the only eyesore was the huge heap of rejects mentioned previously.

General Assessment of the technical performance of the plants

As a general remark it can be stated that the technical level of the Jamaican alumina refineries has been neglected for the last two decades, resulting first of all in a relatively high energy consumption (with the exception of Jamalco) and out-of-date solutions of red mud handling (with the exception of Jamalcan's Ewarton plant). These are the two main areas, where urgent actions would be required.

Table 4.3.1 Environmental impact of bauxite mines and alumina plants

<u>Company</u>	<u>Location</u>	<u>Activity</u>	<u>Effluents</u>	<u>Environmental impacts</u>
Kaiser Jamaica Bauxite Co. Ltd.	Discovery Bay	Bauxite mining, transport and shipping	Slurry discharge from dryer scrubber	Dust, noise, disturbance caused by mining operations. Partial reclamation leaves disfigured landscape but adequate for agricultural purposes. Spent lubricant disposal. Visual contamination.
Jamaica Bauxite Mining (JBM)	Lydford	Bauxite mining (closed)		Partial reclamation leaves disfigured landscape. Visual contamination.



<u>Company</u>	<u>Location</u>	<u>Activity</u>	<u>Effluents</u>	<u>Environmental impacts</u>
Jamalcan	Ewarton	Bauxite mining Alumina refining	Red mud and surface run-off	Dust, noise, disturbance caused by mining operations. Partial reclamation leaves disfigured landscape but adequate for agricultural purposes. Spent lubricant disposal. Visual contamination. Limited leakage of caustic soda to ground water. Emissions from power plant
Jamalcan	Kirkvine	Bauxite mining Alumina refining	Red mud and surface run-off	Dust, noise, disturbance caused by mining operations. Partial reclamation leaves disfigured landscape but adequate for agricultural purposes. Spent lubricant disposal. Visual contamination. Leakage of caustic soda to ground water. Emissions from power plant.
Jamalco	Clarendon	Bauxite mining Alumina refining	Red mud and surface run-off	Dust, noise, disturbance caused by mining operations. Partial reclamation leaves disfigured landscape but adequate for agricultural purposes. Spent lubricant disposal. Visual contamination. Leakage of caustic soda to ground water. Emissions from power plant.



<u>Company</u>	<u>Location</u>	<u>Activity</u>	<u>Effluents</u>	<u>Environmental impacts</u>
Alpart	Nain	Bauxite mining Alumina refining	Red mud and surface run-off	Dust, noise, disturbance caused by mining operations. Partial reclamation leaves disfigured landscape but adequate for agricultural purposes. Spent lubricant disposal. Visual contamination. Leakage of caustic soda to ground water. Emissions from power plant.
Revere	Magotty	Shut down alumina refinery	Left behind red mud lagoons	Leakage of caustic soda to ground water.

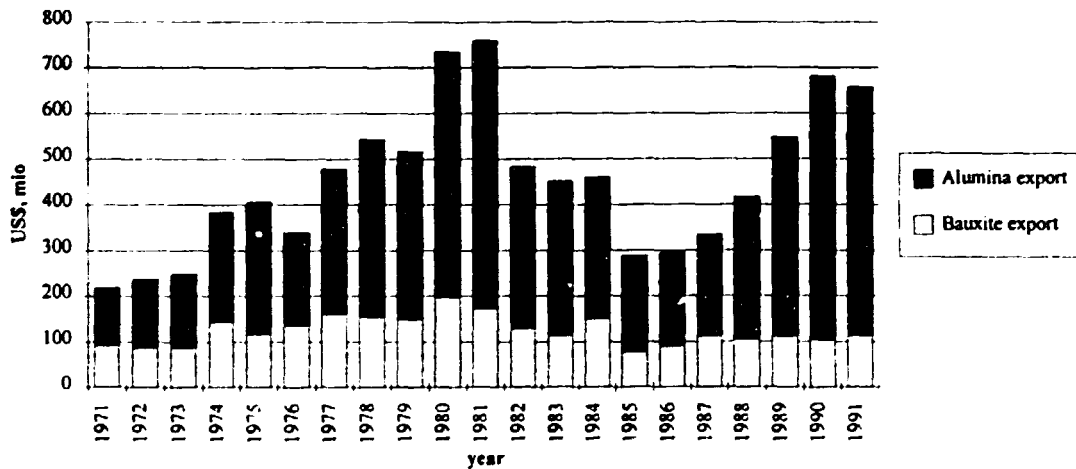


4.4 *Barriers to Sustainable Development*

a. *Structure and profile of the industry in Jamaica*

The bauxite/alumina industry represents the largest industrial sub-sector in the Jamaican economy. It accounts for between 6,5% and 8% of GDP, 60% to 65% of total merchandise export, 45% of net foreign exchange earnings, the highest concentration of skilled technical workers and a major consumer of goods and services from other sectors of the economy (transport, construction, engineering, maintenance and repair services, etc.). Apart from taxes, the subsector is the single biggest contributor to government revenues.

Figure 4.4.1 Bauxite and alumina export from Jamaica



Source: Yearbook of International Commodity Statistics, 1985, 1990 and 1993, UNCTAD



Table 4.4.1 Total production and foreign exchange earnings of Jamaica's bauxite/alumina sector

Year	Total bauxite production (metric tonnes)	Gross foreign exchange earnings, (million US\$)	Net foreign exchange earnings (million US\$)
1989	9,394,883	604	292
1990	10,936,726	668	270
1991	11,608,619	730	247
1992*	11,359,486	587	191

* Aluminium prices decreased substantially in 1991 and in 1992 the trend to historically low levels continues

Source: Jamaican Bauxite Institute

During the last twenty years there have been important changes in the ownership of the industry (table 4.1.3). Although minerals were owned by the state, the companies exploiting bauxite were wholly-owned subsidiaries of North American-based aluminium companies. The Government purchased 51% of Kaiser and Reynolds, 6% and subsequently 50% of ALCOA and 7% of ALCAN; repurchased most of the ore reserves lands formerly owned by the companies. In return, the companies were granted 40-year mining leases.

Jamaica's dependency on the bauxite/alumina industry for foreign exchange earnings combined with the Government's bitter experience in its prior dealings with the multinational aluminium companies (described in paragraph 4.1) have constituted one barrier to establishing policies which effectively control the environmental impacts of the bauxite/alumina industry. Government authorities try to minimize conflict between bauxite-derived revenue and environmental protection.

On the other hand, the severe budgetary and foreign exchange problems do not allow reinvestment of government bauxite/alumina revenue into environmental programmes. In view of the changing market situation combined with the controversial levy system, the companies tried to reduce their investments and costs to the bare minimum and could only marginally keep up with technological progress during the last two decades. As a result, especially the alumina plants, lag behind of their main competitors with regard to technical parameters such as soda and energy consumption and waste management techniques.

b. Status of Regulatory Programme

In Jamaica the Natural Resources Conservation Authority (NRCA) was authorised, under a 1991 Act of Parliament to issue permits for prescribed industrial activities and also licences for the discharge of industrial effluents to the environment. NRCA can also request environmental impact assessments for prescribed industrial activities and in connection with applications for new permits. NRCA has the authority to refuse a permit or licence, to request information on the performance of pollution control facilities, on the quantity and



applications for new permits. NRCA has the authority to refuse a permit or licence, to request information on the performance of pollution control facilities, on the quantity and content of effluent discharged and on the area affected by these discharges. Under the 1991 Act NRCA has power to stop offending activities and close plants. The Act also makes provision for the imposition of penalties for persistent non compliance. NRCA is tasked with drafting regulations which cover, *inter alia*, prescribed industrial activities and polluting substances, and air and water quality standards. In Jamaica the Government is a direct participant in bauxite/alumina operations, consequently the provision made by the act to enable NRCA enforce its controls on the public sector is of fundamental importance.

NRCA is still in the early stage of implementing its regulatory programme. Interim ambient air and water quality standards have been established, but, in the case of bauxite/alumina operations, permitting, licensing and compliance monitoring procedures will not be in place for several years. The legal aspects of effective enforcement are just starting to be addressed.

Prior to the 1991 NRCA Act, control over the environmental impacts of bauxite/alumina operations was exerted by several pieces of legislation, some with a rather narrow focus, and administered by several different government authorities. For example, the 1947 Mining Act administered by the Commissioner of Mines makes provision for reclamation/restoration of mined out land by holders of mining leases, the 1984 Quarries Control Act requires licences for the operation of limestone quarries (limestone is used in alumina refining), the 1964 Clean Air Act was designed to control atmospheric emissions from the industrial operations and an Act of 1962 empowered the Underground Water Authority (UGWA) to require licences for abstraction by the alumina refineries of water resources. Different agencies are involved in administration of the above legislation. This will inhibit the effectiveness of regulations in the bauxite/alumina industry until NRCA assumes effective responsibility for all legislation affecting the industry.

c. Attitude of plant management

Observations of the team suggest that plant management deals on a piecemeal basis with the most urgent and visible environmental problems under the pressure of growing public environmental awareness. In Jamaica the industry was established when there was insufficient appreciation of its environmental impacts. Design of the plants did not incorporate pollution prevention measures which are deemed necessary today. The long period of neglect will be a heavy burden to the companies and require improvement of management practices and attitudes.

d. Site Specific and Technical Barriers

Bauxite Mining

The dispersed, pocket-like nature of the Jamaican bauxite deposits requires the construction of a large number of haul roads, often through native forest. It is difficult to maintain them properly and to rehabilitate them when they are not needed anymore. It seems that less attention is given to their rehabilitation than to that of the pits themselves. A site specific obstacle to a complete rehabilitation of the mining pits and the haulage roads is the lack of



overburden and the usually very thin soil cover of the same - there is very little material available for rehabilitation.

Alumina Manufacturing

The relative ageing of the Jamaican alumina plants makes it difficult to apply the most modern procedures of environmental protection. E.g. completely new mud disposal areas would have to be constructed for at least two (possibly three) alumina plants, new boilers or flue gas scrubbers installed to reduce SO₂ and NO_x emissions. The whole energetics (first of all the digestion system) of the Alpart refinery would have to be modernized to significantly reduce its fuel consumption and the adverse effects (atmospheric emissions) connected with it.



4.5 Strategy for Sustainable Development in the Alumina/Bauxite Industry

a. Strengthening Policy and Regulatory Programmes

The Natural Resources Conservation Authority Act is an important step in establishing a regulatory programme capable of effectively controlling the environmental impacts of the bauxite/alumina industry in Jamaica. Priority must be given to drafting regulations which address standards for ambient air, surface and ground water quality with a realistic timetable for achieving these standards. Licensing procedures are required for the following activities:

- (i) emissions of particulate matter (dust) from bauxite mining, drying and refining operations,
- (ii) for the practice of red mud disposal and the minimization of risks of ground water contamination from caustic soda discharged, particularly in the liquid fraction of red mud, and
- (iii) for emissions of SO₂, NO_x and particulate matter from dryers, calciners and captive power plants.

Licences for the release of effluents should initially be based on the sensitivity of receptors.

In addition to bauxite/alumina, the other large foreign exchange earner of Jamaica is the tourism sector which plays an approximately equal role in the nation's economy. The main asset of the Jamaican tourism is the clean air, unpolluted water along with the stable warm climate. The coexistence of the two sectors is of key importance for the country as a whole. Of critical importance are risks of groundwater contamination from caustic soda given the dependence of the Island's population on groundwater as a source of potable water.

Additional policy measures which will need to be addressed include:

- The need to ensure that the industry takes a "pollution prevention" approach through the introduction of cleaner production and waste minimization. This applies particularly to the release of caustic soda to the aquatic environment and stack emissions from calciners and captive power plants (see section 4.2 for available technical options)
- The need to move towards regulations which take an integrated approach whereby permit schedules (particularly where different government agencies are involved) are harmonized such that companies renew licences for atmospheric emissions, liquid discharges and waste disposal at the same time. The objective here is to move away from single medium licenses which encourage the transfer of pollutants from one medium to another by the use of "end-of-pipe" pollution control technologies rather than cleaner production to minimize waste at source.



b. Institution and Human Resource Development to Implement Regulatory Programmes

The technical staff of JBI and the Industry should be familiarized with waste auditing and pollution prevention concepts to promote cleaner production and waste minimization in alumina refinery operations. To effectively execute its work NRCA will require additional trained human resources. Strengthening is required in environmental engineering and in the legal aspects of enforcement.

For monitoring compliance by the bauxite/alumina industry it is proposed that the Jamaica Bauxite Institute (JBI) will support NRCA. The JBI has technical expertise in alumina refining but very limited trained technical staff and equipment to undertake source or ambient monitoring. JBI will require support, initially with computing and monitoring particulate emissions, and subsequently in monitoring SO₂ and NO_x emissions from captive fossil-fuel combustion plants.

c. Environmental Management at Plant Level

Environmental management at the mines and refineries reflects corporate policies of the multinational companies who are, to a varying degree, direct participants in the Jamaican bauxite/alumina industry. The UNIDO mission was advised that environment teams have been established at all facilities and that environmental audits have been completed and measures are being taken to address sources of pollution identified by the audits. The mission was not able to directly assess attitudes and capabilities of plant supervising and technical staff towards waste minimization and pollution prevention however the performance of the industry calls for the need for training in waste auditing and the identification of opportunities for waste minimization.

Top management should have a sound policy and strong commitment to protect the environment. To put into practice this policy and commitment, environmental management programmes based on cleaner production and a self-monitoring approach should be established and executed through the works manager, middle management, engineers, staff, foremen and workers. Appropriate and clear targets should be formulated for every level and positions.

d. Opportunities for the Introduction of Pollution Prevention and Cleaner Technologies

The most important problem to be solved would be the safe and environmentally friendly disposal of red mud either by the dry stacking method applied in Ewarton or by some drainage system (e.g. like that described at Alumar, Brasil) etc. in at least two, but possibly three alumina plants. This would also make possible the ultimate rehabilitation of these disposal areas, which is very difficult in the case of conventional mud lakes.

Proper attention should be paid to the site selection and safe insulation of new red mud disposal ponds. The possibility of future rehabilitation should be a priority criteria in technology and site selection for red mud treatment.



The energy consumption of the alumina plants has to be analyzed in detail and appropriate measures should be taken to replace energy wasting technologies and practices.

- Modernisation of the Jamaican plants (first of all the digestion and calcination facilities and precipitation technology) would help to reduce energy consumption and atmospheric emissions.
- Alpart's whole process would have to be thoroughly studied and significantly improved to reduce energy consumption by at least 30 to 40% over and above the improvement expected from the new calciners.

Similarly, the soda consumption should be reduced to the levels justifiable by the quality of ore processed.

Further improvement could also be expected from improved housekeeping practices and the elimination of reject dumps.

e. Cost of New, Cleaner Technologies

The solving of the red mud problem would cost a couple of ten million US\$ per plant depending on the local conditions and the solutions adopted. (Some solutions could be even more expensive.) These costs would be partly compensated by a reduced caustic soda consumption. The thoroughgoing modernisation of the Jamaican plants could cost some US\$ 100 million apiece, that of the Alpart refinery even twice as much, but these costs would also be partly compensated by improved energy consumption figures and reduced manpower (both operational and maintenance) requirements. The costs of better housekeeping, reduced dusting and even of the elimination of the reject dumps would be negligible compared to the above figures.

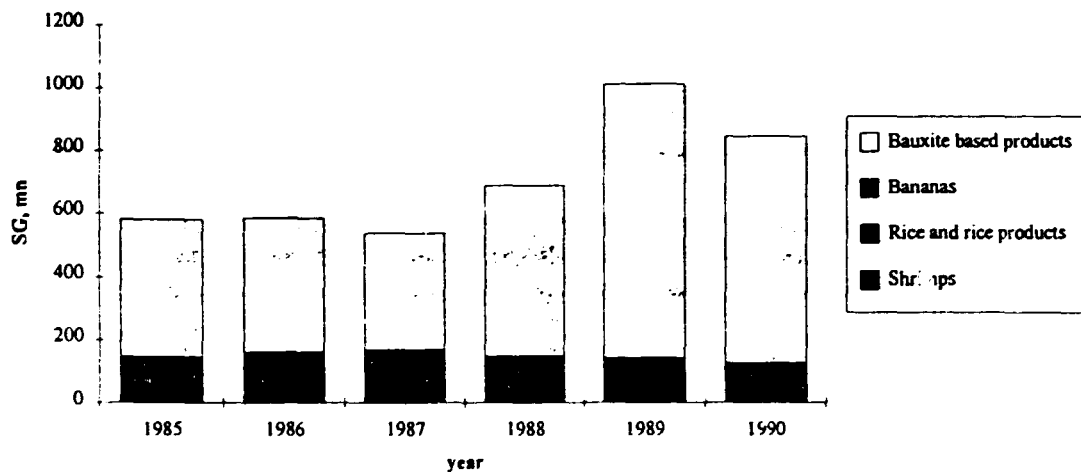


5. SURINAME

5.1 *Introduction*

Suriname's economy is supported by revenue from bauxite based products, agriculture and Dutch aid. In 1992 Suriname was the world's seventh largest important bauxite producer, accounting for about 3 per cent of total world production. The aluminium industry includes the extraction of high grade bauxite, processing of alumina and aluminium smelting. It is crucial to the economy, accounting for about two thirds of total exports and over 10 per cent of government revenues. The bauxite/alumina/aluminium industry directly employs about 2,800 people (estimated population of Suriname is 400,000).

Figure 5.1.1 Main Exports of Suriname



Source: The Economist Intelligence Unit Country Profile 1992-1993

Suriname's heavy dependence on one major export commodity has made the country's economy subject to the effects of price fluctuations of this product. During the 1970s and early 1980s the price of aluminium was depressed and the country experienced grave economic problems. In the late 1980s aluminium price increases helped to stabilize the country's economy. Tax receipts from the export of alumina and aluminium provide the revenue to support the large civil service, which employed about 42% of the working population in 1987¹. However, at the beginning of the 1990s the price of alumina fell sharply and Suriname was again facing economic instability.

The coastal land is the main area of the country's economic activity and also of settlement. At least 75% of the population live on the estuarine lands of the Suriname river, within 25

¹*Source:* The Economist Intelligence Unit



km of the capital, Paramaribo. The major part of the bauxite/alumina/aluminium industry is concentrated also here.

In Suriname the aluminium industry is controlled by one US and one Dutch multinational company. Mining began in 1916 by Surinaamsche Bauxite Maatschappij N.V., a wholly owned subsidiary of Aluminium Company of America. Until 1958 the company was solely engaged in the development of bauxite resources, mining and exporting of the ore. It was then that the company signed the Brokopondo Agreement with the Suriname Government, a joint venture to develop on the Brokopondo reservoir the Afobaka dam with the 150 MW hydropower plant and set up a fully integrated aluminium industry in the country. At the same time the company became the Suriname Aluminium Company (SURALCO), incorporated in Delaware, USA. The power plant was completed in 1965. Construction of the Paranam alumina refinery began in 1963, two units were completed in 1965, two in 1966 and the fifth in 1969. The smelter adjacent to the refinery started production in 1965.

In 1939 the Dutch company N.V. Billiton Maatschappij started its activities in Suriname to exploit the country's bauxite reserves. Billiton became part of the Royal Dutch Shell group in 1970.

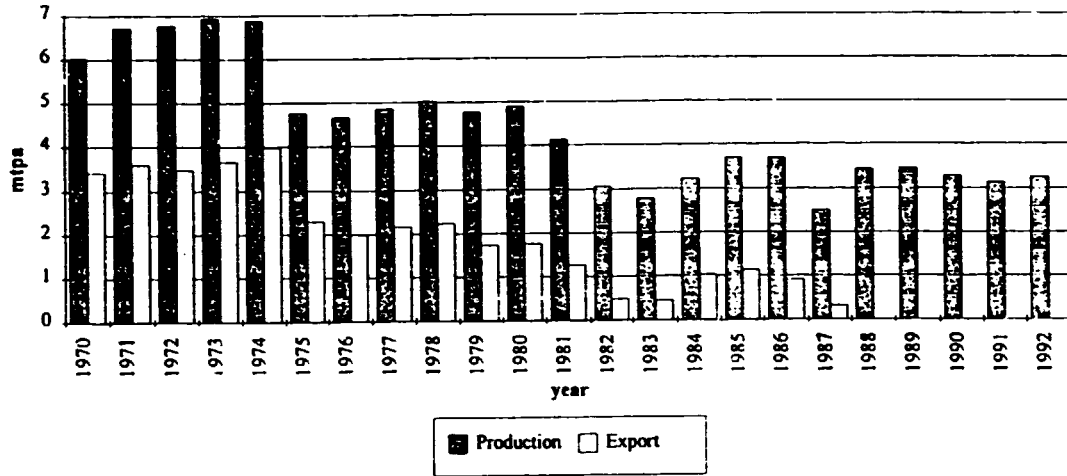
In 1984, SURALCO and Billiton concluded the Joint Venture Agreement in Mining and Refining Operations. Under this agreement SURALCO transferred its bauxite concessions to the Joint Venture and all bauxite mining in the Para area was, from there on, performed by Billiton. Billiton is entitled to 76% of the bauxite mined and SURALCO gets the remaining 24%. The bauxite production cost, as well as the capital investments, are also shared proportionally by the two partners. All the bauxite from the Para area is used for the production of alumina in the Paranam refinery. SURALCO's mining operations in the Moengo area remained active. Billiton obtained 45% interest in the Paranam refinery.

In early 1988, as the reserves at Onverdacht neared to depletion, the mining companies suspended bauxite exports to conserve supplies for their local refinery.

In January 1987, guerilla attacks on the mining town of Moengo disrupted mining and caused job losses. Bauxite was imported from the Dominican Republic, to keep the refinery and smelter in operation, although, in February 1987, the power line from the Brokopondo power station to the aluminium smelter was destroyed by guerrillas and the refinery was damaged by the workers. Alumina production resumed in April 1987, bauxite production in October 1987, but the smelter remained shut down until June 1988. The reopening of the smelter was also delayed by the low level of water in the Brokopondo reservoir. One of the lines of the smelter was never restarted, mainly due to the water shortages. Between September 1989 and June 1990 the Moengo area was in the hands of Jungle Commandos, severely disrupting bauxite production. In 1990 200,000 tons of bauxite had to be imported again, from the Dominican Republic, to maintain stocks and production at the refinery. With the final peace accord worked out with the rebels, in April 1991, the threat posed to the industry by insurgency appeared to have been removed.

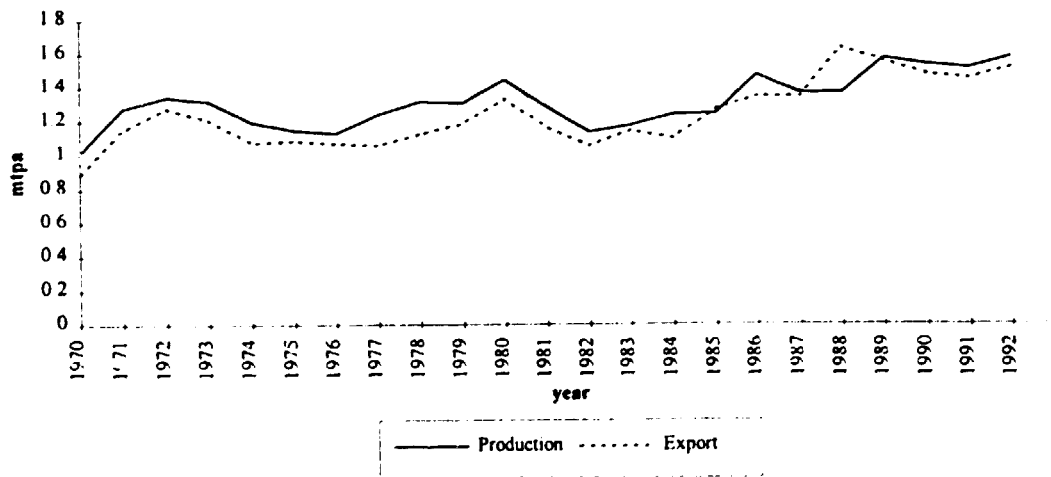


Figure 5.1.2 Suriname's Bauxite Production



Source: Bauxite Institute Suriname

Figure 5.1.3 Suriname's Alumina Production

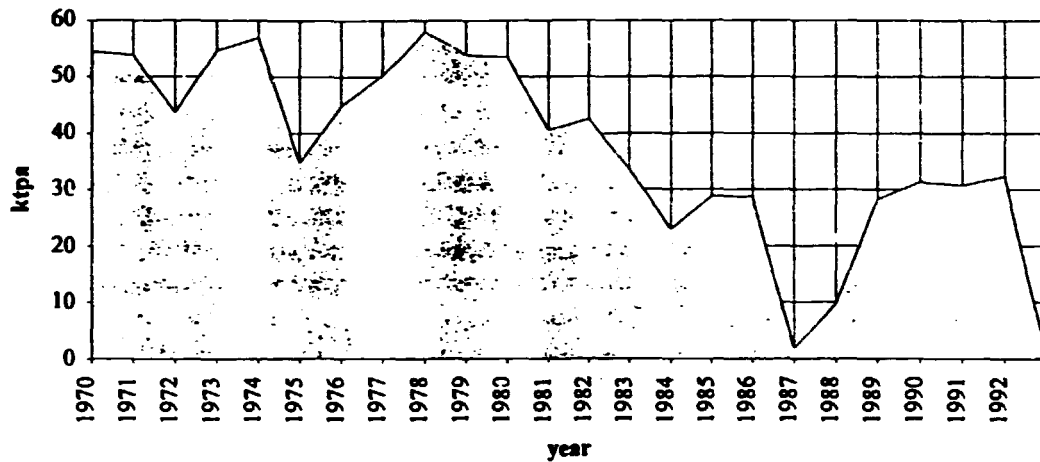


Source: Bauxite Institute Suriname

In 1974 the first Bauxite Levy agreement was signed. It was modified in 1976. SURALCO sustained losses in each year between 1985-1987. In 1986 the bauxite levy was suspended and the companies announced an intention to invest US\$150 million in the industry. However, the investment plans were suspended as a result of the civil war, exploration for new bauxite deposits is continuing.

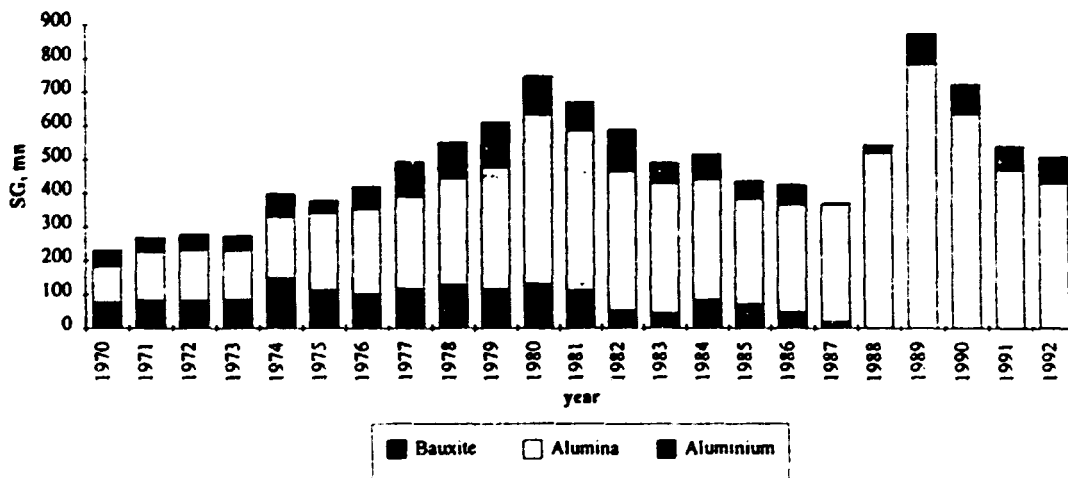


Figure 5.1.4 Suriname's Aluminium Production



Source: Bauxite Institute Suriname

Figure 5.1.5 Suriname's Export of Bauxite, Alumina & Aluminium



Source: Bauxite Institute Suriname



5.2. Description of the industry

a. Bauxite Mining

Geography, Geology

Three major groups of bauxite deposits have been identified in Suriname.

The deposits in the *Para* district are located some 30-35 km South of Paramaribo and lie under the coastal plain, buried by 30-35 m of overburden. The outcrops and shallow deposits have already been exhausted. Here the reserves amount to about 20-25 million t and will probably be exhausted by 2005.

The deposits of the *Moengo* region are located about 100 km East of Paramaribo and cover the tops of low (10 to 80 m high) hills. Overburden thickness is 1.5 m, average ore thickness is 5-6 m. A buried ore body has recently also been discovered in this area to the North of the others. The reserves here amount to about 40-45 million t and could last for about 25-30 years at the present production rate.

The third group of known deposits is in the *Bakhuis* mountains, some 70 km to the West-South-West of Paramaribo, on the top of 350-500 m high hills. Here the proven reserves amount to about 90 million tonnes, the total reserves (proven+probable+possible) to about 200 million tonnes. 3.2-6.4 m thick bauxite layers lie under 0.5-1.0 m overburden. Commercial scale mining hasn't started yet. A feasibility study has been prepared, a 70 km long standard gauge railroad is already operational and waiting for an investor to start mining at the deposit.

Quality

The bauxites of Suriname are of purely gibbsitic type, typically very high in alumina (at least the coastal bauxites), medium in silica, low in iron oxide. The average composition of bauxites from the major deposits is shown in the following Table 5.2.1.

Table 5.2.1 Average composition of bauxites in Surinam

Deposit	Total alumina, %	Total silica, %	Fe ₂ O ₃ , %	Mineralogy	Reserves, million t
Para	59.4	4.2	2.7	Gibbsite	20-25
Moengo	55.0	4.0	9.0	Gibbsite	40-45
Bakhuis	45.0	2.1 (reactive)	19.0	Gibbsite, 1.5% Boehmite	160-200



Bauxites processed and exported in earlier times were of even better quality with about 1-2 % silica beside 59-60 % alumina.

Mining Operations

In the *Para* area the bauxite layers drop gently towards the North, therefore, Para North mining operations were suspended because of worsening bauxite quality and increasing overburden to bauxite ratio. Lelydorp I, Onoribo II and Onoribo III have been exhausted. Actual mining is done in the Accaribo mine, this could last till the end of 1995. After this, Lelydorp III could follow, lasting for about ten years, or Billiton's operations would have to be relocated to the Bakhuis mountains.

In the *Moengo* area the mines close to Moengo itself have been exhausted and the operations moved to the East, to hills belonging to the so-called Coermotibo area. The crushing/bargeloading station was also relocated from Moengo (on the Cottica river) to Coermotibo (on the similarly named river).

Production

Since the middle of the 1980s, when bauxite exports completely stopped (due to worsening bauxite quality and depleted reserves, but also due to the artificial exchange rate system introduced by the government), the production rate of the mining companies is determined by the alumina production which is best explained by the following theoretical example:

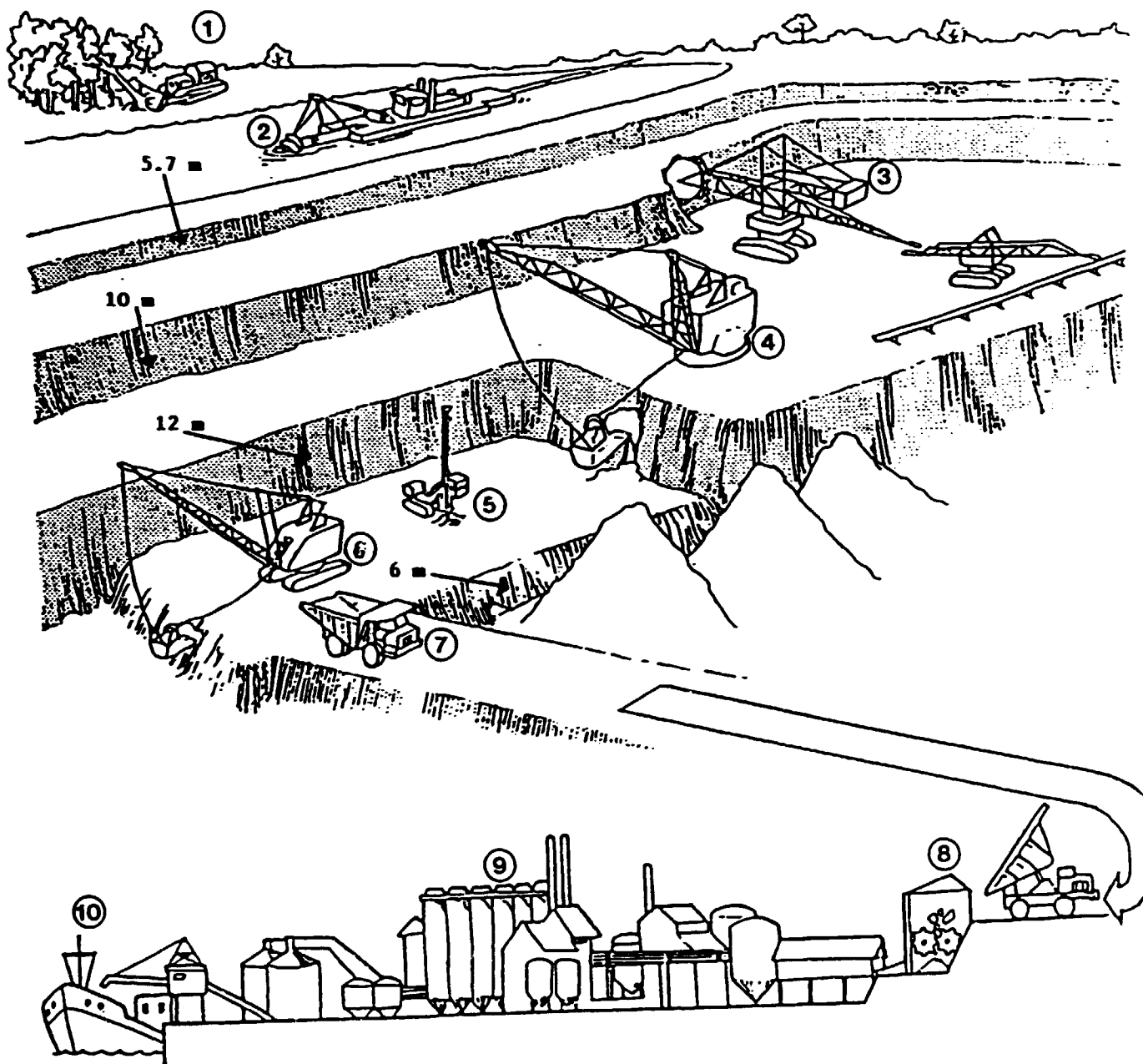
Suppose an alumina production of 1,500 ktpa and an overall alumina yield of 95 % (on available alumina, AA), some 1,580 ktpa of AA has to be fed to the refinery. Since Billiton is entitled to 45 % of production, it has to feed $0.45 \times 1,580 = 711$ ktpa of AA. With an average AA content of 52 % for the presently mined Para bauxite this means about 1,367 ktpa (dry) bauxite. However, this should be 76 % of the output of the Para mines. The total of it should be 1,799 ktpa, of which the other 24 % (432 ktpa) is Suralco's share. This represents about 225 ktpa of AA. Since Suralco has to provide 55 % of the total 1,580 ktpa of AA (i.e. 869 ktpa), the rest ($869 - 225 = 649$ ktpa) has to come from Suralco's mine. Since the ore obtained from the latter contains about 49 % AA, $649 / 0.49 = 1,324$ ktpa of (dry) Moengo bauxite has to be provided by Suralco. Both figures have to be corrected for adhesive moisture. This means that some 2 million tpa has to be mined by Billiton in the Para J-V and about 1.5 million tpa by Suralco in the Moengo area.

Mining Procedures

Since *Para* bauxite is mined in a swampy area, it is necessary first remove the soil and soft wet clay. The tool best suited for this purpose is the "cutterhead suction dredge", which floats in shallow water and pumps the slurried soil to a spoil area. Where there is no free natural water surface but the soil is too soft to support heavy mining equipment, an artificial lake is first constructed by dams to enable the floating dredge to start operation. After the dredge has removed the soft material (soil and clay), a bucket wheel excavator removes the next layer of overburden. The third, most compacted layer is removed by a walking dragline. The total thickness of the overburden to be removed is about 30 to 35 m in the Accaribo mine. The ore stripped of overburden is blasted and loaded by draglines onto 55

Bauxite Mining in Onverdacht Area.

From earth moving to shipping



- | | | |
|--|-------|-------------------------|
| 1. Deforestation | | |
| 2. Overburden stripping by Cutter Suction Dredge | 5-7 m | } 20-30
} overburden |
| 3. Overburden stripping by Bucket Wheel Excavator | 10 m | |
| 4. Overburden stripping by Walking Dragline | 12 m | |
| 5. Drilling for Grade Control and Blasting | | |
| 6. Bauxite excavation by Dragline BE 88HD | 6 m | |
| 7. Transportation of Bauxite to Alumina Refinery | | |
| 8. Crushing and blending of Bauxite (Suralco) | | |
| 9. Refining of Bauxite into Alumina (Suralco) | | |
| 10. Export of Alumina from Paranam berth (Suralco) | | |



t rear dump trucks, which carry it to the alumina plant some 6 km from the mine. Dozers and loaders are also used in the mine. The thickness of the ore layer varies between 4 and 9 m, the average is between 6 and 7 m. The total amount of bauxite mined in the area up to date is about 73 million tonnes. The bauxite is quite seriously contaminated during the mining procedure. The Accaribo mine should give an ore containing about 3.5 % reactive silica according to the geological reports, whereas the bauxite actually supplied to the refinery contains about 5.5 %.

Most of the bauxite in the *Moengo* area can be found on the top of low hills. Here only an average of 1.5 m of overburden has to be removed, this is done by a backhoe. (The vegetation is cleared by bulldozer.) The bauxite (5-6 m thick layer as an average) is blasted and loaded by a backhoe into 50 t trucks. These carry it to the crushing/bargeloading station some 5 km from the presently operated mine. The barges are pushed down the Coermotibo, the Cottica and the Commewijne rivers and up on the Suriname river to the Paranam refinery over a distance of nearly 200 km.

Rehabilitation

It was observed that relatively little effort is made in the *Para* district to rehabilitate the mined-out areas. There is no restoration of the original marshlands but "natural" lakes are allowed to form in most of the mine pits. Some mined-out areas serve as mud lakes of the alumina plant, the rest is intended to be turned into a recreational area after mining will cease in the early years of the next century (or even earlier if the development of the Lelydorp III mine is not approved). This is not a bad proposal since the mine is actually located about half-way between Paramaribo and its international airport.

Some forestation is done on old spoil areas which lie higher than the surrounding terrain. A number of channels have also been dug to connect the lakes with the Suriname river to allow the water to be changed, since sulfuric acid is forming slowly from the pyrite content of the disturbed clay overburden. To limit the acidity increase the overburden is disposed of in such a way, that softer soils are laid under the more solid ones.

As far as the rehabilitation of the mines in the *Moengo* district is concerned, the team couldn't obtain any information on this topic because no visit could be organized. Since here the bauxite is on hilltops and only a relatively small amount of overburden has to be stripped, the rehabilitation should be a much smaller problem.



b. Alumina Manufacturing

There is only one alumina refinery in Suriname, but for quite some time it was the largest in the South American-Caribbean region. Its capacity (1,650 ktpa) has only recently been surpassed by that of Interalumina, Venezuela. It is located in Paranam, some 35 km South of Paramaribo, next to the Para area bauxite mines. It was started up in 1965. Recent production figures (since 1989) varied between 1.51 and 1.63 million tpa.

Processing Features

The bauxite is supplied wet from both mining areas but 7 out of 8 grinding mills are designed for the dry grinding process, therefore, most of the bauxite (75 to 80 %) has to be dried. Two rotary kilns serve for this purpose. Subsequently, it is digested in a medium-concentration liquor (about 137 gpl caustic $\text{Na}_2\text{O}_3 = 235$ gpl caustic soda as carbonate) at 142 °C. A/C ratio is about 0.70 after digestion. Red mud is settled and washed in 7 stages. The underflow of the 7th washer contains 25 % solids and 20 to 25 gpl total soda in the liquor phase. The red mud is pumped to mud ponds constructed in exhausted mining areas. Some 0.7 tonne of water is evaporated per tonne of alumina and subsequently sodium oxalate (some 130 t/month) is precipitated from the strong liquor. The sodium oxalate slurry is pumped to a special corner of an already inactive red mud lake. The product is calcined in Alcoa Mark II fluid flash calciners.

The plant is characterized by the use of relatively small unit size equipment: there are 5 parallel digester lines, 6 settlers, altogether 147 precipitators (arranged in 21 lines of 7 tanks each), 8 calciners, etc. This means that various plant flows have to be united and redistributed after every process step. The concept of parallel, more or less independent, similar capacity processing lines successfully applied by Alcoa in its Western Australian plants is not used in Paranam.

Even though the production equipment is fairly old and outdated, they perform quite well. Recently large amounts of money were spent on instrumentation and process control.

Consumption Data

Bauxite consumption of 2.16-2.20 t/t (dry) is a bit on the high side. With an average AA content of 50-51 % this means an overall yield of only 91 %.

Productivity figures are good but not excellent (60 gpl at digestion, 54 gpl at precipitation).

Caustic soda consumption of 120 kg/t (expressed as a 1000 gpl NaOH solution, corresponding to about 75 kg/t 100 % NaOH) is quite good if one takes into consideration, that the average RS content of the feed is 4.2 %, i.e. more than 90 kg of RS are fed to the process with the bauxite for every tonne of alumina produced.

It is quite difficult to have an exact figure for the total energy consumption of the plant because some of the heat content of the steam produced by the use of fuel oil is used to generate power not only for the alumina plant, and on the other hand, some electric power



is used to generate steam during off-peak hours to save fuel oil. Nevertheless, a safe estimate is 9 and 10 GJ/t, which is a quite good figure for the age of the plant, especially if one takes into consideration that some 9 % of this is for bauxite drying and 3 % for lime burning, which other plants usually do not include in their energy consumption.

c. Aluminium Smelting

SURALCO - the only potline operating in this country consists of vertical stud Söderberg pots of an old design. The plant is located in Paranam, about 30 km south of Paramaribo on the Suriname River. The smelter is adjacent to the previously described alumina refinery producing 1.6 million tonnes per year alumina. The power to the smelter is supplied from the company's 150 MW Brokopondo hydroelectric power station at Afobaka, 100 km southern of Paramaribo. SURALCO is supplying one third of the power to the country's grid.

Production Data

The plant was built in 1965 and consisted of two potlines each of about 35,000 tonnes per year capacity. Due to the limited availability of energy from the hydroelectric generating station, only one line is operating. It is not intended to restart the idle line and it is being dismantled for spares. Production is presently about 32,000 tonnes per year.

Description of the Process Technology and Equipment

The two potlines which were commissioned in 1965 were each equipped with 78 vertical stud Söderberg pots designed to operate at 170 kA. One potline is now operating at 155 kA to produce 32,000 tonnes per year.

The cell was designed over thirty years ago and in Suralco it has not undergone major modernisation. The line is controlled from a central computer. A form of dry paste seems to be used but the anode generates considerable quantities of pitch fume. There are two fume burners on each pot but a number of these were noticed to be unlit. The alumina cover on some of the pots was discontinuous and pot fume was leaking to atmosphere. The pot is operated at low ratio 1.11 and thus such leakage will contain considerable quantities of volatile fluorides.

Alumina is fed to the pots pneumatically from the scrubber area. There is a large dry scrubber treating what fume is collected from the potlines. There is no roof scrubbing.

All metal is cast as 700 kg remelt slab.

TABLE 5.2.2 Primary smelter in suriname

Name	Line	Start date	Last major modification	No. of pots	Pot type	Feed type	Line current, kA	Current efficiency, %	Specific energy consum. kWh/kg	Anode effects per pot day	Net carbon, %	Bath ratio	Control system	Pot life, days	Scrubber type
SURALCO	1	1965	none	78	VSS	SF	155	91.0	15.9	0.9	0.56	1.11	Central Computer	1,500	Dry

VSS - Vertical Stud Söderberg
 SF - Side Feed



Material and Energy Consumption

Table 5.2.3 Main technical parameters of SURALCO Line 1

Line Amps, kA	Current Efficiency, %	Energy Consump. kWh /kg	Net Carbon Consumption t/t Al	Bath Ratio	Pot Life, days	Anode Effects/ Pot-day
155	91.0	15.9	0.56	1.11	1,500	1.0

The current efficiency reported to be 91% for the pot is remarkable. The specific energy usage is on the high side.

5.3 Environmental Impact of the Bauxite, Alumina and Aluminium Industry

a. Mining

The greatest environmental concern in the Para district is that up to the present date some 25 km², most of it natural swamp and marshlands has been turned into mining pits and spoil heaps and most of it will never return to its original state. The construction of a recreational area (if all the plans become reality) is only a second best solution. During the next few years some more virgin land will fall victim to the Accaribo mine. (The Lelydorp III mine would affect mostly developed, inhabited areas, here the problems would be different.)

Water Pollution

Another concern is because of the sulfuric acid slowly forming from the pyrite content of the disturbed clay overburden. Though the natural groundwater is anyway quite acidic in this area (pH typically 4), it is probably not the same for some living organisms to be in a solution of weak organic acids or a diluted solution of a strong mineral acid like sulfuric acid, even if their pH values are similar.

The team can not specify environmental concerns relating to the Moengo deposit because a visit to the site was not possible.

Maintenance practices seem to be very good in the Billiton mine. We did not see any broken down equipment in the operating mine.

Housekeeping is also good, however, some abandoned mine equipment is scattered around the mined out areas. Collection of scrap has been already started.

The workers' safety records are impressive. We did not have any experience with the Suralco mine, but most probably in this field they have also only few problems.



General Assessment of the Technical Performance of the Mine

Efficient, innovative technologies are used in the mines, however, contamination of bauxite during the mining operation in Para requires attention from the management. A large area of virgin marshes and swamps in the Para district has been totally disturbed. Though the situation is not as bad by far as in the Linden area of Guyana, some important decisions regarding rehabilitation will have to be made in the near future, which is especially urgent because the accessible bauxite reserves are slowly running out.

b. Alumina Plant

Water Pollution

As in most alumina plants, the major source of environmental pollution is red mud, but in Paranam the situation is better than usual, even though none of the new solutions (drained bed, dry stacking, etc.) is applied. The reason for this is that the old mining pits used for mud lakes are naturally sealed by clay, since both the "bedrock" and the overburden of the bauxite consist of clay. Another advantage is that even if some caustic seeps out of the mud lake, the acidic ground water would neutralize it (see section 5.2.a on bauxite mining).

The proper handling and disposal of the sodium oxalate precipitated from the process liquor is more of a headache because of its poisonous character. Fortunately, only 1 kg of this material is produced for every tonne of alumina.

Air Pollution

Bauxite dusting is a major environmental concern, first of all because the drying kilns have only cyclones as dust collectors, and neither wet scrubbers no electrostatic precipitators or baghouses. Dust losses are estimated to amount to about 300 to 400 kg per hour per kiln. When including other dust sources like bauxite handling and dry grinding, total dust losses may be in the range of 1 tph i.e. 0.25 % of the bauxite feed.

The lime burning kiln also operates with large dust losses and this dust has a caustic effect on skin and lungs. Therefore, the Joint Venture intends either to modernize or replace the lime burning kiln.

Something similar should be done with the bauxite drying: either eliminate it by modifying the mills for wet grinding or by adding wet scrubbers to the kilns. Alumina dusting is quite low at the calciners but significant at the silos and the shiploading facilities. Attention is being paid to this problem, too.

Atmospheric emissions of CO₂ amount to a little more than 1 million tpa, but SO₂ emissions are relatively low (some 4 to 5 ktpa) because of the low sulfur content of the bunker C oil produced from Surinamese crude.

Maintenance and housekeeping practices seem to be very good at the Paranam refinery. No mud or liquor spills could be seen in the plant area, no broken down equipment could be



observed. Safety rules of the plant are correct, they seem to be obeyed. Safety records are good. Environmental consciousness is good, environmental audits are regularly prepared.

General Assessment of the Technical Performance of the Plant

This is a quite old but at the same time well preserved and well operated alumina plant with acceptable to good technical and consumption data.

Other

The alumina plant effectively contributes to the elimination of some acute environmental problems of Suriname, while the lime burning kiln undertakes incineration of some hazardous wastes, e.g. spent oils and medical wastes.

c. Aluminium Smelter

Air pollution

Since the pots are large Söderbergs, considerable quantities of pitch fume are released to atmosphere via the roof louvres. The potroom ventilation is good and the actual work areas at ground level are relatively free of fume. Conditions above the pot, however, are poor.

There were a number of pots which were not sealed with alumina and thus considerable leakage of dust and fluorides to atmosphere was occurring. Some of the pitch fume burners were unlit.

There was some alumina blowing about the site.

Water pollution

There are no problems of water pollution associated with the smelter.

Solid waste

Like many old smelters, this plant has been dumping spent pot linings in unprotected landfill sites for many years. This has now stopped, although there are no plans to recover this material.

Spent pot linings are now collected and carefully stored in the basement of the shut down line. A properly sealed hazardous waste tip is being prepared. This will be clay-lined and plastic covered and will be used for all future disposal of pot linings.

Maintenance and housekeeping procedures

The work areas in the potroom were clean and free from any obstructions. The courtyards were clean, except for some alumina dust.



Most equipment seen seemed to be in reasonable condition for its age. There was a large workshop which serviced both the smelter and the refinery.

Worker safety

Despite the fume release from the pots, the working atmosphere at floor level was good. It was poor above the pot. Masks were worn throughout the potrooms. Urinary fluorides are measured regularly on employees.

The plant safety record is good with over one million hours between lost time accidents being achieved regularly.

In the past there has been a problem with bath splashing up through the anode stud holes but this has been cured.

Traffic moves slowly and seatbelts are worn in company vehicles.

General Assessment of Technical Performance of the Plant

The plant is a fairly old-fashioned vertical stud Söderberg operation which is giving average performance. It has not been modified since construction.

There is at this time very little monitoring of the fluoride or dust being discharged from the scrubber or roof louvres. Since the bath ratio is very low and many pots are not sealed, the roof louvre discharge must be high by modern standards. The discharge of pitch fume (PAH's) is also likely to be high.

People are well aware of the problems facing this plant and a Senior Manager is responsible for environmental and safety issues. The rectification of problems is the responsibility of the Line Managers working with the Environmental Manager. There seems to be a real effort underway at the plant to improve the situation.



5.4. Barriers to Sustainable Development

a. Structure and Profile of the Industry

The deposits in the *Para* district are owned by a Joint Venture of Billiton Maatschappij Suriname (76 %) and SURALCO (24 %) and managed by Billiton. Billiton is a 100 % subsidiary of Shell, whereas SURALCO is a 100 % subsidiary of ALCOA.

The deposits of the *Moengo* region are owned and mined by SURALCO.

The deposits in the *Bakhuis* mountains are not leased yet to any company.

The Paranam alumina refinery is owned by a Joint Venture (55 % Suralco and 45 % Billiton) and managed by Suralco.

The SURALCO smelter is owned 100% by ALCOA.

In the case of Suriname the team couldn't detect any disadvantages resulting from the foreign ownership of the plants. On the contrary, the multinational companies by following their company policies are making efforts to improve the environmental situation in and around their operations. Of course there are several technical, site specific and financial barriers preventing application of more radical technological changes. Some of these barriers are described in the forthcoming parts of this chapter. In the case of the smelter the strict internal environmental regulations of ALCOA might lead to closure of the plant if no feasible solution is found for its rehabilitation.

b. Status of Regulatory Programme

According to the information given to the team by the various institutions, ministry and the industry there is no environmental law in the country. The safety laws are also inadequate, mainly obsolete regulations from Holland are applied.

In 1946 the land in Para was bought as "useless" swamp for 12,5 US¢ a hectare. There were no environmental related conditions incorporated in the older lease contracts. In the new lease agreements it is stipulated, that the company should return the mined out area to the satisfaction of the Minister of Natural Resources.

In the Para district the concession is valid up to 2006. The same applies for the joint venture agreement. It is expected, that the bauxite resources here will last up to 2010. The company informed us that some sort of "walk-away-strategy" has already been worked out. It has to be noted that the conservation of the drainage canals has to be maintained for a very long period even after completion of mining activity in the region in order to prevent excessive acidity.

The internal company regulations are more up to date. SURALCO for example is subject to regular plant audits implemented by ALCOA Headquarter staff. The last audit was



effected in March 1993, and the company is presently implementing the measures required by the audit team. There is a strict system of biannual reporting of plant management to the Headquarters on the implementation of action plans prepared on the basis of the audits and approved by the Headquarters.

c. Attitude of Plant Management

The mines and plants were designed to meet environmental protection standards that were much less rigorous than those imposed today in many parts of the world. The good level of general housekeeping, maintenance and worker safety of the operations is a sign of proper management attitude.

Since 1989 Billiton operates an environmental department. The Health, Safety, Environment & Quality Newsletter is published by Billiton to highlight information, results and advanced practices in the related fields.

At the newer mining operations much more attention is given to environmental considerations than before.

The refinery is also well run, some actions have already been and are being taken to prevent environmental degradation.

The Management of the smelter is aware that to justify continued operation, the performance of the potline will have to be improved and the impact on the environment will have to be reduced in the fairly near future.

Already vastly improved procedures to deal with spent pot linings are in place. In 1994 a decision will be made as to whether or not to introduce a major retrofitting programme to modernize the cell with tested technology which will be purchased from a European company.

In 1991 SURALCO also established its Environmental Department consisting of two engineers and a technician to organize and implement the substantive work. The department is the focal point for environmental issues. It formulates the target for every department and keeps track of available (not complete) pollution data and environmental projects of the Company.

The management of both companies maintains good cooperation with the authorities. A voluntary environmental committee for Paranam was set up recently with the active participation of plant management. The committee meets monthly to discuss and schedule activities.

There is a great deal to be done but the problems have been identified and a determination by Senior Management to improve the situation so that continued operation can be justified was evident.



d. Site Specific and Technical Barriers

Bauxite Mining

The bauxite reserves of the Para district are close to exhaustion, especially if the approval for mining the Lelydorp III deposit is not granted. The mining of the deposits in the Bakhuis mountains would require a quite large initial investment and it is very questionable, whether Billiton can afford it under the present economic circumstances.

It is technically impossible to restore completely the original marshlands after concluding the mining operation. Therefore, a second-best option of turning the mines into a recreational area has to be accepted.

Alumina Manufacturing

The most important barrier to any sustainable development of the alumina refinery is also the availability of bauxite. Of course, some bauxite could be imported to compensate the exhaustion of the Para mines (similarly to the situation when mining had to be stopped in the Moengo area in 1986-87 and in 1990 because of rebel activity), but this could hardly be a long-term option.

Aluminium Smelting

The small smelter at Paranam presently operates without any severe licensing restrictions. However, the Management realizes that they must improve the environmental protection equipment and the efficiency of the plant if it is to have a future. A decision on whether capital can be invested to achieve the necessary improvements will be made in 1994. If the economics of the situation indicate that such expenditure is not justified, the life of the smelter may be limited.

The prospect of building a new smelter in Suriname is remote in the absence of supplies of hydro power.



5.5. Strategy for Sustainable Development in the Bauxite/Alumina/Aluminium Industry

a. Strengthening of Policy and Regulatory Programmes

In view of the absence of environmental law and regulatory framework in the country concentrated efforts should be taken to create them. In this regard experience of other countries in the Region could be studied and good practices adopted. This approach would be very beneficial in light of the limited human resources available within the country.

b. Institution and Human Resource Development to Implement Regulatory Programmes

Parallel to the establishment of the regulatory framework creation of the necessary institutions is required. These institutions should draw on the human and technical resources available in the country (at the university, various testing laboratories of institutions and industry etc.).

International organizations and donor countries are encouraged to assist Suriname in the establishment of the regulatory framework, development of institutional base and human resources.

c. Opportunities for the Introduction of Pollution Prevention and Cleaner Production at the Plant Level

The rather good environmental performance of the Paranam refinery could be further improved if some of the dust sources could be eliminated.

- One possibility would be to install wet scrubbers to the bauxite drying kilns.
- An even better solution would be to change the process from dry to wet grinding, because this would also give some fuel saving (for 1 t of alumina 6 gallons i.e. some 23 l of fuel oil could be saved and the extra amount of water could be removed by evaporation for about half of this amount).
- Another important improvement would be the modernisation or replacement of the lime burning kiln to prevent lime dusting. According to our information this question is already under consideration.

At SURALCO in the last quarter of 1993 a decision will be taken as to whether the potline will be modernized using purchased technology. If this programme is carried out:

- the anode will be hooded, a new type of pot skirt will be introduced;
- point feeders will be fitted;
- anode effects will be extinguished automatically;



-
- air-conditioned cabs will be installed on crust breaking and anode stud changing machinery thus making working conditions much better;
 - a smelter monitoring system will be installed to measure scrubber and roof discharge.
- This is a costly modernization programme and will require economic justification.

f. Cost of New, Cleaner Technologies

A wet scrubbing system could be installed for a few hundred thousand US\$ to the bauxite kilns.

The cost of transforming the dry grinding mills into wet grinding ones and modifying the equipment serving them could cost roughly the same amount.

The extra evaporation capacity could cost some US\$ 2 to 4 million.

The modernisation of the lime burning facilities could cost about US\$ 1 to 2 million, the installation of a completely new one US\$ 3 to 4 million.

The cost of retrofitting of the smelter is being analyzed by the Company. Based on the short visit to the plant it was impossible for the team to assess its cost precisely but it could be of the order of US\$ 10 to 20 million.



6. VENEZUELA

6.1 Introduction

The Venezuelan bauxite mining, alumina refining and aluminium smelting activities are concentrated in the Guayana region. Alumina is produced at the city of Puerto Ordaz through the processing of bauxite derived from Los Pijiguaos mines in Venezuela. The product is mainly used in the ALCASA and VENALUM smelters adjacent to INTERALUMINA alumina plant. Some is also exported and a smaller amount is used for non-metallurgical purposes within Venezuela.

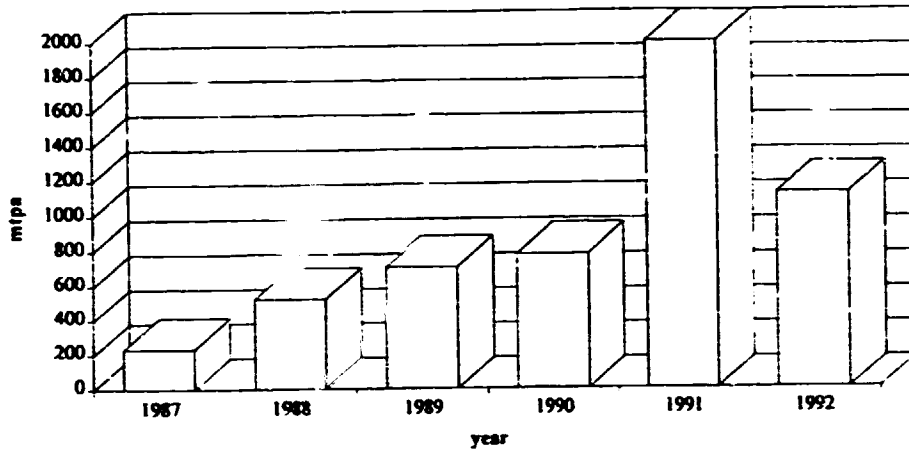
The above-mentioned mine, alumina refinery and smelters are part of a large conglomerate of companies supervised by the state-owned Corporacion Venezolana De Guayana (CVG). CVG is the principal entity responsible for the promotion and coordination of the socio-economic development of the Guayana Region subject to the guidelines of the nation's five year presidential term plan. CVG puts major emphasis on integration. CVG, during its thirty years of existence, has achieved outstanding results. The large Guayana region is one of the major iron ore, ferro-silicon, steel, gold, bauxite, alumina and aluminium producers of the world. The major metallurgical companies are located in the new town of Ciudad Guayana with approx. 0.5 million inhabitants on the banks of the Caroni and Orinoco rivers. Electric power is generated at two hydroelectric power stations on the Caroni River, one of which - the GURI - is the second largest dam and hydroelectric power station of the world. Additional power plants are also under development. The large amount of cheap and clean energy resources offer extremely favourable conditions for the development of the core industries in the region.

The combination of good quality and very rich bauxite resources, cheap and reliable energy supply, good transportation facilities and availability of a well-trained workforce could effectively contribute to the creation of the world's most competitive aluminium industry in Venezuela. The development of the sector followed the backward integration process, whereby the first aluminium smelter (ALCASA) was erected already in 1967, this was followed by the start up of the second smelter (VENALUM) in 1978; the alumina plant came on line in 1983; whereas industrial scale bauxite mining was started in 1992 only after several expansion projects in the smelters and refinery.

The mining company, BAUXIVEN, is owned 55 % by CVG and 45 % by FIV (Fondo de Inversiones de Venezuela). The majority shareholder of the refinery, INTERALUMINA, is CVG (99%) and Alusuisse has a minority (1%) share in it. The ownership structure of the smelters is as follows. ALCASA: 86% CVG, 14% Reynolds (USA), VENALUM: 61.2% Fondo de Inversiones de Venezuela, 18.8% CVG, 7% Showa Aluminium Industries, Japan, 4% Kobe Steel, Japan, 4% Sumitomo Chemical Co., Japan.

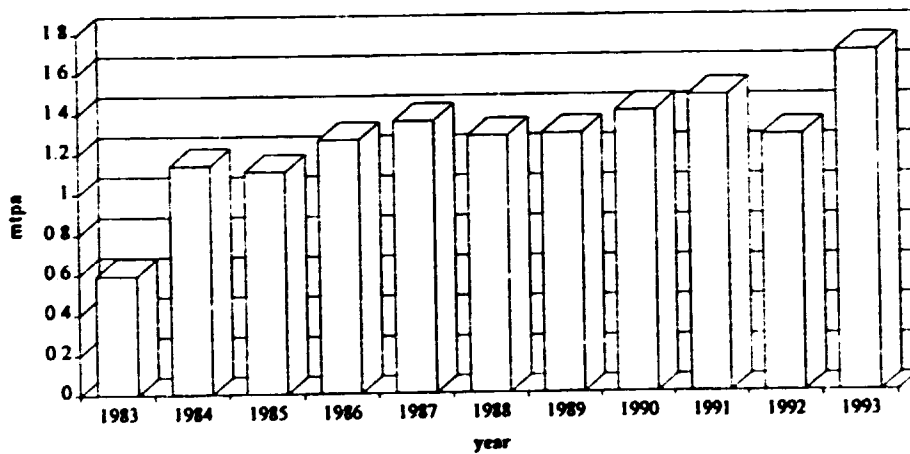


Figure 6.1.1 Bauxite production of Venezuela



Source: CVG

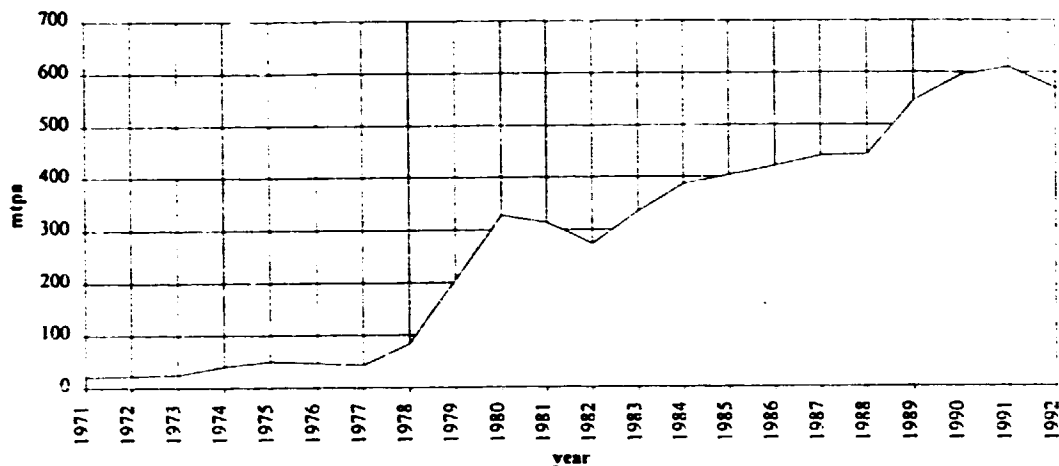
Figure 6.1.2 Alumina production of Venezuela



Source: C.V.G.



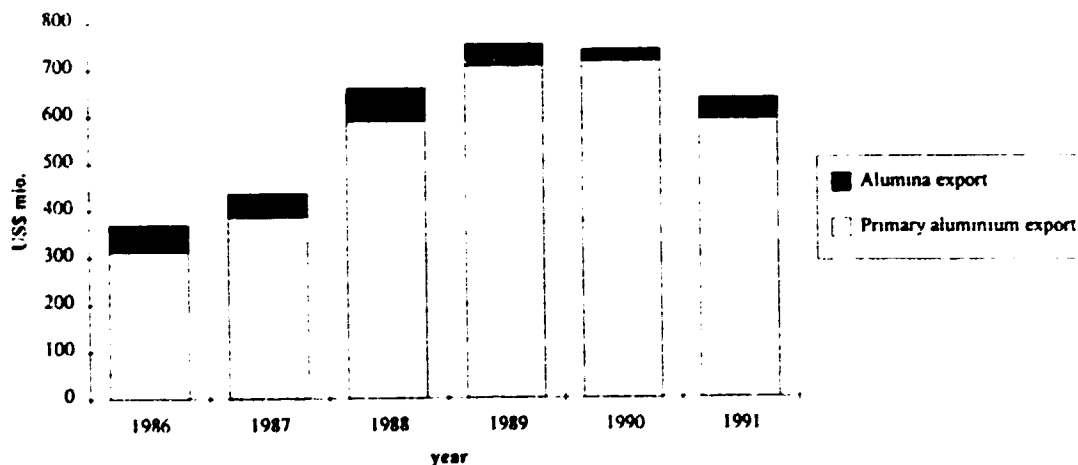
Figure 6.1.3 Aluminium production of Venezuela



Source: Yearbook of International Commodity Statistics, 1985 and 1993, UNCTAD

The aluminium sector is already one of the strategic industries which complements the export earning potential of the strong oil sector. It represents for the country a substantial source of foreign exchange income. However, its impact on the national economy is still relatively modest in comparison with the earnings from the national oil sector.

Figure 6.1.4 Alumina and primary aluminum exports from Venezuela



Source: Yearbook of International Commodity Statistics, 1993, UNCTAD



Table 6.1.1 Principal Exports of Venezuela to major partners 1992

Country	Share in Venezuelan Exports	Volume	Volume of Non-ferrous Metals Exports		Volume of Petroleum Products Exports	
	%	US\$ mio	US\$ mio	%	US\$ mio	%
USA	50	8,636.4	107.3	1.2	7,622.2	88.3
Germany	4.4	940.0	28.9	3.11	862.7	91.2
Japan	3.3	446.8	262.3	58.8	101.1	22.7

Source: CVG

Table 6.1.2 Principal Exports of Venezuela by Items, 1990 (US\$ mio.)

Public sector	15,117	
Petroleum & derivatives	13,380	79.8% of Total Exports
Aluminium	673	3.9% of Total Exports
Steel	303	
Iron ore	197	
Gold	1	
Other	163	
Private sector	2,161	
Coffee	11	
Cocoa	7	
Gold	6	
Other	2,137	
Total Exports	17,278	

Source: The Economist Intelligence Unit Country Profile 1992-93



The limited utilization of the country's potential in the aluminium industry has always been a matter of concern for the Government of Venezuela. During the second half of the 1980s, programmes and plans for the expansion of the sector were developed and initiated. Since 1991, the dramatic downfall of the prices of aluminium have reduced the pace of the expansion process. Nevertheless, the country still maintains its ambitious goal to steadily expand the aluminium industry and reach 2 million tonnes annual primary aluminium capacity. It is expected, that as soon as the international aluminium market shows signs of recovery, the process of expansion of the industry in Venezuela will continue with more intensity and at least a few of the eleven smelter projects under considerations will materialize. In the most advanced stage are the Aluyana, Alcoven, Alisa and Orinoco Aluminium projects¹.

¹Source: Roskill, *The Economics of Aluminium 1992*, London



6.2. Description of the industry

a. Bauxite Mining

Geography, Geology

The only known bauxite deposit of Venezuela is Los Pijiguaos, some 600 km South of Caracas and the same distance from Puerto Ordaz. It was developed on a 600 m high plateau of granitic mountains from the granite parent rock. The deposits extend southwards over a huge area at 400 to 1000 m elevation. Total proven reserves amount to 240 million t, the probable ones to 500 million t, the possible ones to 4 to 5 billion t. The deposits were discovered in 1976 and explored between 1976 and 1979. Mining started in 1987. The full scale industrial operation has been going on since 1992. The thickness of the ore varies between 7 and 12 m, it is typically covered by 0.5 m of overburden. The bauxite lies on granite covered by 5 m thick clay layer. The area of the mine site is 250,000 hectares.

Quality

The Los Pijiguaos bauxite is of a purely gibbsitic type. The average composition of the already explored 9 blocks is 49 % total alumina, 11 % total silica, 2 % reactive silica, 13 % Fe_2O_3 . Its organic content is relatively high, 0.25 %. Moisture content is 11%.

Mining Operation

The Los Pijiguaos mine is operated by BAUXIVEN. The operation consists of the mine, the crushing station, the cable belt conveyor system, the handling and storage area at the railhead, the railway, the handling and storage area at the port, the barge loading wharf and the fleet of barges.

Production

The present production rate of the Los Pijiguaos mine is close to 6 million tpa. All the facilities can handle flows of at least 1,600 tph, i.e. twice the present average production rate. The only problem is that the Orinoco river can not be navigated during the dry season, for about 3 months every year. The large bauxite storage areas (900 kt at the railhead, 600 kt at the barge loading facilities, 1,500 kt at the alumina plant) are provided to bridge this gap. Their storage capacity (but not that of the equipment) would have to be doubled to double the production rate.

Mining Procedures

After removing the vegetation and stockpiling the soil and occasional little overburden by dozers, the hard lateritic crust is ripped and the bauxite is loaded (without blasting) onto off-road trucks. These haul it to the 1,500 - 1,600 tph capacity crushing station where jaw crushers and hammer mills crush the bauxite. (In the rainy season the crushers' capacity might drop to 1,100 tph.) From here the bauxite is carried by a 4.2 km long, curved cable



belt conveyor down to the railhead storage. Here stackers distribute it over 4 parallel piles (max. capacity 225 kt each). Reclaimers carry the ore into silos, from where the railcars are loaded. Trains consisting of two robot locomotives and 28 cars of 90 t payload each shuttle between the two ends of a 52 km long railway. At the downstream end of the railway the cars are unloaded by an automatic rotary car dumper. From here the bauxite is distributed by stackers over another 4 parallel piles (with a maximum capacity of 150 kt each). Reclaimers carry the ore again to silos, from where a belt conveyor of 3,600 tph capacity transports it to a travelling shiploader with the same capacity. Nine 1,500 t barges can be loaded simultaneously. Trains of 12 or 16 barges are pushed by tugs over about 650 km along the Orinoco river to Puerto Ordaz to the Interalumina refinery.

Rehabilitation

Even though only a relatively small area can be considered to be mined out, rehabilitation has already begun. Soil is replaced and trees are planted in regular rows. The only problem with the replanted area is that the new vegetation is quite uniform, little variety can be seen. In this the rehabilitation is less complete than the best practices (seen e.g. in Western Australia) but compares favourably with Jamaica, Guyana and Suriname. CVG states that diversification will start at a later stage.

b. Alumina Manufacturing

There is only one alumina refinery in Venezuela (INTERALUMINA), but its capacity is the largest (2 million tpa) in the South American - Caribbean region. The company is located in the Eastern part of Venezuela, in the Guayana region, at Puerto Ordaz, at the confluence of the Orinoco and Caroni rivers, on the right bank of the Orinoco. The plant was started up in 1983. The original capacity was some 1 million tpa. After minor modifications production reached and fluctuated around 1.3 million tpa during recent years. As a result of further upgrading to nominal capacity of 2 million tpa production in 1993 will probably be close to 1.5 million tpa. The 2 million tpa nominal capacity was proven only during a short test run lasting for 2 weeks in the second half of 1993. This capacity has still to be proven by long-term production figures.

Processing Features

The refinery was designed to process gibbsitic bauxites (low temperature digestion around 140°C). During its lifetime it has processed Australian (Gove), Brazilian (Trombetas), Guyanese (both Linden and Berbice), Sierra Leone and other bauxites. Since 1987 it has obtained ever increasing amounts of domestic (Los Pijiguaos) bauxite. At the time of the team's visit the refinery was running exclusively on the latter bauxite, and this will be typical for the future.

From Puerto Gumilla, bauxite is shipped 650 km down the Orinoco river to the INTERALUMINA terminal at Guayana city. The bauxite unloaded from barges (or ocean-going bulk vessels in case of foreign origin) is cracked and stored in a huge storage area (partly covered, partly open) with a total capacity of about 1.5 Mt (this is required to



compensate for the interruption in the transportation of the domestic bauxite during the dry season). The reclaimed bauxite is crushed in impact crushers and ground in ball mills.

Digestion is performed in a double-stream digestion process at about 140°C in a relatively high concentration liquor (about 175 gpl caustic Na₂O). Extraction yield is typically 98 % (on available alumina, total plant yield is about 93 %.)

Because of the high quartz content of the Los Pijiguaos bauxite an extensive desanding of the slurry diluted to about 140 gpl caustic Na₂O is applied before settling (3 stages of cycloning plus screw classifiers for washing the sand). The amount of sand is about 8 to 12 % of the processed (dry) bauxite and the red mud is 24 to 26 % of the same (dry basis).

The so-called Alusuisse (or Tschamper) process is applied at the precipitation with high liquor productivity figures (75-80 gpl, plans for year-end: 82-85 gpl). Sandy alumina is produced in four Lurgi-type fluid bed calciners, the original 1,400 tpd capacity of which has been increased to 1,700 tpd by modifications initiated by Interalumina personnel.

A relatively large amount (250 tph) of water is evaporated from the spent liquor to maintain the water balance of the process but even this is insufficient because of the excessive quantities of unaccounted water for miscellaneous dilutions entering into the process. As a result of undesirable dilutions the Na₂O concentration of the liquor phase of the last washer's underflow usually exceeds 10 g/l and sometimes it is even much higher. The red mud is pumped into lagoons reinforced by dikes located along the shore of the Orinoco river.

Material and Energy Consumption

Some 2.45 tonnes of Los Pijiguaos bauxite was used for every tonne of alumina produced in August 1993 (dry basis). The composition of this bauxite was: 49.3 % total alumina; 45.6% available alumina; 2.1% reactive silica; 10.8% total silica; 8.5% quartz; 11.9% Fe₂O₃; 1.3% TiO₂; 0.13% C_{org}. This means an overall plant yield of only 89.5 % (on available alumina) in contrast to the 93 % communicated by the plant engineers to the UNIDO team (see above).

In 1992 caustic soda consumption exceeded 100 kg Na₂O (130 kg NaOH) per t of alumina as an average but that time some 30 % of the processed bauxite was the relatively high silica Trombetas one. With the above composition of Los Pijiguaos bauxite the August 1993 figure was only 44 kg Na₂O~57 kg NaOH (acceptable for an amount of 51 kg/t reactive silica fed with the bauxite).

The amount of natural gas consumed during the same month was about 250 m³/t, i.e. about 9 GJ/t (without electric power) - a good figure even for a relatively new plant, if it can obtain the natural gas at a very low price.



c. Aluminium smelting, carbon making

The two Venezuelan plants, ALCASA and VENALUM, are located 20 km west of Puerto Ordaz. They produce about 600,000 tonnes of metal each year. There is a large independent anode manufacturing facility, CARBONORCA, with a capacity of about 200,000 tonnes per year located adjacent to the ALCASA Smelter. Plant by plant description is given in the following chapters.

ALCASA

The plant is located in the Matanzas Industrial Zone about 20 km west of the town of Puerto Ordaz. It lies near the Orinoco River. The first pots were installed in 1968 and following expansions in 1972, 1977 and 1988, the production of the plant has reached 210,000 tonnes per year. This is converted to 500 kg sow, 22 kg ingot and rolling slab.

Description of Process Technology and Equipment

There are two generations of primary production technology at this plant.

a. Original technology

This technology was installed between 1968 and 1972 and consists of two lines of 68 kA cells. The cell is an old prebake design first used in the U.S.A. about forty years ago where, following extensive retrofitting and modernization, many of these cells continue to operate today. The output from the old plant is 40,000 tonnes per year when both lines are operating. The cells are centre-fed with bar breaker, have 28 small anodes and are unhooded.

At this point in time, Line 1 is shut down due to electrical problems following flooding.

Associated with the old plant is a green carbon plant, rodding room and ring furnace. The green carbon plant provides green anodes for both the original potlines and the newer potlines. The ring furnace is of the open type and the exhaust gases pass directly to a 30 m stack without scrubbing.

b. The new plant

This consists of two lines of 160 kA cells. The first line was installed in 1977 and the second, an improved version of the first, in 1988. There are 180 cells in Line 3 and 216 in Line 4. Similar cells have been used in a number of plants. The technology was first used in the Hamburg Smelter in 1969. The output from the new plant is 160,000 tonnes per year. These cells are fully hooded and exhaust gases are fed to modern dry scrubbers. The cells are automated, the system in Line 4 being more modern than that used in Line 3. A bar breaker with four teeth is used for alumina feeding in Line 3. Line 4 is equipped with point feeders.



A modern closed baking furnace is used to bake anodes for these potlines. This is fitted with a Flakt fume scrubber comprising a water cooler and electrostatic precipitator. This is effective and the stack plume is invisible. The scrubber generates large quantities of condensed pitch fume and discharges contaminated water to drain.

Material and Energy Consumption

a. Original plant

Table 6.2. 1 Main technical parameters of ALCASA, Lines 1 & 2

Line Amps, kA	Current Efficiency, %	Energy Consump. kWh /kg	Net Carbon Consumption t/t Al	Bath Ratio	Pot Life, days	Anode Effects/ Pot-day
68	87.5	17.5	0.58	1.45	900	not available

Energy usage is high. The consumption of carbon is high and, as the cells are unhooded, the usage of alumina and aluminium trifluoride will be high.

These figures are to be expected for a cell of this age which has not been hooded and modernized.

b. New plant

Table 6.2. 2 Main technical parameters of ALCASA Lines 3 & 4

Line No.	Line Amps, kA	Current Efficiency, %	Energy Consump. kWh /kg	Net Carbon Consump. t/tAl	Bath Ratio	Pot Life, days	Anode Effects /Pot-day
3	162	89.8	15.4	0.465	1.42 + Li	1,700	not available
4	147	90.5	16.1	0.510	1.42 + Li	800	not available

Carbon consumption in both the new lines is high. The current efficiency in Line 3 is reasonable by today's standards but the performance of Line 4 with point feeders and distributive control should be much better. The pot life in Line 4 is very low at 800 days. Pot lives approaching 2,000 days should be expected in cells of this type.



VENALUM

The plant is located in the Maizanas Industrial Zone about 20 km west of the town of Puerto Ordaz near the Orinoco River. It consists of four lines of 160 kA pots installed in 1978 and one line of 230 kA pots installed in 1988. The plant produces about 380,000 tonnes per year, excluding the output of five large experimental pots.

Description of Process Technology and Equipment

a. Original potlines

Four lines each of 180 pots were installed in 1978, together with associated carbon facilities and cast house. Three of the original lines remain unmodified since installation but Line 3 was substantially modified in 1992/3.

The original cells are 160 kA prebakes without modern automation using centre bar breakers to feed alumina. Each cell has 18 anodes. The cells are hooded but many hoods were damaged, misplaced or missing. Some cells were operating without any hoods at all. (After our visit to the plant 66 cells were furnished with new hoods).

Line 3 has recently undergone substantial modification using modern retrofit technology. Point feeders have been installed and low ratio bath chemistry is being introduced. The addition of lithium to the electrolyte has been discontinued. The cells have been automated with modern distributive control systems but anode effects still seem to be extinguished manually. It is hoped to reduce the anode effect frequency to 0.3 effects per pot-day. (By July 1994 the anode effect frequency has been reduced to 0.38 effects per-pot day.)

An Alusuisse pneumatic alumina conveying system has been installed in Line 3 and seems to be working well but some problems of clogging due to alumina properties were reported. (CVG informed us in July 1994, that the clogging problems had been eliminated).

It is proposed to upgrade the other three lines of 160 kA pots some time in the future.

The courtyards of some of the potlines (not Line 3) contain large piles of alumina which has been swept from beneath the suspended pots.

Flakt scrubbers were operating on all four lines.

b. The new line

Line 5 was installed in 1988. The cell is a modern design and is presently operating at 231 kA. As the equipment is still in good condition and hooding standards are high, the collection of pot fume is excellent. The potroom atmosphere is clear from end to end of the potline.

The cell contains 26 anodes and is fully automated. Lithium is not used in the electrolyte and a low bath ratio is maintained.



The output from this line is 80,000 tonnes per year.

At the end of Line 5, very large experimental pots are being tested with the possibility of currents exceeding 300 kA.

c. Carbon plant

A large green carbon plant using batch mixers and vibratory formers provides anodes to the bake furnace. Some of the anodes formed in this plant are baked at the Carbonorca facility. Two bake furnaces each of 48 plus 32 sections are operated. These are of the closed Riedhammer design. They are fitted with Lurgi exhaust scrubbers which comprise a water cooler followed by an electrostatic precipitator.

Material and Energy Consumption

a. Lines 1, 2 and 4

(These are the unmodified 160 kA potlines.)

Table 6.2.3 Main technical parameters of VENALUM Lines 1,2 & 4

Line Amps, kA	Current Efficiency, %	Energy Consump .kWh /kg	Net Carbon Consumption t/tAl	Bath Ratio	Pot Life, days	Anode Effects / Pot-day
158.5	89.5	15.0	0.45	1.38 + Li	1,300	not available

This is reasonable performance for pots of this vintage and design.

b. Line 3

(This line has been substantially modernized.)

Table 6.2.4 Main technical parameters of VENALUM Line 3

Line Amps, kA	Current Efficiency, %	Energy Consump .kWh /kg	Net Carbon Consumption t/tAl	Bath Ratio	Pot Life, days	Anode Effects /Pot-day
162	89.5	14.5/ 15.0	0.47	1.15	1,300	0.4
165*	91.46*	14.55*	0.453*		1,712*	0.38*

* Latest data (first quarter of 1994), communicated by CVG in July 1994.



The parameters observed during the team's visit indicate poor performance for a pot using point feeders and modern automation. The current efficiency should be in excess of 93% and carbon usage below 0.42 tonnes of carbon per tonne of metal produced.

c. Line 5

(This is the new 230 kA line.)

Table 6.2.5 Main technical parameters of VENALUM Line 5

Line Amps, kA	Current Efficiency, %	Energy Consump .kWh /kg	Net Carbon Consumption t/tAl	Bath Ratio	Pot Life, days	Anode Effects / Pot-day
221.5	89.6	15.0	0.48	1.16	829	not available
223.7*	93.3*	14.14*	0.43*	1.13*	1,243*	0.14*

* Latest data (first quarter of 1994), communicated by CVG in July 1994.

The figures in the first row of the above Table 6.2.5 were provided by potroom management. This is a very poor performance for a modern pot. Current efficiency should exceed 93% and specific energy usage should be below 13.5 kWh/kg. Net carbon should be about 0.41 tonnes per tonne of aluminium produced and pot life should exceed 2,000 days. CVG now plans to reach 2,000 days pot life and 13,8 kWh/kg power consumption by the end of 1994.

CARBONORCA anode carbon plant

The plant is alongside the Alcasa Primary Aluminium Smelter in the Matanzas Industrial Zone, 20 km west of Puerto Ordaz. The green mill is capable of producing up to 196,000 tonnes per year of green anodes. The bake furnace can produce 200,000 tonnes of baked anodes at full capacity.

Description of Process Technology and Equipment

This facility consists of an F.C.B. green mill, two Riedhammer bake furnaces and associated Lurgi fume control equipment.

a. Green mill

This is a modern green carbon plant constructed by Fives Caille Babcock in 1988/89. It is highly automated and uses a 28 tonnes per hour continuous mixer. Pitch is imported solid from the USA, Spain and Germany and melted on site. The Plant is clean and spacious.



b. Bake furnaces

An 80 section bake furnace originally constructed by VENALUM and a 48 section furnace originally constructed by ALCASA are operating. The pit and foundations exist for a further 32 section furnace in the ALCASA building. All furnaces are of the covered type and similar to furnaces operating in the two primary smelters. The furnace halls are clean and all equipment appears to be in an excellent condition.

c. Exhaust gas scrubber

The scrubber on the 82 section furnace was working well but giving rise to the same pitch condensation problems that are apparent in the smelter carbon plants.

The scrubber on the 48 section furnace has not been completed and thus has never operated.

Material and Energy Consumption

No data was obtained but the furnace is well instrumented for fire control and there was no evidence of material wastage. It is presumed that the operation is as efficient as similar furnaces in other parts of the world. The technical department representatives showing the Plant were very impressive in their knowledge of the operation.

TABLE 6.2.6 PRIMARY SMELTERS IN VENEZUELA

Name	Line No.	Start date	Last major modification	No. of pots	Pot type	Feed type	Line current, kA	Current efficiency%	Specific energy, kWh/kg	Anode effect per pot day	Net carbon t/Al	Bath ratio	Control system	Pot life, days	Scrubber type
ALCASA	1	1968	none	140	CWPB	Manual	68	87.5	17.5	n.a.	0.58	1.45 + Li		900	not scrubbed
	2	1972	none	148	CWPB	Manual	68	87.5	17.5	n.a.	0.58	1.45 + Li		900	not scrubbed
	3	1977	none	180	CWPB	CB	162	89.8	15.4	n.a.	0.465	1.42 + Li	Central computer	1700	Dry
	4	1988	none	216	CWPB	PF	146.7	90.5	16.1	n.a.	0.51	1.42 + Li	Distributive	800	Dry
VEN-ALUM	1	1978	none	180	CWPB	CB	159	89.5	15.0	n.a.	0.45	1.38 + Li	Central computer	1300	Dry
	2	1978	none	180	CWPB	CB	159	89.5	15.0	n.a.	0.45	1.38 + Li	Central computer	1300	Dry
	3	1978	1992	180	CWPB	PF	162/164.9*	88.0/91.5*	14.7/14.5*	0.4/0.38*	0.47/0.45*	1.15	Distributive	1300/1712*	Dry
	4	1978	none	180	CWPB	CB/PF	159	89.5	15.0	n.a.	0.45	1.38 + Li	Central computer	1300	Dry
	5	1988	none	180	CWPB	PF	221.5/223.7*	89.6/93.3*	15.0/14.1*	n.a./0.14*	0.48/0.43*	1.16/1.2*	Distributive	829/1243*	Dry

CWPB - Centrally Worked Prebake

CB - Centre Break

PF - Point Feed

n.a. - information not available

* Latest data (first quarter of 1994), communicated by CVG in July 1994



6.3 Environmental Impact of the Bauxite, Alumina and Aluminium Industry

Mining

Bauxite is mined by CVG Bauxiven at Los Pijiguaos by open pit method and delivered by dump truck to a crushing station from where it is transported 54 km by a system of conveyors and locomotive haulage to Puerto Gumilla, the Orinoco river. (Full details of mining operations are given in section 6.2.a).

The mine is located on a plateau appr. 600 meter above the surrounding country and, during heavy rain, water cascades through the working areas into lagoons in the working pits and then down to the valley below. Drainage channels have been built to divert run off away from working areas but there remains a potential for erosion and also pollution from the increased suspended solids concentration of storm-fed streams which flow into the Los Pijiguaos river.

Another environmental concern observed by the UNIDO team was the washing away of some of the bauxite from the railhead storage area by rain and as a result of this the contamination of some natural waterflows by mud. This also affects the quality of the drinking water of the nearby population. However, Bauxiven plans efforts to redress this situation.

There are no agricultural or ranching activities in the mine vicinity and the surrounding environment is naturally acidic so pH is not adversely affected by mine drainage. The mine has been in operation for 5 years and a rehabilitation programme of grading and tree planting is under way. The variety of species used for revegetation is considerably less than the assortment of plants in the natural forest around the mine.

Limited availability of top soil (50 cm thick) for stockpiling and subsequent reuse could constrain rehabilitation efforts as mining proceeds. Soil would need to be imported from a considerable distance.

Maintenance and housekeeping practices in bauxite mining seem to be good. Safety records are also good.

General Assessment of Technical Performance of the Mine

The large amount of proven and the huge probable and possible reserves in this area of Venezuela potentially make the country (together with the large hydro-power potential) one of the largest aluminium suppliers of the world. The mine applies most modern and very efficient mining, handling and transportation techniques. The built-in capacity seems to provide reserve for further production increase. Should vigorous rehabilitation of the mined-out areas continue, there is a large potential for ecologically sustainable development of the mine.



Alumina plant

Environmental impacts of the alumina refinery include atmospheric emissions from power plants and calciners, some dusting and leakage of caustic soda to surface and ground water from red mud lagoons.

Air pollution

Since the fuel used by INTERALUMINA is natural gas and electricity is available from Guayana's substantial hydropower resources SO_2 emissions are practically nil. CO_2 emission amounts to 0.7-0.8 million tpa, they could reach 1 million tpa at a production level of 2 million tpa of alumina. The four fluid bed calciners are equipped with electrostatic precipitators. Total suspended particulate matter and SO_x are the only atmospheric pollutants regularly monitored, however, given the clean energy sources and modern equipment, atmospheric pollution from INTERALUMINA is not likely to be a problem.

Bauxite dusting is moderate to low depending on whether the plant processes dried (imported) bauxites or undried, natural ones. The Los Pijiguaos bauxite is not dried, its typical adhesive moisture content is 11 %. This means that as the latter bauxite's share is increasing in the feed of the alumina plant (now it is close to 100 %), the dusting problem is becoming less and less. Compared to the dust emissions of nearby plants (ALCASA, VENALUM and most importantly a ferrosilicon plant) the dust emissions of INTERALUMINA are negligible (including the dusting of the calciners and alumina silos as well). Should the worst offenders of the area be corrected, at a later date INTERALUMINA will also have to pay more attention to the problems of dust emissions.

Water pollution

The most important source of pollution is red mud. Red mud is pumped into lagoons located along the shore of the Orinoco river. However, the three lagoons used presently for this purpose are more or less filled up. The level of the red mud increases about 1 m every year at the present production rate. As a consequence of the water balance problems caused by undesirable dilutions in the process the plant can not recycle significant portions of the supernatant liquor of the lagoons. Thus, the Na_2O concentration of the supernatant liquor has strongly increased over the years. Presently it amounts to 30-32 g/l (60% in carbonated, the rest in caustic form). It means, that the equivalent of about 200,000 tonnes!! of NaOH is present in the liquor on surface of the lagoons. This huge amount of caustic is a large potential environmental danger but on the other hand it represents large economic value (US\$30-40 million). The possibility of at least partial recovery of caustic from the pond should be considered.

Some liquor seeps from the lagoons under the dikes into the river which sustain subsistence fishing and several rare species. When the hydrostatic pressure difference is large (i.e. in the dry season, when the level of the Orinoco river is low) the seepage intensifies. Unfortunately, this is the time when the diluting effect of the river is the smallest. Work is under way to seal the retention dykes to prevent leakage from the red mud lagoons, and channels have been built recently to divert surface run-off away from the lagoons areas.



At current rates of discharge of red mud, lagoon capacity is sufficient for another 2 to 3 years operation. If INTERALUMINA is to proceed with its plans to expand capacity to 3 millions tonnes, an alternative means of red mud disposal must be found. In addition to leakage of caustic soda into natural lagoons, there is a risk of catastrophic failure of the dyke system which would result in discharge of very large amounts of red mud to the Orinoco river. Plant management is aware of the fact, that this situation needs urgent attention. Several steps were taken and *inter alia* UNIDO, vide project SIS/VEN/93/801 is providing high level advisory services with the aim to assist in the selection of the most appropriate technical solution and facilitate fund raising for the project.

After the visit of the UNIDO team INTERALUMINA has started to causticize water from the red mud lagoons at a rate of 100 - 150 m³/h and recover 4 to 5 t/h Na₂O.

Maintenance and housekeeping practices at the alumina plant are better than in Jamaica but inferior to the ones seen in Brazil and Suriname. Occasional spills of liquor and mud could be seen in the plant area. Worker's safety seems to be acceptable but not excellent.

General Assessment of Technical Performance of the Plant

Interalumina is a large capacity alumina refinery with a very good economic and commercial potential (abundant supply of good quality domestic bauxite; cheap energy; closeness of two large smelters; potential for further smelters to be constructed in the area). The technical parameters are acceptable to good and there are several measures in process to improve them. If its red mud disposal problem can be solved in an acceptable way there would be no obstacle to the ecologically sustainable development of the refinery to capacities of 3 or even 4 million tpa.

Aluminium smelters

ALCASA

Air pollution

The old plant has no equipment to collect fume and is thus releasing considerable quantities of alumina and gaseous and particulate fluorides to atmosphere through the potroom roof louvres.

Potlines 3 and 4 are hooded and connected to large modern dry scrubbers. The pots are hooded but many hoods are misplaced or damaged. The result of this could be seen by the poor visibility down the length of the potroom.

No facilities exist to monitor the louvre emissions. These unfortunately represent the most serious discharge of pot fume from the plant.

Fume collection in the mixer area of the green carbon plant is poor and should be improved.



The open bake furnace has no fume collection but this is not unusual in furnaces of this type. There is, however, a dark plume emitted from a 40 m high stack which might be due to poor firing practices or to packing coke leakage into the flues.

There are no offsite pollution monitors either, although C.V.G. reported that a comprehensive monitoring system for the Matanzas area incorporating such monitors is under consideration.

The closed bake furnace has a Flakt scrubber which comprises a water cooler, followed by an electrostatic precipitator. This does an excellent job of cleaning the furnace exhaust but water contaminated with pitch fume and fluorides is discharged directly to drain and 1,000 gallons of condensed pitch fume is collected each week from the electrostatic precipitator.

Water pollution

As mentioned in the previous paragraph water from the bake furnace scrubbers contaminated with pitch fume and fluorides is discharged directly to drain.

Solid waste

Spent pot linings are dumped upon an open tip near the smelter site along with other solid waste. The material contains, amongst other things, soluble cyanides and fluorides which are extremely toxic. Spent pot linings should be properly stored in buildings until they can be rendered harmless.

Pitch condensate from the electrostatic precipitator of the closed bake furnace is collected in drums and stored on the dump site. Drums are deteriorating and leaking, allowing this noxious material to seep into the ground. The huge accumulation of pitch condensate in drums around the plant is a major environmental hazard.

The consequence of storing thousands of tonnes of spent pot linings, pitch and other hazardous wastes in landfill sites are not being monitored. The water-table below the spent pot lining and other solid waste dump is likely to be contaminated with fluorides, cyanides and the organic components of pitch condensate.

Maintenance and Housekeeping Practices

Cranes, mobile equipment, etc. were observed working and appeared to be in good condition.

All scrubbers were fully operational. The general housekeeping of roads and courtyards was good. Housekeeping in most work areas was normal for the industry.

The condition of pot hoods and end doors was not good and many were damaged or missing.



Worker Safety

There is a safety awareness on the plant and most people observed were using hard hats, masks and protective footwear. Safety programmes exist and are managed by Safety Experts.

The atmosphere in the potrooms and green carbon plant was not good.

General Assessment of Technical Performance of the Plant

In most respects, the performance of the old plant is determined by the technology employed. The old potlines need to be hooded and retrofitted with proven technology to substantially reduce their carbon and energy consumption and improve environmental and overall performance.

There is plenty room for improvement in the operation of the new lines (carbon and energy consumption, pot life). The new potlines need better maintenance and better management. The benefits of point feed and distributive control in Line 4 are not being achieved.

None of the lines perform according to present world standards.

VENALUM

The environmental situation at VENALUM is in many respect very similar to the one at ALCASA.

Air pollution

All pots are fully hooded and fitted with end doors. In Lines 1 to 4 many hoods are damaged and many are misplaced. Some pots are operating without any hoods at all. In consequence, there is a very large discharge of pot fume through the roof louvres. This is not monitored even though this is the major source of air pollution. After our visit to the plant actions were taken to improve hooding standards. Monthly monitoring of discharges and measuring of ambient air quality once in every six months was introduced, according to the information received from CVG in July 1994. Details and reliability of test procedures and their results are not known to us.

In Line 5 the hoods are in place and fume collection is good.

The green plant was very dusty and we were informed that there were no industrial vacuum cleaning facilities. After our visit a vacuum cleaning system was put into operation (fax information from CVG, July 1994).

There was a problem with the pitch fume ventilation system in the mixer area.



The bake furnace scrubbers were efficient and the discharge was invisible. However, there is a problem of disposal of the condensed pitch fume that is collected at the rate of 1,600 gallons per week from the electrostatic precipitators.

Water pollution

Water from the pre-cooler of the bake furnace scrubber, which is contaminated with fluorides and pitch condensate, runs directly to drain.

Solid waste

The method of disposal of spent pot linings to an open tip alongside the plant is the same as at ALCASA.

Pitch condensate from the electrostatic precipitators is collected in drums and stored on the dump site creating similar situation to that at ALCASA. No monitoring of the water table under the dump site is performed.

Maintenance and Housekeeping Practices

The plant appears in most ways to be generally well maintained. Complex equipment in the carbon plant and rodding room was working well and the plant workshops looked well run. Mobile equipment and cranes appeared to be well maintained.

The general housekeeping of the plant was reasonable, with the exception of the courtyard which contained large quantities of alumina swept from potroom basements. The green carbon plant was very dusty.

Worker Safety

There is clearly a considerable effort to raise and maintain safety awareness at the plant although there were, unfortunately, two fatalities in 1993. A large well-staffed Safety Department exists. Safety clothing, industrial footwear and masks are provided and worn in hazardous areas, they should be provided for the visitors as well. Plant traffic moves slowly and parks carefully.

General Assessment of the Technical Performance of the Plant

If the figures provided by VENALUM fully describe the performance of the modernized potline no. 3 and the new 230 kA potline, then the potential of the new equipment is not being achieved. Similar equipment in other parts of the world reaches current efficiencies in excess of 93%, with lower specific energy requirements, net carbon of less than 0.41 and pot lives of over 2,000 days. In the unmodified potlines the performance of the cells is reasonable considering the design and vintage of the pots in use, however, they are not up to the current requirements.



Improvement of maintenance and management routines would assist to reach technical and environmental parameters achieved in the best plants of similar design. Useful experience is accumulated in this respect in Brazil, e.g. VALESUL.

According to the latest information received from CVG effective measures were taken recently to rectify the situation. Some of the results of these measures are reflected in the previous sections of the report.

Carbon plants

CARBONORCA

The carbon plants located at the smelters are dealt with there.

Air pollution

One scrubber is not operational hence the 48 section furnace is discharging noxious organic fumes into the atmosphere twenty-four hours of every day.

Water pollution and solid waste disposal

The scrubber on the 82 section furnace is giving rise to the same pitch condensation problems that are apparent in the smelter carbon plants.

Maintenance and Housekeeping Practices

The Plant is quite new, very clean and in an excellent condition.

Worker Safety

The expert's visit was brief but there seemed to be a good safety awareness on the Plant.

General Assessment of Technical Performance of the Plant

The Plant was performing well. It is kept very clean and in an excellent condition. Anodes were being made for ALCASA and VENALUM and for plants in Russia and the USA.

A visit to the laboratory, which was well equipped, revealed that anode quality was consistently high and better than that produced in the older plants at the smelters.

The major concern regarding the performance of CARBONORCA is that one scrubber is not completed hence the 48 section furnace is discharging noxious organic fumes into the atmosphere.



It is most unfortunate that there is some doubt about the future of this very good carbon plant since the Venezuelan smelters are planning to produce all their own carbon in the near future and the continuation of orders for carbon for other countries is far from assured.

Summing up the findings of the team the following general remarks were made on the smelter and carbon plant operations:

The plants have started modernization programmes but do not yet seem to be achieving the improved performance expected from the technology installed. While there seem to be many plans to improve environmental control, examples such as the operation of totally unhooded pots in a recently modernized potline or the failure to commission the scrubbers on part of a large modern bake furnace do not indicate to employees any real interest on the part of management to take environmental protection measures seriously.

The protection of the environment had not been receiving sufficient attention at many levels. The major problems are:

- High fluoride discharges from badly hooded pots which are not monitored either at the potlines or around the plant.
- The use of landfill sites for the dumping of spent pot linings - a hazardous solid waste with the potential to seriously contaminate water.
- The inadequate storage of large quantities of pitch condensate from open bake furnace fume scrubbers.
- No provision for controlling leaching of hazardous substances into the aquatic environment - data on cyanide and fluoride concentrations in groundwater is not available.

CVG has recently introduced several new measures to improve the environmental impact of INTERALUMINA and VENALUM, as stated in their fax attached to this chapter.

The pot hooding standards and lack of adequate monitoring are an operational management problem. Smelters were intentionally located such that emission plumes are blown by prevailing winds away from residential areas. No significant pastoral farming in the close vicinity was observed. Although there appear to be no sensitive receptors to fluoride emissions down wind of the smelters, systematic monitoring is required.

Spent potlinings should be stored in appropriate buildings until they can be rendered harmless. Methods to render them harmless should be investigated so that the landfill sites can be cleared safely and made available for industrial development.

The disposal of pitch condensate should be a major priority. Puerto Ordaz is not very near to a tar distillery which could accept this material, so alternative means of disposal must be sought. Possibilities include burning with bake furnace fuel oil using special burners or burning in a specially designed destructive incinerator.



These problems require resolution urgently if the Venezuelan aluminium industry is to expand in the future.



6.4 Barriers to Sustainable Development

a. Structure and profile of the industry in Venezuela

BAUXIVEN is wholly owned by Venezuelan entities. 99% of INTERALUMINA is also in Venezuelan hands. The majority shareholders of the smelters are domestic organizations as well (Figure 6.4.1). CVG, as the principal entity responsible for the promotion and coordination of the economic development of Guayana, is in a unique position to ensure the sustainable development of the region. With a clear and firm corporate environmental policy along with a smooth system of implementation embracing all the existing and future basic industries of region, there should not be any barrier in attaining this goal.

The Environment Vice-presidency of the C.V.G. has made large advances towards the design and elaboration of projects and programmes aimed at the integral and ecologically sustainable use of the resources and by-products. Nevertheless, coherent awareness and training programmes involving all the managerial and production level employees are required in order to attain full participation of the production entities.

b. Status of Regulatory Programme

Venezuela has in place a comprehensive body of legislation designed to protect the environment which includes provisions to control natural resource exploitation and industrial pollution. Organic laws on the environment have been in existence since 1978. These were strengthened through the provision of penalties for non-compliance established in 1992. The scope of the law is further complemented by a series of decrees which include technical guidelines for the achievement of environmentally sustainable industrial operations.

The UNIDO team was unable to discuss the implementation of this legislation with respect to the aluminium industry with Venezuela's regulatory authorities. Based on the team's observations of the environmental impacts of mining, refining and smelting operations in the Guayana region (see section 6.3), it would appear that compliance with legislation depends largely on the articulated " pro-active" attitude of the industry itself.

In the Guayana region CVG's Vice - Presidency of Environment, Science and Technology has undertaken a series of initiatives to reduce the negative environmental impacts of the Corporation's activities. These were completed without the benefit of guidance on appropriate industrial policy from the environmental regulatory authorities. In Venezuela these institutions are not as visible as are the equivalent institutions in other countries visited by the UNIDO team. CETESBE & FEEMA in Brazil, for example interact with enterprises to assist them develop coherent industrial policies in line with national environmental objectives.

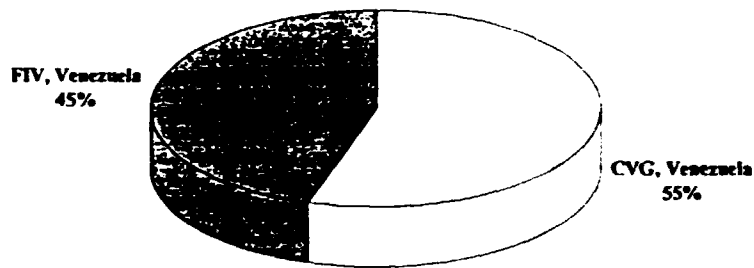


Figure 6.4.1

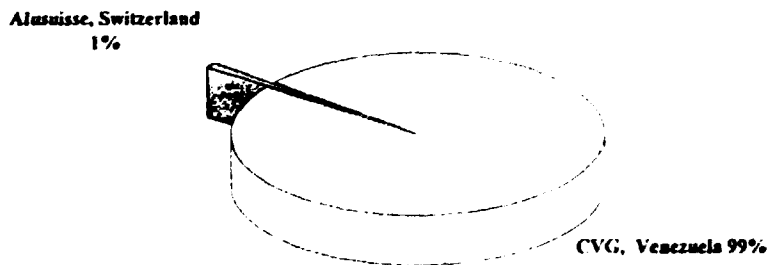
Ownership structure of the Venezuelan Aluminium Sector

Source: CVG, Bauxite Deposits, Mining Operations and Producers of the World, Aluminium Verlag, Alumina Refineries and Producers of the World, Aluminium Verlag, Primary Aluminium Smelters and Producers of the World, Aluminium Verlag, Düsseldorf, 1992

BAUXIVEN

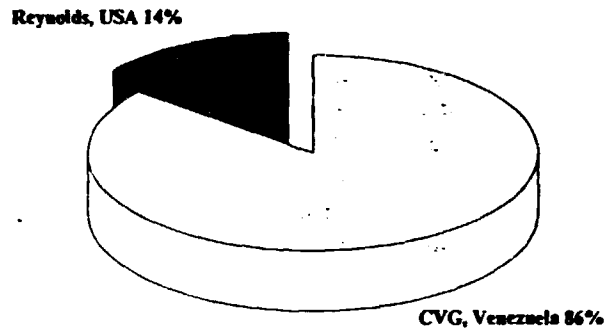


INTERALUMINA

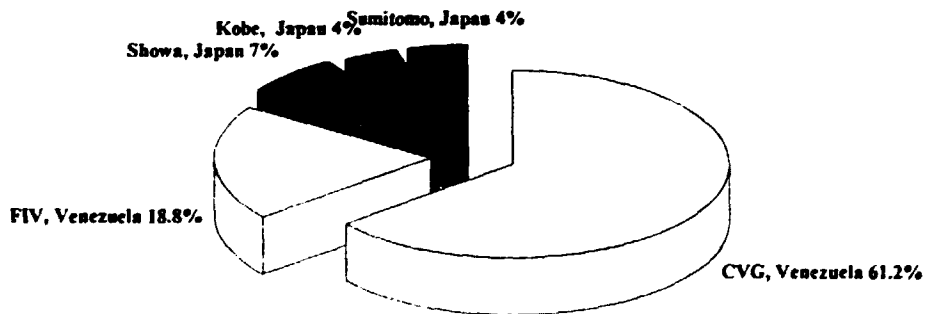




ALCASA



VENALUM





c. Attitude of Plant Management

The attitude of plant management with relation to environment protection measures changes from plant to plant.

The mine is fairly new, thus the problems are the smallest. While the management understands the importance of ecology there are still minor in comparison with the magnitude of the investment and running costs of the operation issues, which require urgent resolution, like the contamination by run-off rain water of the small river close to the railhead bauxite storage area.

The alumina refinery now suffers heavily from the previous lack of attention to the problem of hazardous waste management. The management is taking serious efforts to rectify the situation.

At the time of our visit at the smelters and carbon plants managerial shortcomings were observed. Following constitute real barriers to sustainable development of the industry:

1. The failure by Senior Management to convince the total workforce that the protection of the environment is of the first importance.

Vast expenditure in the industry on test cell programmes while a major bake furnace operates without a scrubber, recently modernized cells operate without hoods and hazardous waste are carelessly collected and disposed of sends the wrong message to people operating pots.

2. A failure to achieve high standards of efficiency from recent modernization programmes. The capital invested in Line 5 at Venalum and in retrofitting older lines in Venalum and Alcasa is not yielding a proper return in greater productivity and efficiency.

d. Site Specific and Technical Barriers

Bauxite Mining

The only technical barrier to further development of bauxite production is the seasonal variation of the navigability of the Orinoco river. Because of a 3 to 4 month interruption in bauxite transportation every year huge stockpiles of bauxite have to be kept both by the customer and at the mine itself (though the latter could be reduced by a more seasonal operation).



Alumina Manufacturing

The site specific barrier to a sustainable development or even to the further operation of the Interalumina refinery is to find a proper place for red mud disposal and/or a technology that makes possible to deposit very large quantities of red mud into very small areas. Just to show the gravity of the problem: Interalumina wanted to obtain a total area of 384 hectares to establish a new red mud disposal area and has been promised only 28 hectares. The allocated site is on a hilly area not really suited for mud disposal. This is not the place to go into technical details, the more so since a UNIDO project is under implementation to prepare a separate study for the resolution of this problem.

Aluminium Production

There are no real site specific barriers to sustainable development of the primary aluminium production, however, the large concentration of aluminium smelters and other metallurgical industries require special precautions, stringent monitoring and permanent discipline on every level in application of pollution prevention measures.



6.5 Strategy for Sustainable Development in the Bauxite/Alumina/Aluminium Industry

The country has a good geographical situation, vast reserves of bauxite and hydroelectric energy, availability of experienced workforce and expandable alumina refinery capacity. It already produces 600,000 tonnes of primary aluminium each year. Thus, all preconditions for the growth of the aluminium industry are available. For the sustainable development of the sector, however, several measures should be still taken.

a. Strengthening of regulatory bodies

To enhance the capability of the regulatory bodies in Venezuela to address the pollution problems arising from aluminium industry operations it is recommended that MARNR could benefit from the knowledge and resources available within the regulatory authorities in Brazil. UNIDO could assist this process through the provision of training and experts' services.

b. Human resource development and strengthening management skills plant level

CVG is mandated to address the environmental aspects of its development programme. A Vice-President is responsible for environment, science and technology. The Vice-President incorporates environmental considerations into CVG's development planning. The environmental vice-presidency also develops new projects which specifically address pollution control. Two new proposals have been developed, one to establish an integrated waste recycling facility in Guayana city, a second project will put in place a source and ambient monitoring system to generate real time data on atmospheric and water pollution levels, also in Guayana city.

All operational companies visited by the team had in place functioning risk assessment/safety/environment staff. These staff are familiar with the safety/environmental impacts of the processes and procedures at their respective plants.

General housekeeping and safety should be strengthened especially in the smelters. In some instances, for example at the two smelters, where lack of adequate hooding procedures resulted in avoidable fluoride emissions, safety/environment staff could benefit from additional equipment and training in analytical techniques and monitoring procedures. Thus, the team felt that the operational management and staff does not consider environment and safety as a first priority rather a time and money consuming task. Corporate management should formulate the companies' mission in this respect and break down the tasks for every level of employees down to the shop floor.

Concepts of cleaner production and pollution prevention, while they are understood within CVG's corporate environmental vice-presidency, are not actively appreciated at the plant level. Technical staff could benefit from information on waste auditing and experience with waste minimization from smelters and refineries in developed countries with effective regulatory programmes.



Comprehensive training programmes, like the one shown in Table 6.5.1., could strengthen the environmental awareness of plant personnel.

Table 6.5.1 Fundamental Environmental Training Programmes

LEVEL	No.	ASPECTS
CEO, CGM, Div Managers, GM Env.	1. 2. 3. 4. 5.	Environmental Awareness Session Environmental Planning Environmental checklist Auditing Job description
Env. Supervisors/Managers Env. Dept. Personnel Bus. Unit Manager	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.	Environmental Awareness Session Environmental checklist Auditing Induction Training Programmes Plant Environment Incident Response Plan Environmental Quality Assurance Manual Licenses Media Techniques Legislation Updates Job descriptions
Superintendents	1. 2. 3. 4. 5. 6. 7.	Environmental Awareness Session Environmental checklist Induction Training Programmes Plant Environment Incident Response Plan Environment Quality Assurance Manual Auditing Job descriptions
Employees operating environment treatment plants/chemical storage, etc.	1. 2. 3. 4. 5.	Environmental Awareness Session Standard Operating Procedures Chemical Register and Control Plant Environment Incident Response Plan Job descriptions
Employees - General	1. 2. 3. 4.	Environmental Awareness Session Standard Operating Procedures Plant Environment Incident Response Plan Job descriptions



c. Opportunities for the Introduction of Pollution Prevention and Cleaner Production at the Plant Level

- The Los Pijiguaos mine is based on a large bauxite reserve which will provide ore for very long period of time. The mine is well equipped to substantially increase its output. Apart from establishment of proper run off water management systems further efforts should be devoted to improve the quality of mine rehabilitation activities. In this regard the practices of Brazil and Western-Australia should be analyzed and implemented to the extent possible, taking into account the specific features of the mine site.
- A safe and environmentally sustainable solution of the red mud problem would be a significant contribution to the reduction of the pollution problem caused by the present mud disposal lagoons. Without fresh mud and caustic liquor pumped to the present disposal areas the existing amounts of caustic would be slowly washed out by rainwater and neutralized by acidic ground or river water and/or at least partially could be recycled to the alumina plant in case of economically feasible concentrations. Further details will be available in the report of the project SI/VEN/93/801.
- In the field of primary aluminium production there are several possibilities to improve the present situation and make way for sustainable development by introduction of pollution prevention measures and cleaner technologies. These measures detailed in the previous chapters can be summarized as follows:
 - i. The pot hooding standards should be improved.
 - ii. Adequate monitoring of air pollution should be established and permanently applied. Total fluoride emissions should be reduced below 1 kg/t aluminium produced.
 - iii. Spent potlinings should be stored in appropriate buildings until they can be rendered harmless. Methods to render them harmless should be investigated so that the landfill sites can be cleared safely and made available for industrial development. In this respect experience of the Brazilian aluminium industry can offer acceptable solutions. C.V.G. outlined a plan to deal with many forms of solid waste at a central facility. The objective of the facility would be to render such waste harmless and to recover as much value as possible from the waste.
 - iv. The disposal of pitch condensate should be a major priority. Puerto Ordaz is not very near to a tar distillery which could accept this material, so alternative means of disposal must be sought. Possibilities include burning with bake furnace fuel oil using special burners or burning in a specially designed destructive incinerator.



- v. Extensive retrofitting and modernization of old ALCASA lines according to the best available practices as are currently used in similar potlines operating in the U.S.A. (KAISER, REYNOLDS, ALCOA etc.) will lead to substantial energy saving and improvement of productivity, performance, working conditions and environmental impact. In case this rehabilitation proves economically not viable closure of the lines might be considered.
- vi. The on-going rehabilitation of potlines should be finalized and improved performance and efficiency should be achieved on the rehabilitated and recently installed modern potlines (Line 3 of VENALUM, Line 4 of ALCASA). After careful assessment of the experience of rehabilitation and performance of the new potlines in both smelters the best technology should be selected and introduced on all lines, including up to date automation, point feeders, low ratio bath chemistry without lithium addition.
- vii. Careful performance monitoring of the smelters' technical parameters should be established and continuous action should be taken to upgrade them to the best level attainable with the available equipment and technology.
- viii. Reduction of the number of anode effects/pot day should be targeted in order to reduce generation of greenhouse gases (polyfluorinated carbon compounds like CF_4 and C_2F_6).
- ix. CVG might consider the utilization of the full capacity of CARBONORCA (after installation of the missing scrubber) and mothball the most polluting and least modern carbon plants attached to the smelters.
- x. Technical cooperation between the plants within the country and on regional level should be strengthened as an important source of information for the introduction of pollution prevention measures and cleaner technologies.

d. Cost of New Cleaner Technologies

Alumina plant

According to the preliminary results of the UNIDO project report (SI/VEN/93/801) the introduction of new red mud treatment and disposal technology including thickening and filtration (dry red mud stacking) will cost about US\$ 10 million. The rates of return depending on the selected technological solution is in the range of 2 to 10 years. The new technology would give a long term and safe solution to the red mud problems of INTERALUMINA.

Smelters

The cost of upgrading the old pots is almost impossible to estimate without a great deal of investigation and a clear idea of the degree of modernisation to be carried out. A rough



estimate of the cost of upgrading the two lines of prebake pots at ALCASA including of installation of dry scrubbers might be as high as *fifty or a hundred million US dollars*.

The potline needs physically levelling, new cathodes are required, as are modern computer control and automation of the cells, hooding, ducting and scrubbing. The possibility of increasing anode size would need consideration. Large technology fees would arise and expatriate staff would be required. In a prefeasibility study the properly developed cost of modernisation could be compared with the value of extra metal produced, the savings in raw materials, energy and manpower and the improvements in the environmental impact.

In other parts of ALCASA and VENALUM the proposed measures are substantially cheaper as in most cases the fundamental prerequisites are/were available and the present task is to properly apply them and the best available practices.