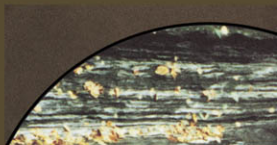

Mining and the Environment

Case Studies from the Americas



edited by Alyson Warhurst

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INTERNATIONAL DEVELOPMENT RESEARCH CENTRE
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CHAPTER 7

ENVIRONMENTAL MANAGEMENT IN THE BAUXITE, ALUMINA, AND ALUMINUM INDUSTRY IN BRAZIL

Liliana Acero

This paper briefly presents the main results of a study of the bauxite, alumina, and aluminum industry in Brazil, conducted to investigate hypotheses of the Science Policy Research Unit network (Warhurst 1991a) and the Brazilian team within it (Rattner et al. 1991). Examining recent international trends, the study documented how that industrial sector operates in the economy (Acero 1993).

The main objectives were to

- Document specific environment-management practices of various companies operating in Brazil;
- Relate these practices to recent governmental and societal laws and regulations on environmental controls and planning;
- Measure or illustrate possible industrial changes in environmental management and technical solutions resulting from legislation or the pressure of different social sectors; and
- Document community-level environmental impacts of current practices and the firms' responses, where possible.

A word on environmental costs

The basic rationale for environmental costs at the micro- and macrolevels has been widely debated in the past 10 years (see, for example, Hurrell and Kingsbury 1987; Adams 1990; Nappi 1990). Alternatively, it is argued that in developing

countries, a level of environmental degradation is an unavoidable condition of economic growth that in the short run diminishes the costs of development; and that unless some environmental degradation is allowed, then enterprises tend to externalize the costs of environmental controls and antipollution measures, costs that are ultimately borne by the public in developing countries. More technically speaking, there has also been some concern about how to discriminate between the environmental and capital costs of any economic activity.

Although in this chapter I do not discuss these issues in depth, one should be aware of the magnitude of the academic and policy problems, which involve changes in the ways management and general administration collect data on economic and financial investments and costs, especially within developing countries. This issue exceeds the scope of the present study. However, I do take a practical approach to the issue here.

First, I tried to collect and analyze the fragmentary type of information that firms gather during their activities. Second, I analyzed, with the interviewees, the main parameters that firms use. Third, I organized the data so that I could do an interfirm comparison. Fourth, in some cases, I requested that similar data be gathered by firms that had not done this before. However, the information should be considered indicative of an order of magnitude, rather than a comparison of practices between establishments.

The firms' costs for their activities tended to be differentiated into two major categories:

- *Operating costs* — These usually include all running costs attributed to the environmental department, such as wages of permanent and sub-contracted personnel, material replacement, and input and capital costs of new laboratory materials, and amortization rates of existing capital; and
- *Investment costs* — These involve costs of major environmentally oriented investments, such as specific projects, like the deposition of tailings and red-mud slurry, or major capital investments for anti-pollution purposes, such as the closure of prebaked cells.

In both cases, similar types of activities were listed for each firm. However, the results should be treated with caution: they are not to be regarded as absolute numbers of real performance. This is for a variety of reasons, some of which relate to the specific characteristics of the production processes for bauxite, alumina, and aluminum. First, some of the machines normally used in the production process embody antipollution technology, such as dry-scrubbing, that in

turn is material or input saving. This is not commonly included either in operating or in investment costs. Second, minor technical adaptations considered more environmentally sound but undertaken for reasons of efficiency are also excluded from the parameters; an example of this would be changes in the feeding devices of prebaked cells. So, in some ways, the results underestimate activities immediately related to the environment.

Despite these limitations, these data were relevant to the study because this information provides a reference point for drawing comparisons and because, based on this type of information, enterprises carry out their negotiations with local policymakers and environmental bodies. Ultimately, these data also serve to illustrate the problems with making measurements of this kind in an industry that combines input and materials savings with environmentally sound technical solutions. In the next section this point will be discussed in detail.

Nature and extent of environmental degradation

The three phases of this industry — bauxite mining and exploration, refining, and smelting — can each have many effects that are potentially hazardous to the environment. But before addressing these concerns, I will briefly consider the production process, as described by Warhurst (1991a, p. 23):

Bauxite is the raw material from which alumina is extracted. Bauxite occurs in a small number of high-grade deposits mainly within a tropical zone extending up to 20 degrees north and south of the equator. The technology of alumina production varies with type of bauxite ores which fall into three groups: Monohydrate bauxite is generally found in boehmite in Europe and northern Asia and is processed using a European version of the American Bayer process (described below); Trihydrate bauxite is found as gibbsite in Surinam, Guyana, Guinea, Ghana and Australia and is processed by the American Bayer process. The Jamaican type of bauxite is characterized by a mixture of gibbsite and boehmite and is found in Jamaica, Haiti and the Dominican Republic. It is processed using a method which combines elements of the European and American Bayer process.

The basic Bayer process involves the following operations Dried, ground bauxite is mixed in a large digester vessel with caustic soda which dissolves the aluminum oxide under strong pressure. Impurities, such as iron oxide and silica, are filtrated out in their solid state. Then the sodium aluminate liquor is seeded with hydrated alumina crystals and part of the solution combines with the "seeds" to form alumina hydrate crystals. These are then calcinated in long rotary kilns under high temperatures. This leaves calcinated aluminum as a white powder which is then ready

for transformation into aluminum metal. On average, 2.25 tonnes of bauxite generates one tonne of powder.

Finally, aluminum is separated from its oxide by the highly energy-intensive Hall-Heroult process. The process takes place in carbon-lined reduction cells. First, alumina is dissolved in a molten salt called cryolite to which aluminum fluoride is added continuously to maintain the required density, conductivity and viscosity. Second, a carbon anode is lowered into the solution causing a continuous electric current to pass through the mixture to the carbon cell lining, which acts as the cathode. This causes the dissolved alumina to separate out into aluminum metal and oxygen, and since the former is heavy it is attracted by the cathode to the bottom of the pot, while the oxygen settles on the carbon anode to form carbon dioxide. The molten aluminum in the pot is syphoned into crucibles and transferred to alloying furnaces to make alloys. Finally, the metal is cast in an ingot mould.

The potential hazardous impacts of these processes can be divided into those strictly affecting the physical and natural environment and those of a socio-economic nature (UNEP 1984).

Mining

In ore mining, the environmental effects are highly site specific, but, on the whole, the main impact comes from clearing the vegetation in bauxite mining, exploration, and mine development. A secondary effect is that brought about by the dumping of wastes or the inadequate management of tailings. This can degrade the habitat of local flora and fauna and make future land use difficult for reforestation, agriculture, or cattle breeding.

Mining can also affect local water and air quality. For example, with the removal of overburden, runoff can become contaminated, more acidic, and more turbid. Erosion within the mined areas can be rapid if the soil is not recovered and reforested. The removal of vegetation can then bring about loss of flora and fauna, destruction of wildlife habitats, a possible spread of plant disease, increased soil erosion, changes in weather conditions, dust, and a possible need for runoff water treatment. In open-cast or surface mining, the areas cleared of vegetation may disrupt the landscape and produce a negative visual impact.

Beyond this, fugitive dust and noise from heavy machinery and explosives may be a source of disruption in the external environment for nearby communities and a health hazard in the working environment.

Adverse socioeconomic impacts depend largely on the proximity of the mines to established communities. Impacts can include breakup of cultural traditions, lifestyles, and kinship groups; substantive changes in agricultural crops,

techniques, and marketing resulting from weather and soil disruptions; and lack of infrastructure, other employment opportunities, housing, and educational and recreational facilities for the personnel.

Refining

In refining or alumina production, the environmental impact largely depends on the composition and quality of the ore and the processes used to extract bauxite. The principal hazards arise from the disposal or storage of bauxite-residue slurry (red mud), which is the main alkaline effluent from the alumina plants. This is either disposed of on land or discharged (dewatered or untreated) into sealed or unsealed artificial or natural areas or into the deep sea. Liquid and solid phases in slurry have the following potential effects (UNEP 1984):

- Seepage of the alkaline liquid into groundwater, which might contaminate industrial, domestic, and agricultural water supplies;
- Spillage from damaged pipelines or from retaining-dyke failure;
- Reduction in the availability of arable land;
- Dust pollution in arid regions; and
- Aesthetic impacts.

Airborne pollutants (dust and noxious chemicals) are another kind of hazard from stockpiles, mills, and calcination operations. The air pollutants are bauxite, lime, and alumina dust, SO_2 , NO_2 , dust from low-grade bauxite, and suspended vanadium pentoxide. The quality of SO_2 pollution depends on its concentration in fuel oil, its specific form of consumption, and the ways power is supplied to the plant. Gas emissions not collected or insufficiently collected, especially in the case of SO_2 , can contaminate the workplace and the general environment and, in reacting with water, can produce acid rain.

Spills can occur at different stages in the refining process. Acidic drainage, if untreated, can damage local flora, fauna, and even human beings. The work environment can be extremely hazardous where people handle corrosive chemicals, such as caustic soda and acids, or where there are reverberation, fumes, dust, and certain toxic chemicals.

Aluminum production

In aluminum production, the main environmental problem is air pollution caused by fluoride emissions in the smelting process. These can have a strong effect on workers' health inside the plants (excessive intake can cause fluorosis and skeletal disorders), as well as on the surrounding flora and fauna. As molten cryolite is used in the electrolysis of alumina, the fumes emitted from the cell have gaseous and particulate fluorides. Gaseous fluorides are also contained in the exhaust gas of the anode baking furnace and are emitted if unscrubbed. They can also be generated at a lower degree from the cast-house furnaces. Other fumes emitted by some types of cells are tar fumes (that contain suspected carcinogens) and SO_2 (when petroleum coke with sulfur is used for the anodes); SO_2 is also produced by anode-baking and cast-house furnaces, especially in plants using thermal power. At these last two stages, nitrogen oxides are also emitted. Dust is found at different stages in the production of aluminum.

Other problems are polluted water, solid waste, noise, and heat. Water pollutants are stronger when a wet-scrubbing system is used to clean fumes emitted in the cells. The water contains fluorides and suspended solids, such as alumina and carbon, that need to be treated before discharge. The main solid-waste problem is that of spent potliners, as cells have to be relined every 4 or 5 years. The linings can leach fluorides and cyanides to surface or groundwater when they are stored in the open air and in pits. Cast-house furnaces generate drosses that can produce fugitive-dust losses or gases that can evolve into ammonia if wetted. Noise and reverberation in most smelting stages and heat in the potline rooms tend to be at very high levels and insufficiently controlled in Brazil. This can affect workers and inhabitants of local communities.

Another indirect hazard to the environment is due to the intensive consumption of electricity in the aluminum-smelting industry. These plants must be located near cheap sources of electricity, mainly hydroelectric dams. The construction and the operation of these dams also pose a potential threat to the environment. Large areas have to be depopulated and flooded for dam building, changing the ecosystem of a whole area. This has potential negative effects on flora and fauna and even jeopardizes human health in the area.

Economic restructuring

Several factors are contributing to the reduction in the growth rates in aluminum consumption worldwide. The growth of industrial production is slower than that the growth of the service sector in the developed world. The substitution process whereby aluminum gained market shares from other materials has slowed down.

The only new and substantive market for aluminum has been that for aluminum cans (which have replaced tin ones). This market is still expanding, especially in the developing world. In the rest of its final uses, aluminum has maintained its quotas; however, aluminum recycling has increased significantly in the last decade, further reducing the potential expansion of aluminum consumption.

Another reason for restructuring in the industry has been the increasing participation of developing countries, especially through government enterprises in different phases of the industry. Developing countries have tried to make better use of their comparative advantages in natural resources and energy, usually by raising the prices of exported raw materials and obtaining a higher elaboration in mineral production (products with value added). In this sense, the new strategy adopted by large world producers has been either to increase the value added and quality of their products or to explore new types of activities, such as developing new aluminum products (for example, Kaiser Aluminum Corporation) or using more modern materials (for example, Alcoa Alumínio S.A.).

An additional factor has been aluminum's appearance on the London Metal Exchange (LME), which took away the major companies' control of overpricing, removing one of the industry's most important entry barriers.

In 1990, Brazil had an installed production capacity for primary aluminum of 1.132×10^6 t. Bauxite production accounted for 9.875×10^6 t, of which 55.3% was exported in 1990; alumina was of the order of 1.654×10^6 t; and aluminum reached 930 000 t. The domestic price for primary aluminum, as fixed by LME, was internationally competitive: 1 738.69 United States dollars (USD)/t in 1990. This was partly due to the subsidized energy tariffs charged to most of the large aluminum complexes. These tariffs were 25.61 USD/MW·h for high-voltage transmission to ALUMAR and Alumínio Brasileiro S.A. – Alumina do Norte do Brasil (ALBRAS-ALUNORTE), for example, and 27.48 USD/MW·h for low-voltage transmission to firms in the southeastern region (in São Paulo and Minas Gerais). Most employment is in the primary-aluminum integrated firms; in 1990, for instance, 40% of the 66 780 people working in the alumina and aluminum sector worked at such firms. Meanwhile, 1 543 people were employed in bauxite firms that year.

In 1980–90, Brazil had the second largest growth rate in production (257%) among the largest primary-aluminum producers. It was only outweighed by Australia (307% growth). Since 1989 it has become the fifth largest producer in the world and holds the third largest bauxite reserve (10.2% of the world's 22.7×10^9 t). Almost 60% of production was exported in that year. Production continued to grow until the present, with export rates substantially outweighing expansion for the internal market. In 1990, sales in the industry represented 0.8% of

the gross domestic product. However, Brazil has one of the lowest per capita consumption rates among the main primary-metal producers (2.7 kg per person in 1989), but it is an average level when compared with other industrializing countries in Central and South America.

The next section will explore the legislation that directly or indirectly affects activities carried out in this sector in Brazil. It will emphasize the implementation of the environmental-control laws since the new Constitution that have had the most recent effect on the industry.

Regulatory and institutional mechanisms

Four types of regulatory mechanisms, established in the last decade or so, apply directly or indirectly to activities carried out in the bauxite, alumina, and aluminum sector:

- The constitutional norms of 1988 relating to the mineral sector;
- Legislation on the exploration and use of mineral resources;
- Environmental legislation on mining and its industrial transformation; and
- Tax laws.

Currently, there is no new mining code functioning (the last one being from 1967). Actual practices are ruled by a set of independent laws, based on the spirit of the 1988 Constitution and passed after it. However, a law project to form a mining code was presented to the national Congress in 1991. The main innovations within the Constitution are the following:

- The republic has sovereignty rights over mineral resources (including those of the subsoil), resources of the archaeological and prehistoric sites, and natural resources of the continental platform. This allows the republic to dispose of these resources as their sole owner and makes the republic obligated to protect them. Dual property rights, over land and subsoil, plus sovereignty rights of the republic over minerals shape the spirit of the new mineral rights and public policy, legitimizing the republic's sovereignty. However, the Constitution allows the owners of mining concessions to have ownership rights to the products they extract.

- The republic may decentralize administrative functions pertaining to natural-resources management. The Constitution establishes that only the republic can pass legislation governing mineral resources, not the states (as had been the case in the former Constitutions). It admits that new laws might be passed allowing the states to legislate on limited and specific questions. In turn, the latter can register and monitor mining concessions, as can municipalities. In future, these tasks will be distributed, depending on technical and administrative competence, between them and ruled by a mining code.
- All levels can pass legislation pertaining to the defence of natural resources, the protection of the environment, and protection controls. If the laws are contradictory, the republic has to fix the more general criteria.
- The republic has the right to limit the form of participation of foreign capital in mining.
- By law, as of April 1991, the National Defence Council (CDN) has authority over the use of national-security areas (especially frontier regions) and the preservation and exploration of natural resources of any type. The Departamento Nacional de Produção Mineral (DNPM, national department of mineral production) verifies whether these demands are fulfilled, because the attributes of the CDN are still formulated in very generic terms. Two of the main new norms are that 66.6% of employees in the companies operating in such areas and the majority of management must be Brazilian citizens.
- The states and municipalities are to receive compensation for the results of natural and mining-resource exploration. This is tied in with tax laws.
- The republic imposes a new system of taxation for the mineral sector and revokes the Imposto Único sobre Mineral (unified tax on minerals), a unique tax.

The forms of mining concessions and their life spans have also changed. Durations of mining-research permits have been shortened. Some entrepreneurial groups have been fighting for a lifetime research concession, a mode of operation

that would rule out contractual agreements and is thus internationally outmoded. Moreover, research and exploration authorizations have been restricted to Brazilian firms with national capital or Brazilian individuals. Thus, foreign capital is only allowed to have a minority participation in the firms, whose effective control and capital are to belong to local residents. However, subsequent regulations, known as the "transitory dispositions," ameliorate these limitations by allowing 4 years for companies to adapt to new restrictions and by virtually eliminating the restrictions for those firms that in that time locally promote the industrialization of their mining and beneficiation activities. These firms can receive research and extraction concessions if the minerals are intended for use in local industrial processing. Authorizations can be canceled if they were not initiated in the terms established. The Constitution makes a clear division between the rights of the owners of land and the rights to the subsoil. But it is guaranteed that the owner of the land receives benefits for the results of mining. Finally, mining research and extraction on lands occupied by native populations require Congressional approval; mining titles are suspended in those lands because Congress has still not passed ordinary laws concerning this.

Environmental legislation was virtually nonexistent in previous Constitutions, but the 1988 Constitution devotes a whole chapter to it. The *Mining Code* of 1967 only mentioned generically that the owner of the mining concession should avoid air and water pollution resulting from its works. But already in 1981 the first National Policy for the Environment was passed as a law (law No. 6, 1981), and it established the *Systema Nacional de Meio Ambiente* (national system for the environment). These previous laws were taken up and given constitutional status in 1988. Four main aspects are considered in the Constitution:

- The firm's obligation to have an environmental-impact study (EIS) before setting up any activity with a potentially hazardous impact on the environment;
- The firm's obligation to rehabilitate degraded environments;
- The establishment of penal and administrative sanctions for the degraders independently of their obligations concerning rehabilitation; and
- The ruling of responsibilities for damage caused to the environment.

Mineral extraction is subject to laws passed by the Republic and by the states and must comply with laws passed by both. Licencing depends on the state or on the

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais e Renováveis (IBAMA, Brazilian institute of the environment and renewable natural resources), when appropriate. Two resolutions of the Comisión Nacional del Medio Ambiente (National Commission of the Environment), passed in 1989 and 1990, deal specifically with environmental licencing in mining.

For research, the companies require an operational licence, which includes an evaluation of its environmental impacts and an analysis of the measures to be adopted to solve them. For extraction, three types of licences are required: the pre-operational licence, which also includes the EIS; the installation licence, which requires a detailed plan for environmental controls; and finally, for actually operating, registration at DNPM (if the ministry approves the operational licence).

The EIS should cover the following technical activities:

- An environmental diagnosis of the area;
- A baseline analysis and description of the environmental resources and their interactions (before the project);
- The definition of suitable measures against negative impacts; and
- A program to monitor the positive and negative environmental impacts.

A second report, the relatório de impacto ambiental (RIMA, environmental-impact report), is accessible to the public. It must

- Discuss the conclusions of the EIS, mainly to outline the aims of the project;
- Describe the technological alternatives;
- Provide a synthesis of the area diagnosis, including a description of possible environmental impacts;
- Characterize the future atmospheric quality of the area;
- Estimate the possible results of the proposed impact controls;
- Establish a detailed monitoring program;

- Recommend the most favourable control alternatives; and
- Provide illustrations (maps and graphics).

The EIS and the RIMA should both include a program for post-operation land recovery and rehabilitation. Both documents have to be developed by a multi-disciplinary team, which must be authorized to carry out this type of work.

A further environmental-policy tool provided for by the 1988 Constitution is public audiences. The public environmental bodies set up these public audiences, at which they present, for discussion, information on the project's probable environmental impacts. This discussion is compulsory in some states, such as those in the Amazon region.

A number of sanctions have also been established for enterprises that fail to fulfil the above requirements: fines, the loss or restriction of fiscal incentives or benefits, the loss or suspension of the firm's participation in government loans, or the temporary or definite suspension of its activities. New developments in environmental laws (a preproject formulated by a commission assessing the Executive and sent to Congress) suggested that two important amendments to the Constitution would be included in its revision, foreseen for 1993. First, all licencing concessions for mineral activities should be concentrated at IBAMA, thus disengaging the authority of the states to rule over and administer them. Second, licencing evaluation should take into account the economic need for mineral extraction. These two clauses, as well as one on *garimpos* that does not relate directly to our research, tend to make procedures more bureaucratic and to centralize decision-making. This contradicts the original spirit of the constitutional text, although it means regulating aspects more related to minerals policy-making.

The tax system provisions for mining and processing activities is complex. National, state, and municipal departments administer direct and indirect taxes: taxes on revenue, profits, and sales; taxes on products, services, and loans; and social taxes. The main taxes are the Imposto de Renda Pessoa Jurídica (IRPJ), a rent tax; the IPI, a tax on industrial products; the ICMS, applied to the circulation of products and services; the Imposto Sobre Operações Financeiras, charged on financial operations; the Financeiro Compensação Pela Exploração de Recursos Minerais, a financial-compensation tax for mining; and a number of social contributions, such as Finsocial, Fundo de Garantia por Tempo de Serviço, the family wage, and the Programa de Integração Social applied to sales. Tax reductions for IRPJ are given to firms operating in underdeveloped regions, and tax exemptions for IPI are given to exporters.

The current Constitution has advanced enormously in legislating mining operations and processing, as well as their environmental impacts. But the country seems to be caught in a transition between a very liberal law in the past and the present legal framework, characterized by instability and contradictions between different laws and policy instruments. In several areas, the constitutional decrees still lack regulations, mainly those needed to cover mining in native peoples' lands, the landowners' rights over the products extracted, and the relative decentralization of the administration of mineral resources. The new *Mining Code* has not yet been approved. Moreover, in practice, restrictions are only applied to foreign mining companies in frontier regions. Also, the past government explicitly intended to do away with most of the proposed restrictions on the operation of foreign capital.

Three main aspects of environmental laws have been somewhat neglected:

- A thorough cost–benefit analysis to help evaluate the feasibility of environmentally related investments vis-à-vis profit, by type of firm and by size;
- The need for uniform criteria across legal requirements, given the devolution of legislative responsibilities and administration to the states and municipalities; and
- An evaluation of the states' expertise to manage environmental policy and of the quality of their specific legislation.

As a result, entrepreneurs are faced with conflicting demands and are left much on their own to administer and harmonize conflicting interests and make them sector specific. This will be widely illustrated in the next section with case studies of specific firms in the bauxite, alumina, and aluminum sector.

Environmental behaviour of mining companies: strategies and responses

Five main phases can be distinguished in the history of the Brazilian bauxite, alumina, and aluminum sector.

- In the 1940s to 1950s, primary-metals production began, especially in the southeastern region (Minas Gerais and São Paulo). These operations were carried out both by transnationals (mainly Alcan) and domestic

firms, such as *Companhia Brasileira de Alumínio*. Most inputs at that time were imported, and the local and smaller bauxite reserves, especially in the state of Minas Gerais, also began to be mined.

- In the 1960s, the big bauxite reserves in the Amazon were discovered, and the older firms continued to expand production and began to export.
- The 1970s saw greater expansion of aluminum projects oriented toward the domestic market while the largest projects in the North and the Amazon were being established.
- In the 1980s, however, expanded capacity at Alcoa's ALUMAR complex and at *Companhia Vale do Rio Doce's* (CVRD's) ALBRAS-ALUNORTE complex was directed mainly to exports. Meanwhile, the state-owned CVRD further activated its bauxite extraction and beneficiation project in Trombetas, developed by *Mineração Rio do Norte* (MRN).
- The 1990s, in contrast, seem to be oriented toward further rationalization of ongoing projects (especially those distant from the southeastern region), further verticalization, and reduced energy and labour costs. However, environmental measures only began to be applied in the 1980s, especially after the new Constitution.

The case of *Companhia Vale do Rio Doce*

CVRD entered the aluminum sector in 1974, but it wasn't until 1990 that this became its second main activity. In 1986, the firm supplied 72% of domestic bauxite production, and its primary-aluminum production (by ALBRAS and *Valesul Alumínia S.A.*) accounted for 25%. CVRD's aluminum-related exports constituted 57% of Brazil's total aluminum exports.

Four main periods can be distinguished in the firm's environmental policy. In 1956, the firm bought part of *Mata Atlantica* in southern Brazil for wood to build a railway line. But this unintentional initiative became, in time, a 21 700-ha private conservation area. In the 1970s, the company undertook its first projects with ecological aims. The projects related to feasibility studies for the Carajas project, the Minas Gerais mines, and the port of Tubarao; and to pollution controls for the Vitoria-Minas railway. In the 1980s, CVRD created GEANAM, an independent scientific-research area for environmental subjects and specializations. The

firm formed seven internal commissions for environmental control, in different areas of the firm.

Two main types of environmental action were also defined: the corrective and the preventive. The first is included in all of the company's projects. The socioeconomic diagnosis of the Carajas project initiated the second. It was extended in the 1980s to environmental-engineering and natural-resource diagnoses, as well as scientific research, on specific topics, administered by university departments. The firm set up two laboratories for air and water control.

In 1986, the firm established the Superintendency for the Environment, subordinate to the Direction of Entrepreneurial Communication and Environment. The firm's subsidiaries set up their own environmental departments and internal environmental commissions (CIMAs) (17 in all). At present, the area of vegetation research is very developed within CVRD. Work is undertaken jointly by the Wood and Cellulose Superintendency, the Studies and Research Superintendency, and Rio Doce Florestas. Eight research centres function in the Amazon region, developing genetic studies of native and exotic species.

The 1990–95 environmental program established the following priorities: (1) the management of natural resources; (2) environmental engineering; and (3) the development of research and studies in the area. Fifty-three percent of the environmental investment was to be applied to carrying out the second priority, especially for pollution-control reforms in old operating systems and for preventive actions in new mining areas. In natural resources, 30% of the investment was to be used to develop a master plan and manage the wildlife-conservation areas of the firm, a total of 764×10^6 ha distributed in north, south, and central Brazil.

In 1980–88, the cumulative total investment in and operational costs of environmental management were 314 million USD, of which investments in infrastructure, equipment, and other improvements in the system accounted for 88.5%. Most of the firm's personnel for environmental tasks work for firms linked to CVRD and carry out reforestation.

Mineração Rio do Norte

MRN is the main producer of bauxite in Brazil. It is formed by domestic private, state, and foreign capital. However, in 1990, CVRD held 46% of the shares, with the participation of Alcan (24%); CBA (10%); and Billinton B.V., Billinton Metals S.A., Norsk Hydro, and Reynolds (5% each).

MRN's production is key to Brazil's status in the international bauxite market. In 1986, with its production capacity of 5.5×10^6 t/year, MRN was the fourth largest bauxite-mining company in the world; by 1988, it was ranked third. Moreover, together with Guinea and Australia, Brazil has some of the largest

bauxite reserves in the world. In 1987–88, it contributed 8.6% of world production (UN 1988). The firm has, since its origin, directed most of its production to export. By the end of 1988, MRN had commercialized 38×10^6 t of bauxite, with 81% in the international market and only 19% in the local one. However, in 1990, it expanded its sales to the local market (28%), as a result of ALUMAR's having bought a significantly increased volume.

The firm's environmental department has two sections:

- The technical section, consisting of only one person, who is a senior employee, botanist, and special assessor reporting directly to the company's general superintendent; and
- The operational section, consisting by nine employees at the time of this research (November 1991): one general manager, one fieldwork contractor, one environmental engineer, three environmental technicians, two botanist auxiliaries, and one administrative auxiliary.

The department is part of a general department called Environment, Health and Security, and each section (including Security and Occupational Health, with eight people) has its own coordinator and is semiautonomous in decision-making. Actually, one of the problems expressed by our informants was that they tended to work too independently of each other.

The two sections in the environmental department proper have totally different functions. The operational section is responsible for revegetation, erosion control, pollution control, landscaping and gardening, greenhouse operations, meteorology, environmental inspection, and internal and external technical assistance. The technical section is in charge of formulating and following up on the environmental master plan (describing and relating the environmental risks of MRN's projects, problems, and solutions). This plan is revised every 2 years. The technical section develops or subcontracts relevant research and develops education and training plans for the environment in the firm and the community, carries out the internal monitoring, keeps a regular data bank, designs environmental rules and norms for the company, and establishes permanently protected areas. In 1989, the company persuaded the government to create a national forest of 429 600 ha around the bauxite reserves to protect the surrounding virgin forest. MRN maintains the physical integrity of this forest (for example, felling of trees and hunting are prohibited) and another 385 000 ha on its side that forms the Trombetas' Biological Reserve. MRN supports IBAMA's scientific research in those areas.

MRN has been concerned about the environment right from the beginning. The environmental department, run by the environmental assessor, was created in 1978. The firm has had a CIMA since about that time (as is the general policy in CVRD). The size of the department has varied throughout the years, but it was only subdivided into two sections recently. The plan for the future was to have the three subsections, including Health and Security, interact much more and bring environmental responsibility as much as possible to the shop floor. As part of the total-quality-control (TQC) plan, everyone becomes responsible for what and how they produce. The master plan can be translated into TQC measures for the environment. Beginning in 1992, the environmental assessor was to organize, according to the Environmental Executive Measures, a plan for environmental training of managers. Then, in turn, these superintendents and top managers were to train their people in each department, with support from the training department.

CIMA reports to the environmental department and the directorate and receives about 250 000 USD annually from the company. The main criticism of this type of organization is that it has a tendency to act as a political, instead of fiscal, body. Moreover, it acts as a normative body and not as an executive body, given that all firms within CVRD have their own environmental departments. The suggestion for the next few years is replace CIMA with another body that can really act as a fiscal body. It might include independent representatives from the community, such as householders, school teachers, and doctors.

Environmental costs can be divided into annual investment, which can vary substantially from year to year, depending on specific measures; and operational costs, which are more stable. Operational costs only vary according to the number of personnel in the department and the number of hectares deforested and reforested at the mine. The general superintendent's estimates of operational costs for 1992 are shown in Table 1.

Table 1. MRN's operational costs for environmental items, 1992.

Item	Operational cost ^a (USD)
Deforestation costs (including subcontractors for felling trees)	175 500
• Average: 135 ha/year @ 1 300 USD/ha	
Area preparation (including reforestation, leveling hills, returning topsoil, planting, replanting, breeding plants, combating ants)	256 000
• Average: 80 ha/year @ 3 200 USD/ha	

Source: Interviews.

Note: MRN, Mineração Rio do Norte; USD, United States dollars.

^a Estimate.

Table 2. MRN's environmental investment, 1992.

Item	Investment ^a USD
IBAMA agreement to maintain the national forest and biological reserve	350 000
Reclaiming Batata lake	300 000
Erosion controls and landscaping	400 000
Small projects (such as for air-pollution control)	200 000

Source: Interviews.

Note: IBAMA, Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais e Renováveis (Brazilian institute of the environment and renewable natural resources); MRN, Mineração Rio do Norte; USD, United States dollars.

^a Estimate.

Total expenses for the year were about 1.6 million USD, which is in turn 0.41% of the original investment in the Trombetas project (390 million USD) and only 2% of the profit for 1991 (60 million USD). This was one-third of the environmental investment planned for 1992. Informants among top management supplied information on investment planned for 1992 (Table 2). However, sometimes there are extraordinary expenses related to reclaiming degraded areas. In 3 years, MRN had to spend 70 million USD, about 1 year's profit, to transport the washing plant to the mine site, partly recover Batata lake, and build new lakes (near the mine site) for the disposal of red mud from the extraction and washing of bauxite.

The master plan was formulated in March 1988, before the relocation of the washing plant (November 1989). So some of the environmentally degrading actions were already partly stopped. Although it was said that the plan is revised every two years, I did not have access to these revisions, if they were available.

Table 3 shows the main problems in the Trombetas' environment and their causes. The master plan points out that the worst problems are found in the area bordering Rio Trombetas, where one finds the industrial installations and urbanization. These degrading actions covered 1 752 ha in all by March 1988: 1 000 ha (57.1%) from Saracá mine (although 315 of 700 ha was reforested), together with the railway. The second important areas were those eroded by red clay from bauxite washing: 418.5 ha, or 23.9% of degraded areas.

MRN's reforestation projects seem to be the most advanced in Brazil (and can even be considered an example for the other mining companies, says Alcoa's environmental manager at Poços de Caldas). The environmental assessor made a detailed study of the species of the region and determined the format that reforestation must take, in what would otherwise be a rain forest. The format follows a

Table 3. MRN's classification of main environmental problems, 1988.

Problems	Environmentally degrading action
1. Deforestation, soil degradation and erosion, and river erosion	<ul style="list-style-type: none"> • Excavation in the plateau • Railway (30 km) and urban site building (100 ha) • Bauxite tailings sent to Batata lake after washing process
2. Water pollution	<ul style="list-style-type: none"> • Effluent from industrial area sent into Agua Fria and Fundao channels • Solid materials from degraded areas sent to the channels by rainfall • Effluent from offices and laboratories dumped into Trombetas river • Sanitary sewage • Oil accumulation in 5 km
3. Air pollution	<ul style="list-style-type: none"> • Dust in mine entrance • Dust on plateau • Dust and toxic gases in industrial area
4. Sound pollution	<ul style="list-style-type: none"> • Noise in industrial area • Unregulated transport and vehicles • Social events

Source: MRN (1988).

Note: MRN, Mineração Rio do Norte.

natural process of succession of species, considering especially those that will bring the fauna back, such as fruit trees that the local birds enjoy. The birds will propagate, via seeds in their excrement, new trees in the region. These innovative reforestation criteria are based on the way the forest grew originally — very different from the type of reforestation that focuses on fast-growing, nonlocal trees or aggressive plants and grasses and seems to aim at merely maintaining a green appearance. Ninety native species and about 12 exotic ones are used in replanting. After 10 years, when the soil has been rebuilt, shade-loving forest species will be introduced to finalize the reforestation process. The cost of this type of reforestation was estimated in 1989 at 2 500 USD/ha, which is 0.07% of the direct costs of the mine. In 1991, bauxite costs (shipping price) were about 10.5 USD/t, whereas the year before they were higher (13.64 USD/t). Almost half (500 ha) of the mined land was already reforested at the time of this research.

MRN bauxite deposits cover 40 000 ha of its 420 000-ha concession. At present, on average, 70 ha is mined annually. The wood from the rain forest, which used to be cut and burned, is nowadays used commercially. This has been enforced by an IBAMA law, and the company is still developing its plans for recutting the wood from trees felled near the mine and establishing the commercialization process. This process is not so easy because of the distance of the place from other populations and the high costs of transport.

The recovery of Batata lake, the site of one of the most denounced environmental problems in Brazil, needs to be discussed further. Since the beginning of the reclaiming of silted areas from this lake, different researchers from the University of Rio de Janeiro have evaluated the programs and recommended solutions. Professor F. de Assis Estevez did research on models to establish a new ecological equilibrium in the eroded regions. The main aim of such work is to recover the part of the lake affected by residue slurry, but a second objective is to help train scientists specializing in the recovery of tropical lakes. The erosion took place on the sides and in the western portion of the lake, and it had impacts on the flora, the fauna, especially the fish, and the hydrophilic vegetation. The extension of the eroded area is 318 ha of Batata lake (including the buried red mud); 92 ha of the small river or arm called Igarapé Caraña, which was being recovered; 5 ha of the Agua Fria branch; and 3.5 ha of Fundao Igapó. Solid effluent in these rivers ranges from 6 to 9%. The only impact on water quality is a higher turbidity where the water mixes up with the red mud; the clay itself is nontoxic. Analysis of water samples gathered at four stations (the first three affected by the red mud and the fourth without residue) show a smaller concentration of nutrients, such as phosphorus and nitrogen, at the first three points (MRN 1990).

An indirect problem developing from this change in the ecosystem is the exposure of the soil to the erosion produced by heavy rains in the region. This lack of protection for the soil, in turn, inhibits the permanent recycling needed by the nutrients in the biomass, which maintains soil fertility. In sum, the soil has lost fertility in the whole of Batata lake and surrounding area. However, the research projects focus on the creation of an organic substratum in the lake, with characteristics similar to the natural one; the revegetation of the whole area; and the recolonization by fauna (native species, especially fish). Two other problems pointed out during fieldwork on soil erosion have been the erosion of the sides of various rivers and the landslides and loss of forest from the slopes of the plateaus in the early stages of bauxite mining. The latter is being controlled by leaving a 5-m belt of bauxite at the margin of each plateau. The first of these two issues has not been satisfactorily tackled.

The ALBRAS-ALUNORTE complex

In 1974, as a result of an agreement between CVRD and the Light Metal Smelters Association of Japan, feasibility studies were developed to establish a project in the municipality of Barcarena, in the state of Pará, to produce alumina and aluminum. But because of delays in negotiations with the Japanese counterparts (financial, machine, and technology suppliers), its first exports of primary-metal ingots did not take place until 1986. That year, as a result of a lack of capital, the

construction of ALUNORTE had to be temporarily stopped. Until 1990, ALBRAS had to rely partly on the imports of alumina and partly on supplies from ALUMAR.

ALBRAS — ALBRAS was conceived as a project oriented toward the export of primary metal; CVRD had an explicit policy of not competing for the internal market with the former local suppliers of aluminum. ALBRAS' environmental policy derived from CVRD's general policy for the Amazon-region ecosystem and was monitored by the local body, SESPA, the State Secretariat of Health of Pará. So far, the main problems faced by the firm have been the following:

- *Fluoride gas emissions from the open prebaked cells in potline 1 of the smelting area* — Thirty percent of the gases generated in this reduction line are still treated by the wet-scrubbing system, which generates mud residues with fluorides. These have to be deposited and treated, a difficult task because it can provoke liquid pollution, especially in a micro-region so full of small rivers. To avoid the generation of liquid residue, the cells are being closed off and their feeding system is being changed.
- *The need to change all gas treatments to dry-scrubbing, also in the anode baking factory* — These changes are also under way.
- *Damage to the vegetation surrounding the factory related to excessive levels of fluoride deposits* — Measures are being taken to evaluate fluoride levels, but there is not a well-organized program. Every month, SESPA monitors these levels at eight points distributed between 1.0 and 8.5 km from the industrial plant. Similar problems in the fauna of local small rivers have been detected, but they have not been as thoroughly examined.

Interviews showed the problems had been detected but had not been thoroughly faced. Two reasons were given:

- The lack of personnel to tackle the problems, as a result of the complicated organization of the firm's environmental planning; and
- The lack of adequate prevision of effects because these issues had been loosely dealt with in the past.

The past is now coming to light. Flaws are informally attributed to inadequacies of the technical assessments of the past, on which the company had relied heavily; the problem was that the Japanese assessors had been unfamiliar with the climate and geographic conditions of Brazil. Besides these problems, observations from fieldwork showed that hazardous wastes and noise pollution, along with workers' health, would probably require closer attention. Quantitative information on noise pollution and health aspects is also scanty. This may be considered another indicator of the possible significance of the problem.

ALBRAS' organizational chart for the environment shows 150 employees. CIMA, established after the firm was set up, has representatives from the state and municipal governments, the Federation of Industries of Pará, and the *Compañía de Desenvolvimento de Barcarena* (Barcarena development company), responsible for the port's construction. CIMA dedicates a lot of its effort to environmental-education campaigns. It is more a political and diffusion body, although in the past, CIMA made some major decisions regarding policy implementation, such as the establishment of controls for emissions affecting water supplies near the plant; and decisions on the form of treatment and dumping of solid residues. It was also decided to set up six air-sampling stations for air-quality measurements. CIMA must regularly survey the results of the fume-collecting system, environmental hazards in transportation, industrial waste, sanitary sewage system, reforestation plans, and environmental-laboratory functioning. CIMA is not, however, an executive body.

Environmental investment was estimated at 120 million USD at the completion of phase 2 (August 1989), but the firm had not yet systematically calculated operational costs at the time of this research. These costs are for air- and water-quality monitoring. Air-quality control is done at the soil level and at the level of atmospheric emissions. The plant has a network formed by four automatic stations and 20 monitoring points. SESPA collaborates in this area to fix sulfation rates. The water-quality plan is rather limited and follows the specifications established by SESPA. But considering the dimension of the problem in a water-rich area (according to number of river branches and level of rainfall), it seems low. According to such programs, the standards reached in air emissions, liquid effluent, and vegetation were for 1990 (year for which information was available) in agreement with those fixed by the federal and state governments. However, the agency's local headquarters in Barcarena were not functioning.

ALUNORTE — The ALUNORTE project was initiated in 1980 and continued successfully until 1983, when it met adverse international market conditions. Then it stopped altogether in 1986, when NAAC froze its participation. However, a

preferential agreement was reached in 1988, whereby ordinary capital and part of the already-granted financial aid became preferential shares. Then, with favourable market conditions, the project was reinitiated, but as a national private-capital firm. CVRD has its control and management and is looking for new potential partners. In August 1990, total final investment for the project, including what had already been paid, was estimated at 806.4 million USD.

During the interviews, environmentally oriented investment was estimated with the help of specialists in the field. Initial direct investment in environmental controls — including construction of tailings for red-mud slurry, urbanization and landscaping, sand and mud filters, laboratory equipment, and red-mud pumps — added up to 14 820 USD. This would be only 1.84% of global investment and 4.04% of total direct investment. ALBRAS is expected to provide much of the environmental experience and organization of ALUNORTE. However, the actual details of its functioning are not yet entirely clear. Information obtained from the interviews shows that beyond introducing adequate controls within production, little is really being done for the environment in this implementation phase, nor is the topic really seriously thought of or debated in management. Lack of advanced training on the issue is also among the flaws in this phase, especially given that much emphasis was placed on general training before project implementation.

Valesul

The history of Valesul begins with a proposal from the Reynolds' group to build an aluminum smelter near Rio de Janeiro. In a phase of high imports of primary metal and delays in the construction of the ALBRAS-ALUNORTE complex, the Brazilian government decided to take over the initiative. The government controls Valesul by having CVRD's majority of shares in the new firm and defining it as a public enterprise. The firm was created in 1976, but the participation of the Reynolds' group decreased over time. Subsequent operations only started in 1986. One of the main reasons for the interest in setting up this project was the possibility of locating the firm near the main urban centres with industries that use the primary metal, mainly Rio de Janeiro, Minas Gerais, and Sao Paulo.

The Environmental and Laboratory Division was established basically to execute the decisions made at a more global level by the firm. It was formed in 1991 with 7 permanent employees, 26 subcontracted workers, and 1 autonomous worker. The distribution of employment by type of qualification, form of contractual agreement, and task shows that 50% of the personnel carry out reforestation and 36.4% take care of residue treatment and conservation of green areas. For liquid-effluent treatment, there is only one operative. Finally, these staff constitute

only 4.3% of total Valesul employment. Permanent, skilled employees (chemical engineers and technicians) constitute only 0.92% of total employment.

The environmental master plan was directed mainly to implementing a green area around the industrial complex in 1989. The general superintendency of CVRD for the environment, together with Rio Doce S.A. Forests, designed and established the implementation and maintenance costs of that endeavour. The latter company could draw on its previous experience at Tubarao and was hence responsible for technical support. But Valesul was to provide the operational human resources, materials, and equipment. The aim was to isolate the pollution sources, improve the scenery, and make the environment comfortable. CVRD's greenhouse at Linhares (state of Espirito Santo) provided the species to be planted. By the end of 1989, 72 326 plants of 69 species had been planted in the following proportions: pioneers, 77.7%; secondary, 6.4%; fructiferous, 9.3%; and ornamental, 6.6%. Until then, the total costs of the initiative had been 38 060 USD, a cost per plant planted of 0.52 USD. In June 1991, this cost increased to 0.63 USD, including maintenance, and this made the initiative totally feasible. Other aluminum plants in Brazil have taken the green area as a model.

Other programs for the environment involve, first, monitoring the plant's pollution levels, done jointly with Fundação Estadual de Engenharia do Meio Ambiente (FEEMA, state foundation for environmental engineering), with parameters established by FEEMA in February 1985. Monthly and yearly emissions of total particulates, as well as total fluorides, are significantly lower by international and FEEMA's standards, with more efficient treatment of particulates than of fluorides. Second, there is a plan for the deposition of solid wastes, spent potliners, and dross. Although the problem has been studied sufficiently, with environmentally sound solutions either proposed or under study, not much has actually been implemented. In 1988, the Environmental Laboratory Division started coordinating efforts in this area, but lack of investment or political decisions have somehow delayed this program. Several important studies for the recovery of solid waste are under way at local universities and other firms, which will provide input to possible future solutions.

General information from the firm's archives showed that Valesul's cumulative investment in the environment before 1989 was about 28.42 million USD. This included the purchase of dust-collection equipment (by Brazilian standards, an advanced pollution-solving technology), the creation of a solid-waste facility, landscaping, and the purchase of necessary equipment for the environmental laboratory. Environmentally oriented investment has a constant tendency to increase.

For 1990, the operational costs and investment chart of the firm showed that investment in environmental protection for this year was minor, only 12.83%

of the total environmental expenditure (1.304 483 million USD). Almost the total capital is used by the firm for the reproduction of its operations, on a scale similar to that of the year before. Moreover, 75.74% of operational costs were in the smelting section, and 77.84% of investment was used by the laboratory to purchase equipment and accessories for pollution-control operations.

The study of CVRD's firms' environmental protection showed that much remains to be done, especially in water-quality control, dust and solid-waste deposits, and recycling. Workers' health and safety measures are also deficient.

The case of Alcoa

By the end of World War I, Alcoa had become a model of large-scale integration, from the mining of ore to the production of finished aluminum. With World War II, aluminum demand doubled, along with Alcoa's production capacity. Postwar demand for peace-time aluminum products helped the company grow still more in the 1950s and 1960s. It also started an aggressive program to sell aluminum on the international market. Today, Alcoa is the world's largest aluminum company, with activities all over the world. The United States has 105 of its operations. Brazil follows, with 15, and Mexico and Australia have 13 each. The firm is vertically integrated in all production stages and in raw materials, energy, and transport. But a clear-cut division exists between mainly local operations and those abroad. Third World operations involve the main bauxite mining and alumina and primary aluminum production, and these are on the rise.

Since the 1920s Alcoa has taken some type of action for the environment. Its basic concerns have included making environmental control compatible with economic growth. For this reason, it tries to collect and recycle all the materials it can within the production process and to incorporate controls into this process. Chemical materials, if recycled, reduce possible discharges of different types of liquid effluent. The technology has mostly been developed by Alcoa in the United States to satisfy both aims, especially since the 1970s, when controls tightened in the United States. The *Clean Air Act* amendment passed in 1970 to control air quality led to the creation of the Environmental Protection Agency, which established types and standards of pollution control. Alcoa increased its environmental investment from 5% of invested capital in 1971 to and 14% in 1979. This was a consequence of pressure from environmental movements of the late 1960s and legislation passed in the 1970s. In the 1970s, Alcoa spent 288 million USD on environmental protection alone. In 1981, Alcoa in the United States invested about 63 million USD in capital expenditures (9% of total capital investment) in the environment and 49.5 million USD in operating expenses for environmental needs. But the company recovered 43 million USD worth of materials to be used again.

Smelting is a good example: in 1981, the value of materials recovered through effective control technology in the smelting division exceeded 35 million USD, not enough to recover all of the operating and capital costs required to install, run, and maintain the equipment, but certainly a sizeable sum.

Alcoa in Brazil

Alcoa has operated in Brazil since the 1960s, and in 1970 it started its primary-metal production at Poços de Caldas in Minas Gerais. But the company Alcoa bought had been producing bauxite locally since 1930. In the late 1970s, Alcoa expanded its activities in the Poços de Caldas area, buying an electric-wires plant and installing an aluminum-powder plant. In 1980, it also began the country's most ambitious alumina and aluminum project, the ALUMAR complex in São Luiz, in the state of Maranhao. This was mainly to recover from setbacks to expansion already obvious at the Minas Gerais' operations. This process led to significant sales growth in the domestic market, opening of new export markets, and launching of new products in lamination, aluminum, metallic structures, and car bodies.

For general guidelines and execution, Alcoa in Brazil has differential managerial levels, complementary, but with different functions. The Corporate Department of Environmental Issues reports directly to the firm's local directorate. It has under its charge the formulation of policies and objectives for the environment and articulates with the departments in the plants. They in turn develop daily controls. They coordinate their work with that of the CIMAs, which are formed by representatives of all departments in the plant. In conjunction with the environmental department, they periodically analyze the relevant problems.

Table 4 shows the principal activities of the Corporate Department of Environmental Issues in São Paulo. The programs for the evaluation of environmental impacts, the audits, the plans for the prevention of environmental accidents, and the plans for environmental monitoring are the main executive vehicles of the plants' environmental departments and managers.

Alcoa (Poços de Caldas)

In 1967, Alcoa organized the firm *Companhia Mineira de Alumínio (ALCO-MINAS)*, which had Alcoa as almost its only shareholder (99.9% of capital) and the support of the state government, through the *Instituto Desenvolvimento Industrial* (institute for industrial development) and the *Banco de Desenvolvimento do Estado de Minas Gerais S.A.* (development bank for the state of Minas Gerais). In 1980, Alcoa reduced its shares to 67.9%. But in 1982, it reinvested. By 1984, it recovered the position of control it had had at the beginning.

Table 4. The Corporate Department of Environmental Issues of Alcoa: principal tasks.

Type of activity	Tasks
Normative and political	<ul style="list-style-type: none"> • Establish and implement aims • Revise, interpret, and provide alternatives to environmental legislation • Represent Alcoa's position on the environment to private and governmental organizations • Assess its factories to obtain legal licences
Technical and diagnostic	<ul style="list-style-type: none"> • Assess factories in the implementation of environmental controls • Promote and follow up on monitoring programs for air, water, soil, and vegetation • Promote exchange of technical information with government bodies • Revise impacts of expansion projects or new investment to determine equipment needs for environmental control and monitoring • Research and determine the possible environmental impacts of different projects • Assess the firm's solutions to environmental problems

Source: Research.

In 1970, ALCOMINAS was the first local producer of aluminum, and it also produced alumina. This was Brazil's first project to include investment for the environment.

The environmental policy and operations for alumina and aluminum production follow the same pattern as those of the ALUMAR complex, described later, so special emphasis will be placed here on those developed during bauxite mining. However, relevant control and measurement standards were not obtained during the field research on activities in Poços de Caldas. Probably the older technology in use (Soderberg type) made this material unavailable.

The firm is on a plateau near the city, which in turn is 180 km from São Paulo. The plateau is circular; it is 1 200–1 600 m high and about 400 m high at the periphery. Bauxite is concentrated in the northern part of the plateau. Alcoa works yearly on 5–10 ha and has an overall reserve of about 356 ha. Topsoil from the area to be mined is stockpiled until it is needed for recovery and reforestation.

When the mining is completed, terraces are created in the sloping soil. The terraces allow rainfall to concentrate but stop the soil erosion that would otherwise occur. Topsoil is then distributed to the mined areas to prepare for planting. Calcium and chemical fertilizers are added because high acidity levels and lack of nutrients have been discovered. Drainage systems orient rainwater to reservoirs built in the mined area. This increases the soil's capacity for absorption and avoids erosion.

At present, the reforestation program uses native species and has the input of professional staff from the University of Campinas in São Paulo. This is the modern approach used by Alcoa; in the past, reforestation depended on commercial and homogeneous species, such as eucalyptus. Reforestation costs depend on the specific characteristics of each area, but since 1979 they have been about 0.00065 USD/t of ore mined. This is quite a small relative cost, even if, considered in absolute terms, the recovery of a whole mined area seems costly. For example, in 1982–83 an area of 4.42 ha (a year's mining work) was recovered for 7 425 USD. But as it produced 225 234 t, the relative cost was of 0.00145 USD/t. The firm has been developing these operations since 1977 and has already recovered 135 ha. Labour costs in operational costs for each stage of recovery (terrapiain, drainage, revegetation, maintenance, and greenhouse) were 55.80% of total costs. In sum, the cost of recovery per tonne of bauxite is about 1% of the cost of mining it and transport it to the alumina factory; that is to say, it is economically feasible.

The ALUMAR complex

The ALUMAR alumina and aluminum complex is on São Luiz island (which has an area of 900 km²), in the state of Maranhao. The complex occupies 1 700 ha. It is part of the Northeast Region in Brazil, but legislation made it part of Legal Amazon in 1967 (decree 200). This means that it has a right to all the subsidies for economic projects in that region, but it is also subject to all the controls. The area has a very rich hydrological system; the most important rivers for ALUMAR is Rio dos Cachorros and its tributaries, Igarape Andiroba, Pedrinhas, and the little Coqueiros river, which is the main drainage system for the plant. Only 34.5% of the 1 938 km of rivers is navigable, because of the lack of more adequate infrastructure. Mango trees occupy 15% of the island. However, many of the previously existing species were devastated by the activities of people, and this reduces the variety of animals for human consumption and accelerates the area's erosion.

At ALUMAR, the concept of incorporating environmental controls into the production process implies a major initial and gradual investment. The environmental department's budget for 1990 was about 2 million USD, used mainly for operating costs, such as training, wages, landscaping activities, and laboratory controls. During the fieldwork for this research, investment in 1990–92 for environmental activities at ALUMAR was estimated at 55.14 million USD, distributed as shown in Table 5. Levels are high because they include the rehabilitation of one of the lakes for deposits of red mud.

Table 5. ALUMAR's investment in environmental control and recovery, 1990-92.

Items	Investment (million USD)
Building	52.8
Stocking building for SPL	
Bauxite residue lake 2	
New ash deposit	
Expanding or creating systems	1.3
Alumina-transport system	
Expansion of sewage system	
Gas-treatment system in anode baking	
Recovery of bauxite-residue lake 1	
Irrigation system	
Opacity-measurement system	
Technological development	0.1
Recycling of SPL	
Environmental recovery	0.9
Recovery of west area 261 (10 ha)	
Landscaping plan	
Greenhouse	
Degraded area recovery	
Environmental park	
Emergency	0.1
Emergency-action plan	

Source: Data from ALUMAR's archives.

Note: SPL, spent potliners; USD, United States dollars.

In 1984, the consortium built and started operating a lake for bauxite residue, covering 15 ha. It had been designed to be used for 4.5 years, but it was enlarged to increase its capacity. The artificial lake is formed by dykes built with local solids, and it has a double impermeable membrane of polyvinyl chloride, 0.8 mm thick, that covers the base of the lake and the sides of the dykes. This membrane avoids the infiltration of residue into the superficial waters, which could thus be contaminated. In 1990, a new lake was put into operation. Investment in this was about 27 million USD. The lake has a capacity for $4 \times 10^6 \text{ m}^3$ of residue and took more than 1 million working hours to build. As this new lake begins to receive residues, the older lake no longer collects effluent, but it is still not deactivated. In 3 or 4 years, through rainfalls, it is expected to have a natural cleaning process. Only when its water is considered environmentally sound will it begin to be recovered. This is an ongoing process.

The environmental effects of the construction and operation of this complex were studied for 3 years before the project was implemented. This study had the participation of the environmental department of ALUMAR and Alcoa, the Hydrobiological Laboratory of São Paulo University, and the State University

of Maranhão through contracts and consulting agreements with ALUMAR. It is very interesting that the evaluation of environmental impacts anticipated the Brazilian dispositions that began to be applied in 1986; ALUMAR started operating in 1984.

Total fluoride emissions and particulates were above international standards in the potroom in 1990. For fluorides, this continued into 1991, although at a much lower level. The environmental department is working hard to limit them, especially those related to the operators' inadequate handling of the equipment, such as when they keep pots open for too long while they perform certain functions. Because of this, a third instrument, a spill-prevention plan, was established to identify and inventory all potential spills. Accidental spills of oil or hazardous products resulting from operating failures or breakage of tanks or ditches can cause critical pollution problems for the environment and the workers. As part of this plan, every morning and before each new shift, 10 min is devoted at the ALUMAR complex to discussions of hazardous working-environment issues.

Both cases

In both the case studies (CVRD and Alcoa), the following environmental-control procedures were used:

- An EIS, whose monitoring measures are mainly applied to fluoride emissions and particulates;
- Partial land and tailings recovery;
- CIMAs; and
- Some form of environmental training (although here there were substantial differences between the content and extent of the programs applied by each company).

What also varied between companies was their knowledge of the best practice for certain environmental controls and their applications. The multinational firms had wider knowledge. The companies also used basic health, safety, and accident-prevention monitoring, which will be further discussed in the next section. However, very few companies had sufficient water-quality controls, locally specific land recovery, or full reforestation. Dust controls were virtually nonexistent, and so were noise- and heat-level controls. The companies did very little recycling of by-products. Solid wastes from alumina and aluminum production were not

thoroughly protected in stocking. Finally, monitoring of local flora and fauna was inadequate (especially near tailings). Moreover, environmental-laboratory technology tended to be either outdated or insufficient.

Innovation and human-resource development

This section explores the main approaches to innovation and technical change, employment, training, and health and safety in this sector. Whenever possible, I will be drawing on more detailed information from the case studies.

Technology

Technological change in the domestic industry is represented by two main stages in the smelting process: Soderberg smelting and prebaked smelting, which is a more environmentally sound technology. The two types of smelting differ in the type of anodes employed: prebaked smelting involves a multianode; the Soderberg continuous anode, which is baked *in situ*, uses the heat generated by an electrical current passing through the cell (UNEP 1986a). However, a series of incremental innovations is a later part of either stage, although this is more characteristic of the prebake technology. Both types of pots can be closed or opened, hooded or unhooded, which makes a big difference in the gas emissions in the workplace and in the atmosphere. The types of cells also differ in the ways the anodes and alumina are fed into the process and the ways the anodes are replaced. The less the inputs are in contact with the atmosphere or the operator, the cleaner and safer is the technology. Other incremental technical changes have taken place in the size of the smelting pots, process controls, magnetic stability in the pots, and operational and control parameters in alumina feeding.

Since 1930 researchers at Alcoa in the United States have searched for an effective system to collect and recycle fluorides. In 1967, the first unit of Alcoa 398 technology was put into operation. It is a dry system of fluoride-fume treatment and recovery; 99% of fume-fluoride content can be collected and recycled in the smelting process. New plants were built with that process, and almost all older plants have had their systems replaced. In 1979, people thought that if the system was changed in all plants, this would produce savings of 80 million gal (1 gal = 4.546 L) of water and reduce fluoride supplies by half. In 1975, the 446 process was designed, a dry-scrubber to remove tarry materials with fluoride from the carbon blocks in the baking process. Other less extended developments have included, in 1979, the new smelting technology to produce aluminum without cryolite, avoiding fluoride emissions altogether. With that technology, dry-scrubbing is still needed for other contents of gases (particulates, chlorines, and other

compounds). The policy with respect to water is conservation plus reuse. Both the 389 and 446 technologies help to reduce water pollution insofar as they do away with wet-scrubbing. By replacing 75 wet-scrubbers with dry-scrubbers, Alcoa reduced water use in 1967–90 by more than 5×10^6 gal/d. Another advance has been an improved treatment system to recover almost 90% of waste water for reuse; this is achieved through the elimination of dilute oil. Other Brazilian firms now use similar prebake technology and dry-scrubbers.

All aluminum smelters in Brazil have foreign technology, although some incremental technical changes have been designed and applied locally. However, larger projects make no provision for developing local technology, except of course in terms of some of the architectural designs that are so central to the industry. Research and development (R&D) institutes and centres are scarce in this industry; any that exist are found mainly locally in ALBRAS, Alcan, and CBA. The main areas of R&D have been in process automation, optimization of technical parameters in smelting, selection of more efficient materials, reduction of energy consumption, etc. On selected topics, the industry has professional input from R&D at local universities.

Innovation is largely embedded in imported machinery. However, plenty of scope exists for incremental technical change, especially in the smelting rooms. These can be environmentally oriented, as this also reduces waste of materials, thus making it economically feasible. Still, power failures, which are not infrequent, can reduce the productivity and environmental soundness of increasingly cleaner technologies. This seems to be an urgent problem. Lack of communication between the technical and production departments and the environmental and health and safety sections also hinders the firms' implementation of a more integrated innovation policy; it also reduces environmental quality. The role that training can play in the development of a more integrated effort will be discussed in the next two sections.

Employment

Table 6 shows the distribution of direct employment in the aluminum industry by type of activity and type of job for 1990. Total employment was 66 780 people, with the majority (84.4%) occupying technical positions. The latter include blue-collar workers, as well as technicians and professionals. The table shows the importance of the independent manufacturers as employers: 56.3% of employment was in that subsector, whereas 40.3% was in the primary-aluminum integrated firms, those mainly studied in this research.

Table 6. Brazil's direct employment in the aluminum industry, 1990.

Subsector	Administrative (n)	Technical (n)	Total	
			(n)	(%)
Primary-metal integrated	4 879	22 032	26 911	40.3
Secondary	380	1 873	2 253	3.4
Independent manufacturers	5 169	32 447	37 616	56.3

Source: ABAL (1990).

The evolution of employment in 1984–90 by type of job shows an increasing share of technical jobs in general employment. Technical jobs were responsible for all employment growth in 1984–90. However, in the 1990s, the number of jobs has decreased in absolute terms. This reflects the policy adopted by the large corporations in this sector. Among integrated primary-metal producers, the policy was mainly to decrease administrative jobs so as to reduce production costs and maintain competitiveness in the international market as metal prices fell. This was partly a result of specific management techniques, such as TQC. In contrast, technical jobs remained quite constant in this period in the category of primary-metal integrated firms and rose more regularly in the other two subsectors. Brazil is one of a group of countries that have low wage costs; the others are Australia, India, South Africa, and Venezuela. Social wages form a large part of average wages, although the proportion is not necessarily higher than in other producing countries. Furthermore, during the recession, the producers have shown a preference for hiring workers on a subcontractual basis. Social costs are then to be borne by the subcontractor, rather than the employer. However, subcontractors are subjected to fewer government controls.

Other information on employment and wages, published by the Instituto Brasileiro de Geografia e Estatística (IBGE, Brazilian institute of geography and statistics), shows that in terms of number of jobs and wage levels the recession in the domestic industry has been stronger in the mineral-extracting sector. This has resulted in job losses and wage decreases (IBGE n.d.). Unfortunately, the criteria for collecting employment data in bauxite production in Brazil differ from those used in the aluminum industry. The DNPM data are the best available and are published in the *Brazilian Mineral Yearbook* (DNPM 1990). This source is built with periodic information filled out by the firms themselves. Employment was at 1 543 in 1989, with the vast majority being blue-collar workers, and this level remained stable for several years.

Strategies for training, health, and safety

All firms studied had their own training departments. Some of these training departments (such as those of ALBRAS and ALUNORTE) were even operating during the development phase of the project, before installation. Many of the engineers, technicians, and managers had been sent abroad to train or retrain at the mother company or with technology suppliers. Local retraining was usually done systematically, during operation. For example, by August 1989, already 92% of ALBRAS' workers were local people. They had all been trained in the plant, because no one in the area had had previous experience with aluminum or heavy industry. Delays in project implementation gave the company time to develop, well in advance, training plans to be used locally and in the national universities. However, technical personnel had to be recruited from outside the region and even from outside the state, sometimes from other CVRD firms. To initiate the project, the firm also had 60 Japanese technicians and aluminum specialists from Mitsui. However, it was harder to estimate what proportion of this training was related to the environment. In the environmental departments, usually only the heads had such training abroad; middle managers and technicians participated in national conferences and courses, but not systematically.

Alcoa had one of the most advanced training programs in the sector, and this can be illustrated using the employment and training practices at ALUMAR. In June 1991, permanent and subcontracted employment was at 3 358 persons, almost one-third of Alcoa's general employment in Brazil. Permanent employment was at 2 872: 68% were paid hourly; 15% were paid monthly; and 17% were hierarchical technical and managerial staff (15 in all were employed in the environmental department). Personnel had higher wages than similar workers in other regional industries, and their jobs were more stable than similar ones at MRN. Schooling levels were also higher than at other local firms. Moreover, ALUMAR did systematic and permanent in-plant training, especially in the most technical areas. It also regularly sent top- and middle-ranking managerial and technical staff overseas for training. Table 7 shows the firm's training budget, 579 374 USD, for 1991: of this, 8 011 USD, or 1.38%, was destined for personnel in the environmental department.

The company also had daily 5-min discussions of health and safety — a legal requirement. However, part of this time was sometimes used to discuss environmental issues. Training is one of the main methods for dealing with these issues — training in emergency-action plans at the level of day-to-day details and routines. At ALUMAR, a follow-up was also made: information on the number

Table 7. ALUMAR's budget for personnel training, 1991.

Area	Training costs (USD)
Operational management	96
Materials	20 003
Port	6 116
Human resources	45 751
Environment	8 011
Public relations	583
Accounts office	11 004
Quality	2 369
Security	26 379
Systems	19 091
Refining	39 823
Smelting	31 118
Ingot factory	2 638
Engineering and maintenance	25 072
Administration	1 012
Alcoa and subsidiary	923
Start-up	5 567

Source: ALUMAR's archives, Administração Industrial (1991).

of accidents and the attitudes of those involved was added to a data bank. For example, at ALUMAR in 1990–91 (until July 1991), of 18 accidents occurring in the calcination section, 5 (27.8%) were caused by human error. Of 116 accidents in the clarification section, 40 (34.5%) were caused by human error; 15 (12.9%), by spills in tabulations; and 14 (11.9%), by faulty equipment. The environment departments investigated each accident to classify it by degree of environmental damage, identify its cause, and establish corrective or preventive action. If human error ranked high as a cause of accidents in a section, a questionnaire was distributed to that section's operators. This was supposed to be a consciousness-raising experience and was considered useful in evaluating and eventually increasing — through training — the workers' knowledge of environmental and personal risks in their section.

Other departments at ALUMAR carry out other training activities complementary to those strictly oriented to the environment. I must at least mention general training activities and industrial-hygiene programs. The first considers, in

a limited way, environmental training in the recruitment phase. All recruits are shown a film on environmental controls at the plant; for certain jobs, environmental aspects are included in initial training programs. Workers in some situations, such as potline workers, receive environmental training when certain pollution standards are not being met. The plant also promotes some environmental training with community groups, offering 1- or 2-d programs with open discussions of the topic, etc., and also gives technical assistance for setting up communal greenhouses. In the past, the company made some fairly high investments in retraining its process engineers and environmental engineers, either domestically or abroad. However, the recession drastically reduced its training investment.

Industrial-hygiene programs are crucial in this industry because one of its main problems is the need to improve the direct working environment, principally in the potrooms, at the anode-fabrication plants, and in some sections of refining. Heat and noise levels tend to be high at most stages of the production process. At ALUMAR, this is especially so, considering the location of the complex is already extremely hot and damp. Mean exposure levels by job class, as agreed internationally, are periodically compared with real levels attained in various sections of the plant. Two of the main difficulties are still the reduction of noise levels and human exposure to corrosive chemicals. For this reason, the plant provides a complete list of the main agents and the numbers of people potentially affected by their activities per stage in the production process. This is used to monitor workers and technology.

MRN has also developed a very comprehensive program to tackle health and safety problems, and the firm has been most interested in reducing work-related accidents, which are common in all mining activities. In 1991, a new program was developed to reduce the accident rate relative to 1990. The firm elaborated some policy instruments for supervisors to put into practice in various areas. The firm uses posters, talks, etc., to publicize the general security policy. Also of use are monthly meetings on health and security; daily 5-min security talks; auditing of insecure actions; preventive analysis for various jobs; and programed security inspections.

Tables 8 and 9 show the number of accidents among permanent employees and subcontracted ones at MRN between January and September 1991, along with those foreseen by the company for that period. The tables indirectly measure the level of risk of each accident according to two categories, that is, whether or not they resulted in lost time. Most accidents were without lost time (more than three-quarters of cases among both types of personnel). The company's predictions were somewhat higher than the results.

Table 8. Work-related accidents among permanent employees at MRN, January–September 1991.

Accidents	With loss of time	Without loss of time	Total lost time
Actual			
<i>n</i>	5	25	30
%	16.5	83.3	100.0
Predicted			
<i>n</i>	11	35	46
%	23.9	76.1	100.0

Source: Company archives.

Note: MRN, Mineração Rio do Norte.

Table 9. Work-related accidents among subcontracted employees at MRN, January–September 1991.

Accidents	With loss of time	Without loss of time	Total lost time
Actual			
<i>n</i>	15	121	136
%	11.0	89.0	100.0
Predicted			
<i>n</i>	32	142	174
%	18.4	81.6	100.0

Source: Company archives.

Note: MRN, Mineração Rio do Norte.

The number of accidents among the subcontracted workers was 4.5 times higher than among the permanent personnel. But the number of subcontracted workers (2 869) was more than double that of permanent workers (1 282) for that year. The data show that MRN's industrial security policy has much greater success reaching the permanent personnel. The mine is obviously the most risky place to work. The mine, the port, and the beneficiation area together account for 84.61% of all accidents. Fieldwork observations showed that the workers most affected by accidents are, in order of severity, maintenance personnel, blue-collar workers, and drivers. Accidents usually happen because mechanical parts bump inattentive workers or tools fall from their hands. Company estimates show that fingers are the body parts most frequently affected. This category accounts for 21.88% of cases; arms and face, 9.38%; and back and forearms, 6.25%. Other body parts are rarely injured.

In ALBRAS-ALUNORTE and Valesul, training in general and training on the environment and safety were less advanced than at the other companies studied. But conflicts arise in all companies over the articulation of training endeavours — between the general training offered by the personnel and training department and the more specific forms of training needed by the environmental and health and safety sections. Moreover, the environmental input does not inform all these training policies, which tend to function independently in most firms. Above all, hardly any systematic integration exists between the technology and production sections and the different training initiatives. This partly shows how little environmental training has been planned in this transition phase. Environmental training is done without taking a holistic approach to all sections of the company. The next section, however, analyzes indications that this might begin to happen in companies or in the government's future plans.

Company strategies and government policies for the future

Main conclusions and policy recommendations

The case studies illustrated, to the extent possible, the everyday environmental behaviour of two central Brazilian companies. The data from these two companies cannot be extrapolated to the whole sector, but the studies offer a sound illustration. From this, some trends can be derived regarding the relationship between environmental regulations and company behaviour (environmental management and technical solutions) and — although in a more limited way — between social pressure and company behaviour.

The case studies revealed the main forms of relationship between environmental regulations and company behaviour:

- Regulation, either local or home country in the case of transnationals, is a necessary but not sufficient condition for implementation of a sound environmental policy at the company level in Brazil.
- The level of environmentally sound behaviour varies between aspects of environmental planning, showing a set pattern across companies. In other words, some regulations are more systematically applied than others. This in turn is positively correlated with the direct economic gains companies obtain from obeying regulations and only secondarily with the existence or enforcement of the regulations or social pressure. For example, fluoride-emission control is heavily monitored across

companies, whereas sound reforestation and riverbank erosion are controlled less uniformly.

- Regulations and social pressure are the main motivators for the companies to implement adequate measures against negative environmental impacts that are more visible to the wider public or that affect a broader population. Regulations and social pressure are interrelated: usually, general social pressure results in new regulations, whereas particular social pressure results in a more thorough implementation of rules, along with careful monitoring.
- Even in cases where environmental soundness in a company's behaviour is triggered by regulations established as a result of social awareness in the home country (as with Alcoa), companies can demonstrate time lags, resistance, or denial in carrying out the necessary adaptations to the local environment. This shows that the local environmental efficiency of some transnationals does not derive mainly from acceptance and enforcement of local regulations, but from the companies' greater technological and financial capacities, which are only in a limited sense a function of environmental regulations in the home country.
- Corrective maintenance predominates in this sector. This is partly a result of the characteristics of local regulations for the sector (recent, flawed, or contradictory, as explained earlier) and partly a function of the type of growth the government fosters.
- Even if regulation is the more direct cause of positive changes in companies' environmental practices, flaws in the implementation of the laws and policy measures diminish the potentially positive impacts of environmental regulation.
- Not all transnational companies are at the forefront in the use of environmental-control technology or management in Brazil — in certain respects, the national laws do not lag the industry's environmental practices. For example, CVRD's behaviour, as shown by this study, is more advanced than Alcan's local practices, and the national laws on reforestation and land rehabilitation using local species are very convincing and adequate on paper, if not in practice. The main problems are establishing an adequate institutional setting and the mechanisms to

monitor implementation and to make regulations effective; and creating political power to enforce the regulations vis-à-vis different economic groups. These problems are clearly illustrated by the scanty application of environmental regulations that directly affect the workplace. These regulations are precise and available, but they are not effectively applied. The workers have little power, and government practices do not support the workers.

Ultimately, then, environmental soundness depends not only on the instrumentation of environmental regulations and sound technical choices but also on having an institutional setting that favours their application and having the educational skills and political power to create these instruments. Without these, neither regulations nor technical and managerial solutions are enough, although they constitute an essential precondition.

Let us look now at the case-study results in more detail. The case studies showed that most of the companies had production-expansion programs under consideration. MRN intended to expand its production capacity of 3.5×10^6 t/year to 5.5×10^6 t/year and to supply the ALUNORTE plant once it started operating. ALUMAR of Alcoa planned, for 1993, to increase production to 950 000 t of alumina and 380 000 t of aluminum, almost doubling its 1990 capacity, both for export and for the supply of its domestic manufacturing plants. It was continuing its verticalization process. ALUNORTE was to begin its operations as the main supplier to ALBRAS. With this, ALBRAS was to expand its production of primary aluminum substantially, to 340 000 t/year. However, ALUNORTE intended to produce 1.1×10^6 t of alumina/year for the global market by 1996.

For most of these initiatives, the companies upgraded their technology, usually through incremental technical changes. These resulted indirectly in a cleaner production processes. The best international practices were adopted for new endeavours, such as that of ALUNORTE or the expansion of potline sections within smelting, at ALBRAS. These tended to be environmentally sounder. ALUNORTE even chose the Giulini system for disposal of red-mud slurry — one of the most advanced systems in the world. However, in the plants operating with older technologies (the Soderberg vintages), less was being done in both these directions, that is, toward the expansion of operations and toward technological upgrading with environmentally sound hardware. Partly, this reflects the limitations imposed by the technology; partly, the firms' lack of motivation to innovate. Moreover, local R&D for these technologies is scarce, and so is the knowledge on best practices.

Differential environmental experience was shown within the firms studied. In most, the controls, whether regulated by recent laws or not, were applied more in a corrective than preventive manner. In other words, they were considered and used after the technology had been selected and only when some of the problems presented themselves. This trend had been stronger in the past among firms with less experience in producing bauxite, alumina, or aluminum, such as some of CVRD's plants. Some multinationals, such as Alcoa, had had environmental regulations in their home countries earlier. These companies also tended to have a greater capacity to embed the necessary controls in the technologies they developed. Familiarity with production and R&D capacity made it feasible for some companies to plan ahead and develop a preventive policy from the implementation phase of a new project. These activities also made it somewhat easier for these companies to keep up with domestic regulatory standards. However, the companies tended to lack experience in the specific environment they were dealing with.

The general environmental laws applied to the sector are contradictory regarding standards and types of controls or they are highly specific to each state or region. This makes it complex to set up common guidelines across activities within one company or across companies. As the regulations are generic for mining or for industries as a whole and deal with air pollutants, chemicals, or water pollutants by type, entrepreneurs and environmental departments are generally left to decide their own activities. Fortunately, the Associação Brasileira da Indústria do Alumínio (ABAL, the Brazilian association of aluminium producers) has been able to draw on its past experience in the sector, systematize the legal information (ABAL 1991), and informally draw up some common guidelines. The association holds periodic meetings for environmental departments, a general conference, and annual training workshops to discuss environmental information relevant to the sector. This seems the right forum for generating a more preventive environmental approach for the whole sector. Alcoa's initiative is very strong in ABAL, and it exerts its influence widely, given its longer trajectory in the area.

However, ABAL has accomplished little toward devising policies covering solid waste and dross recycling in the industry; aluminum can and scrap recycling; or heat, noise, and reverberation reduction. These are the most prominent environmental hazards still largely unresolved in the Brazilian alumina and aluminum sector.

There is no body that is equal to ABAL or develops similar tasks for bauxite mining, exploration, and development. IBAMA tends to fulfil a more administrative role as a government environmental agency. Some research on the local flora and fauna, as well as on specific rehabilitation of degraded land, is being done at the Goelde Museum in Pará; at local universities all over the

country; at R&D institutes belonging to the companies, especially those of Alcan, Alcoa, and CVRD; and in the local environmental agencies. The latter often hire the heads of the companies' environmental departments for their expertise. However, there has been little systematic integration of research results.

The case studies also illustrate how much the advances in formulation of the laws are not reflected in coherent implementation practices within the companies. For example, some government measures are applied bureaucratically, that is, without assessing the possible results of differing implementation schemes in particular environments. Conflicts between departments in the firms make it difficult to devise a more integrated approach to training staff to implement environmental measures.

The skills of personnel in the environmental departments also need to be upgraded. This is especially the case with national firms, which either have too few people dealing with the environment or too few professionals and many more subcontracted labourers in manual operations. On the other hand, manual and low-tier supervisors and technicians have no access to vocational-training programs with an environmental approach. Until recently, SENAI (the industrial vocational institution) has not considered setting up any new programs with this concern or including this concern to any substantial extent in its regular curriculum.

A lot more needs to be done in all sectors to protect the workplace environment. This also applies to current domestic environmental regulations. The case studies show how relatively little has been done to diminish the adverse effects of heat, sound, or reverberation in the workplace or, in some cases, the nearby neighbourhood.

The proposed (preproject) amendments to the environmental legislation in the Constitution will do little to increase the environmental soundness of the sector. These are the clauses commented on in the second section of this paper: they call for further administrative and legal centralization of controls, monitoring at IBAMA, and restrictions on participation of foreign capital.

The regulation of the use of native lands for mining endeavours also awaits further resolution. For this, the wider participation of interest groups is not only desirable but advisable. The public-audiences policy instrument for the discussion of RIMAs before project implementation has not yet been widely promoted by government regulating agencies. Despite this, it may prove an interesting tool for public awareness and participation.

The following main policy recommendations arise from this research:

- The need to emphasize a preventive versus a corrective approach to the environment among firms and in government policies and legislation;

- The need to develop a more systematic social policy at both levels, which may in turn benefit the environment and the different actors; and
- The need to further engage the various social agents in discussion and participation (for the sake of open dissemination of information) and in decision-making on environmental issues, as these tend to have a wide-spread effect at a local, regional, or national level.

A word of comparison

Using other studies undertaken for the Mining and Environment Research Network (made available from China and Ghana), I will briefly discuss some similarities and differences in the trends found in environmental management and land reclamation, most especially as they relate to the aluminum industry and bauxite mining (see Acquah 1993; Acquaisie 1993; Lin et al. 1993).

First, in all three cases — Brazil, China, and Ghana — strong regulatory institutional settings were in operation when the case studies were developed. These settings differed in their time frame, the type of pressure that set them in motion, and the degree of linkages with local industry to make their policies effective. China had the oldest initiative, dating from 1973, followed by Brazil. The more recent initiative is articulated in Ghana's National Environmental Action Plan for 1991–2000. Although in Brazil and China, environmental initiatives at the national level derive from general social awareness and pressure, in Ghana they stem more clearly from the World Bank's guidelines as preconditions for loans. A typical example is the Ghana Environmental Resource Management Project, a 5-year plan to develop the necessary institutional and technical capabilities to combat soil and resource-base degradation. Industry linkages seemed to be far reaching in the case of China; not especially notable in the case of Brazil; and apparently just beginning in the case of Ghana.

Second, the cases in Brazil and Ghana were similar in having a double channel for environmental soundness: on the one hand, government monitoring and control; and on the other, corporate practices (that is, transferring to the Third World the environmentally sounder technology developed to meet First World standards). In Ghana, transnationals seemed to be doing this, but practices were not so clear cut in Brazil. Brazil was also more complex, as some industrial initiatives were outside the hands of the transnationals. Because the transnationals were operating under technology-transfer agreements, they had a lot of room for in-plant adaptations and incremental technical change, which can alter environmental soundness significantly. In China, initiatives were developed locally,

especially in land reclamation for bauxite production, and this always involved a high level of local R&D and research *in situ* at each mine.

Third, China seemed to have the highest levels of R&D expenditure on the environment at national and sector-specific levels. China was also the only country that had established quota-based, or market-type, instruments for environmental control: since the 1980s treatment-control funds have come from the polluting organizations, rather than from the state. As we have seen, Brazil has an orientation in this direction, but not Ghana, where the command-and-control approach predominates. Also, in China, by law, 7% of technical-innovation funds must go to the struggle against pollution (Rothwell 1992; Skea 1993).

Fourth, none of these countries had policies disaggregated to a sector-specific level, leaving associations of producers to determine largely their own parameters and operationalization, with the exception of the land-reclamation programs in China. These were highly sophisticated and mine specific, usually with the objectives of making mined land arable again and achieving the standards of the local farmers.

Fifth, in all cases, the general focus of policy, in theory, was on prevention, but in practice the focus was on environmental controls for problems that had already surfaced — that is, on correction rather than prevention. In all cases, the main obstacle was the lack of managerial skills for environmental preservation. The literature in the three cases also indicated that best environmental practices could be attained with community involvement in policy-making. These are specific concerns and setbacks in attaining environmental soundness in developing countries, and they should be taken much more into consideration by those who are developing research and policies for sustainable development.