Environmental management in the Brazilian non-metallic small-scale mining sector

Arlei Benedito Macedo *, Décio José de Almeida Mello Freire, Hércio Akimoto

Instituto de Geociências, Universidade de São Paulo, São Paulo, Brazil

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Abstract

Non-metallic mineral resources, albeit very important to meet the needs of the Brazilian population and for exportation, are ill-favored by governments and ignored by the public. Most of this mining is performed by small-scale companies and informal operations that cause extensive and widespread environmental damages. In addition to examining the current state of the industry and its environmental impacts, this paper outlines a series of initiatives for improving (environmental) performance. The suggestions made include improved coordination among public entities responsible for the control of the mining sector; the undertaking of environmental management and reclamation initiatives; research and diffusion of mining and environmental technology; the development and implementation of appropriate licensing procedures for small-scale mines; and the reviewing of environmental impact evaluation and enforcement procedures, and improved regional planning. It is concluded, however, that the proposals will only become a reality if the necessary political actions are taken, and are supported by adequate financing and technical assistance. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

This paper provides an overview of the historical and present conditions of the Brazilian non-metallic small-scale mining industry, together with the efforts made by governmental and non-governmental organizations to improve mining technology and the environmental management of resident operations. The contributions of non-metallic mineral output to total mineral production are commonly overlooked in Brazil, since no commodity produced in this sector of industry dominates the export or import list. Non-metallic small-scale mines are both individually- and family-operated, and many feature highly rudimentary techniques.

Though less intense, the environmental impacts of non-metallic mineral mining and processing are more extensive than those of metal and fuel mining operations. Operations primarily occur on a micro scale and generally do not release toxic residues. However, preventing environmental impacts in this sector of industry has often proven onerous because of the overabundance of operations and their widespread distribution.

Although historically, the environmental management of Brazilian non-metallic mines — particularly small-scale operations — has generally been poor, the efforts made by government agencies and various associations have nonetheless helped to improve environmental administration.

2. Statistical data

The following figures represent the most recent official data recorded by the Brazilian National Department of Mineral Production (DNPM) and National Association of Producers of Aggregates for Construction (ANEPAC). A large proportion of non-metallic mineral production is produced and consumed locally without tax payments. Moreover, a significant amount of operations are located out of the reach of the Government and associations of legalized miners such as ANEPAC. Thus, actual production is much larger than that declared...
in Government and agency documentation, and in all likelihood, exceeds the production value of most segments (e.g. metal, energy and gems) of the Brazilian minerals industry.

In 2000, of the US$18 549 244 630 worth of minerals produced in Brazil [1], output of non-metallic minerals accounted for US$3 036 319 610, much less than the US$10 386 838 778 production value for energy mineral commodities, of the same order of magnitude (US$3 761 784 938) as metallic minerals, and much higher than the US$108 240 262 production total for gems and diamonds. In Brazil, disorganized mineral production is largely attributable to the absence of a national mineral policy, and although the net value of minerals production is relatively small (approximately 2% of national GDP), the value of the economic activities that depend on minerals for raw material inputs accounts for approximately one third of national GDP.

From a production standpoint, Brazil’s most important metallic mineral is iron ore; some 274 million tons were produced in 2000. In the same year, however, the DNPM determined the production of crushed stone to be 103 million cubic meters, and sand and gravel production to be 155 million cubic meters [1]. These data, however, should be significantly higher because a large percentage of operations are informal, the production from which continues to be largely undetermined. Sources within the informal small-scale mining sector estimate the annual production of sand to be 248 million tons, and other experts consider crushed stone production to be significantly larger than that declared.

Non-metallic minerals play an important role in Brazilian society. For example, the transportation, sanitation, housing, and hydroelectric energy sectors all rely heavily upon locally mined construction materials. In fact, it is expected that demand for such commodities will continue to grow because [2]:

- at present, there is a deficit of 13 million homes nationwide;
- some 30% of existing houses do not have access to drinkable water, and 65% are not connected to a sewage network; and
- 50 000 unpaved streets still exist.

It will be exceedingly challenging, however, to meet such a demand without causing significant environmental impacts.

The distribution of production is widespread amongst the different segments of the Brazilian non-metallic minerals sector. In terms of value, however, according to the DNPM [1,2], the most important commodities mined in the industry are crushed stone (25.78% of the sector); limestone (9.46%); construction sand and gravel (16.33%); clays (4.38%); mineral water (7.61%); phosphate rocks (7.20%); kaolin (6.05%); asbestos (3.15%); dimension stones (3.53%); industrial sand (1.11%); potassium salts (2.91%); and magnesite (1.04%). The minerals used in civil construction represent the largest volume and production value of all non-metallic commodities mined in Brazil, and their extraction thus demands more manpower than any other mineral. According to the DNPM [1], in 2000, of the 100 190 workers registered in Brazilian mines and processing plants (with the exception of petroleum), 51.2% belonged to the building materials sub-sector (including cement), compared to only 12.5% employed in other non-metallic mineral segments.

The above-mentioned figures, however, are those declared by miners in Annual Mining Reports submitted to the DNPM, and do not include those employed in the informal mining economy; for example, in most Brazilian states, the majority of those employed within the sand, gravel, building stone and clay (for bricks and small ceramic industries) industries operate informally. The ANEPAC estimates, the number of workers — in both the informal and formal segments — employed at resident sand mines to be 45 000 and crushed stone mines, 15 000, markedly different figures to DNPM’s calculations of 7738 and 14 911 [3]. In some areas, stone is still crushed by hand, and quite commonly, entire families are seen breaking rock with hammers without any mechanical assistance. The informal nature of these operations enables miners to avoid having to declare production totals and earnings to the DNPM, and thus freeing them from having to pay taxes.

The majority of Brazilian mines are classified as ‘small’. According to the Mineral Summary, some 73% of all operating mines are considered ‘small-scale’ (<100 000t/year); ‘22.2%’, medium-scale (<1 000 000t); and 4.8%, large scale. To provide an indication of the importance of the Brazilian non-metallic small-scale mining sector, in the case of sand mines, 60% produce <6000 m³/month, 35% between 6000 and 15 000 m³/month, and only 5% produce <15 000 m³/month. For miners of crushed stone, 60% produce <200 000t/month, 30% between 200 000 and 500 000t, and 10% <500 000t.

Fig. 1 shows the locations of important non-metallic small-scale mining regions in Brazil.

3. Environmental impacts of mining in Brazil: a historical perspective

In 1603, the first Regulation of the Mineral Lands of Brazil provided for the protection of water streams against pollution from mining [4], its rules being repeated and enlarged in later codes. However, it took until the 1980s for environmental protection to commence. The evolution of mining technology and mining environmental management in Brazil is best understood using the following superimposed models [5]:
1. small mines featuring inadequate technology;
2. large mines featuring inadequate technology;
3. mines featuring adequate extraction technology, but without environmental control; and
4. mines featuring environmental control.

Before examining these models — each of which is associated with particular time periods — it is important to clarify that environmental protection in the mining industry has generally been non-existent in Brazil, and for the most part, continues to be a largely ignored issue.

3.1. Model No. 1: small mines featuring inadequate technology

This group of operations is engaged in the mining of easily extractable minerals using primitive techniques and minimal capital. They first appeared during early colonization periods, when it was possible to easily locate and extract precious minerals — mainly gold — from sedimentary deposits. Other examples of such operations are those engaged in the extraction of building materials, sand, gravel, clay, and lime on a small-scale, again using mainly manual methods. Such operations are still found scattered throughout the country.

This type of mining dominated 16th century Brazil, and prevailed throughout the 17th and 18th centuries up until the discovery of the great gold and diamond deposits in Minas Gerais and Mato Grosso. These types of operations do, however, periodically reappear in reactivated claim areas, where faiscadores or requeiros

1 Faiscadores are micro-miners who work with manual tools; they become requeiros when they process the wastes left by previous miners.

scratched out their survival by working alluvium and tailing deposits in a similar fashion to those that worked the old garimpo areas such as Diamantina or Poconé, and newer regions like Serra Pelada. Independent micro miners are often found to be working in the same areas as companies or better-equipped garimpeiros [6]. Miners engaged in the extraction of gold and cassiterite still operate in the most distant reaches of the Amazon, while miners extracting building materials are found in close proximity to many cities and towns.

Almost all mineral extraction for direct use in civil construction also occurs on a small scale using inadequate mining technology. Sand is still manually extracted and transported by canoe or mule train, and the manual crushing of rocks is still widespread, with outputs supplying large cities such as Manaus. Even where there is some degree of mechanization, there is minimal mineral evaluation and environmental control. In fact, environmental impacts are conspicuous around all the inhabited points of the country, although in some states, there is some effort made by government agencies and mining associations to improve existing environmental conditions.

From a legal viewpoint, these small mines almost never have mining titles or environmental licenses, unless they work near large cities in states where environmental control is effective. However, because of their small capacity, the combined environmental impact of these mines is limited, and in most cases, natural recovery is sufficient to heal the damages of their operations.

3.2. Model No. 2: large mines featuring inadequate technology

When larger mineral deposits were discovered, settlers established the necessary accompanying production infrastructure. The design of the initial pre-19th century large-scale mining operations was based largely upon the availability of Native and African slave workers; the design of subsequent operations was based largely upon a paid labor structure and machines. These operations, because of their scale and use of inadequate technology, cause a wide range of environmental impacts.

A more recent example of this type of mining (1980s) was the Serra Pelada garimpo operation. The mine employed tens of thousands of workers, operating in a similar fashion to the slaves that worked deposits centuries earlier, the most significant similarity being a complete disregard for overall working conditions. Even the old excavations made by groups of thousands of work-

2 The word ‘garimpeiro’ comes from the habit of clandestine diamond miners working in the ‘grimpas’ (tops) of hills to escape the repression of the colonial government, which allowed mining only under strict conditions.
ers, such as those made at the Ouro Preto and Diamantina sites, still scar the landscape and have been responsible for substantial siltation and erosion over the years.

Modern garimpo activities have had tremendous adverse environmental impacts. To reiterate, and as indicated in Law No. 7805 of 18 July 1989, the terms ‘garimpo’ and ‘garimpegam’ are classifications for mines and mining activity carried out without previous evaluation of ore. This Law, however, granted permission for ‘lavra garimpeira’ (mining by garimpegam) to mine any mineral commodity, provided that it had been determined by the DNPM to be minable without previous exploratory work to establish the shape, size and composition. Mineral extraction in these terms has contributed to the destruction of many deposits.

Companies duly legalized by the DNPM and environmental control agencies readily ignore their already inadequate projects, and ambitiously attack the richer parts of a deposit without any mining technology, consequently destroying the environment and leaving behind a deposit unfit for future use. These environmental problems are left for society to remediate. This type of mining activity still occurs in Brazil, especially in the case of many non-metallic minerals, such as sand, clay and limestone.

3.3. Model No. 3: mines featuring appropriate extraction technology, but without environmental control

In mines of this type, geologic and mining engineering techniques are applied to prospecting, evaluation, extraction and processing, but with minimal consideration for the environment. Moreover, degraded areas that supported this mining activity are rarely reclaimed.

Mining technology has only been introduced — albeit selectively — in recent decades in Brazil. Since the Regulation of 1608, the hiring of expert miners has been regulated, although most technical positions have been filled by highly uneducated people [7]. Only early in the 19th century did Brazilian and foreign employees begin to exercise scientific and technical knowledge. Geological and mining education began locally in 1876 with the establishment of the Escola de Minas de Ouro Preto (School of Mines), and it was only recently in 1959 that formal undergraduate programs were established in various geological fields. Up until this time, little was known about the geology of the country, notwithstanding the efforts of the National and State geologic services.

The most effective mining, geological and technological systems have been adopted by the state-owned companies. Research and the application of mining technology have also been stimulated by the Brazilian Institute of Mining (IBRAM) — which represents privately-owned companies — and the Center for Mineral Technology (CETEM). Although mostly dedicated to large mines and metallic minerals, some efforts have been made to support non-metallic mining.

In summary, up until the end of the 1970s, the Brazilian mining industry was focused on increasing production and improving equipment, but with minimal environmental concern. In many operations today, both large- and small-scale, this attitude of contempt still prevails. Environmental laws and regulations are not enforced, or, in the worst-case scenario, are enforced in the cavalier ‘Brazilian’ fashion: forms are completed, and plans are formulated containing the bare minimum requirements for a license to operate, again, with minimal emphasis on environmental concerns.

3.4. Model No. 4: mines featuring environmental control

Beginning in the 1970s, concern for environmental degradation began to spread throughout Brazil, fueled largely by the ecological movements in developed countries, the visible consequences of disorderly economic growth, and the swelling of many of the great cities. However, the DNPM only began encouraging environmental protection in the 1980s, influenced by other sectors of industry and Brazilian society as a whole. Its performance, however, has been highly irregular and insufficient.

Some of the historical landmarks made legislatively to protect the environment in Brazil — particularly with reference to mining — include the following:

- Pioneer state laws, such as No. 997 of São Paulo (31/5/76), which established pollution control and various environmental protection measures at the state level.
- Federal Law No. 6938 (31/8/81), altered by Laws 7804 (18/7/89) and 8028 (12/4/90), which defines the National Policy for the Environment.
- Federal Law No. 7347 (24/7/85), which regulates Public Civil Actions.
- Resolution no. 01 of the National Council for the Environment — CONAMA (23/1/86) — which requires a previous Environmental Impact Study to be undertaken as a condition for constructing a potentially polluting enterprise.
- Resolutions Nos 9 and 10 (6/12/90) of the CONAMA, which regulate the environmental licensing of mining activities.
- Regulatory Norms for Mining (reg. 237, DNPM, 18/10/2001), which regulate environmental and working conditions for mining.

Another point of significance is the fact that Brazil is one of the only countries that has made it a legal requirement in its constitution to reclaim areas degraded by
mining [8]. Article 225 states that “Everybody is entitled to an ecologically balanced environment”, and specifies the following:

- First paragraph: “To assure the effectiveness of this right, it assigns to the Public Power”
- Item IV: to demand, in the form of the law, a previous study of environmental impact for installation of work or activity potentially provoking of significant degradation of the environment… and
- Item V: to control the production, commercialization and employment of techniques, methods and substances that present risks to life, the quality of life and the environment; and
- Second Paragraph: “That whoever exploits mineral resources is required to reclaim the degraded environment, in agreement with a technical solution requested by the competent public agency…”.

Brazilian legislation, if properly applied, offers adequate protection for the environment. This, however, has not been the case, although some important strides have been made since the 1970s to improve environmental control in the mining sector. Major companies have established environmental services, and have begun promoting partial control of impacts and the reclamation of more visibly degraded mined lands. This has also been practiced at quarries and sand pits in the larger metropolitan areas, largely because of the promotional activities of mining company associations. Table 1 details some of the responsibilities of governmental departments and activities of organizations with regard to mining and environment in Brazil.

For some time, the DNPM and IBRAM have sponsored research and courses on mining environmental technology, with the aims of convincing mine owners and managers of the importance of environmental protection in mineral extraction activities. States have established structures for environmental control, enforcing legislation, but with varied results. In the more developed of Brazilian states, serious work has been undertaken, whereas in other states, environmental control has yet to be taken seriously; in such cases, state environmental agencies are controlled by garimpo owners, and there is a lack of funds available for mining environmental management.

The dismantling of public services, which began in 1991, has strongly affected the patrimonial control of mining (DNPM) and its environmental agencies. Experienced teams, with professionals trained at high costs, were dispersed. Moreover, at this time, the activities conducted by federal and state organizations to promote the organization of small-scale miners into cooperatives, as well as industrialization of the sector, were largely discontinued.

4. Technological and environmental aspects of the Brazilian non-metallic small-scale mining industry

The environmental management of mining is not a priority at any level of the Brazilian government; this applies to both the large and small-scale mining sectors. The main consequences of this disregard are as follows:

1. A visible division of mining into two segments. The first group of operations is that of an organized mining segment. The miners pay taxes; build infrastructure used for developing the area in which they work; pay wages; provide reasonably safe working conditions and assistance to workers; and are progressively adopting environmental control measures, and reclaim degraded areas. The second group, informal mining operations, is characterized by pitiful working conditions, and operators exploit workers, destroy mineral reserves, cause widespread environmental degradation and, in the case of precious metals, participate in criminal activities. The small-scale mines of non-metallic minerals tend to be more organized than the typical garimpos of precious metals, and better integrated within local economies.

2. The persistence of rudimentary technological models of mining. This has led to predatory extraction and environmental degradation, even in those mines operated by organized and properly legalized companies.

3. Wide-ranging environmental impacts that have affected the entire country. Although operations degrade smaller areas than agriculture and construction operations, mining in Brazil caused the following environmental impacts [5,9–11]:

- deforestation, which has contributed to reduced plant and animal biodiversity and loss of fertile soil;
- mining scars, sometimes of great extent and depth, which have been particularly problematic in urban areas;
- pollution of surface waters by sediments, or toxic effluents, mainly mercury used for gold recovery;
- tailings of all ores, which continue to pollute waters, soils and air;
- alteration of the flow and deteriorated quality of groundwater;
- destruction of dunes for construction sand in the Northeast, and industrial sand in the Southeast;
- air pollution by dust or gases from processing plants; and
- a wide range of social impacts.

To reiterate, the environmental problems caused by the extraction and processing of non-metallic minerals in Brazil, though less intense, have been more widespread than those in the metallic and energy mining sectors.

The mining activities engaged in the extraction of
Table 1
Responsibilities of Brazilian governmental departments and resident civil society organizations with regard to mining

<table>
<thead>
<tr>
<th>Governmental Department or Civil Society Organization</th>
<th>Responsibilities and actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal — Ministry of the Environment Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA)</td>
<td>Execution of the environmental policy. Regulation and enforcement. Support to environmental research and activities.</td>
</tr>
<tr>
<td>State Department of the Environment State Council of the Environment (CONSEMA)</td>
<td>Equivalent to CONAMA at the State level, with different performances according to the organization of the society.</td>
</tr>
<tr>
<td>State Department of the Environment — executive agencies</td>
<td>Equivalent to IBAMA at the State level. Different organizations and performances.</td>
</tr>
<tr>
<td>Municipal governments</td>
<td>Patrimonial control of minerals for direct use in construction. Local environmental protection. Land use planning and regulation.</td>
</tr>
<tr>
<td>Federal and State Attorney Offices</td>
<td>Law enforcement, in some cases in specialized environmental offices. Support to groups of the civil society to apply the Laws of the Public Civil Action and of Environmental Crime.</td>
</tr>
<tr>
<td>Brazilian Institute of Mining (IBRAM), National Association of Producers of Aggregates for Construction (ANEPAC) and equivalent State and Municipal mining associations</td>
<td>Organization of mining companies and individual miners for legislative lobbying. Promotion of technological and environmental education and execution of demonstration projects.</td>
</tr>
<tr>
<td>Environmental Non-Governmental Organizations</td>
<td>Environmental policy. Promotion of environmental education, protection and research.</td>
</tr>
</tbody>
</table>

minerals used for building and construction purposes have been responsible for more extensive environmental impacts. Although individually, these operations are almost always small, pits and quarries are commonly left abandoned, particularly in regions where environmental control is deficient. In addition to the obvious visual impacts, these unreclaimed, excavated areas have contributed to the siltation of watercourses. Explosives are commonly used at quarries, thus generating high levels of noise and vibration and, in some cases, causing the release of rock fragments outside of mining areas. Mining in rivers cuts banks, thus altering the shape of riverbeds.

Sand and crushed stone have low value but high production volume. A high proportion of the final cost is for freight. This in turn forces operators to base mine sites inside or very close to urban areas, which more often than not reduces the availability of potentially productive land available to the urban and suburban dwellers. An additional problem is the fact that poorly mined areas have become inappropriate for other land uses, although quarries are commonly enveloped by urbanization and later expelled by the surrounding population.

In Brazil, mining is rarely incorporated into Municipal Master Plans, and there are no areas reserved for its development, even in areas with high resource potential and those already occupied with mines in full operation. Macedo [11] measured the progress of urbanization in the Metropolitan Area of São Paulo in areas mined for sand. Even though municipal and metropolitan planning agencies, which participated in the project, had full knowledge of these sand mining operations, urbanization nevertheless continued without any measure prevent enveloping of mining activities. Among the areas identified (in 1985) as adequate for sand mining, many were made unfeasible for mining in later years by urban subdivisions, the construction of which could have commenced after the exhaustion of deposits [12].

Degradation caused by mining can be a serious problem in urban areas, where each degraded square meter is precious for residential or industrial use or for urban infrastructure. The obligation to reclaim degraded areas
is recent and still not fully enforced. The absence of a performance bond, a pecuniary warranty for the execution of a reclamation plan, allows the miner to escape the obligations by abandoning the area.

Environmental and mining legislation in Brazil has proven highly ineffective in preventing widespread environmental complications in the sector. First and foremost, it is highly complicated, featuring overlapping laws, ordinances, resolutions, orders and instructions. Furthermore, as can be discerned from the discussion thus far, some fundamental legislative initiatives have yet to be implemented, including:

- The regulation of the common competence of all levels of government for the protection of the environment and for registration and enforcement of the concessions of mining activities.
- The establishment of real warranties, such as performance bonds, which are the only efficient means for guaranteeing the execution of reclamation projects.
- Mandatory inclusion of mining in Municipal Master Plans.
- Regulation of mining in native reserves, where, at present activities are both prohibited as legalized activity and tolerated as garimpo.

Another noteworthy point is the fact that laws are poorly enforced. The National Department of Mineral Production remains without material and human resources, and without political support to perform its duties with minimal efficiency. Efforts to computerize should be continued, as past efforts have enabled access to mining laws and statistics through Internet media (address http://www.dnpm.gov.br). Continued regulation of the mineral patrimony and environmental and working conditions of mining, also a duty of the DNPM, has also been ineffective.

In most cases, the municipal governments of Brazil, which have the duty to manage the mineral patrimony in relation to construction materials, as well as to regulate land use and protect the environment, are improperly equipped and rarely prioritize mining activities. Only certain state capitals and large cities regulate mines and quarries; moreover, few municipal governments view the industry’s operations to be legitimate users of land. Municipal actions are only taken to prohibit mining in cases where land use conflicts reach an impasse. Prohibitions are lifted only when it becomes more costly to buy construction materials in another city than to control local operations. Even so, these conflicts rarely lead to comprehensive legislation, but rather are resolved case by case, according to political and economic pressures. Smaller mines suffer more from this absence of warranties, because their operators have less money and political influence than those of larger activities.

Therefore, a contradictory situation exists in Brazil. On the one hand, it has proven feasible to mine illegally throughout the country — more specifically, without due concession and an environmental license. On the other hand, to operate in accordance with regulations is extremely difficult [16]. In order to mine ‘legally’ in Brazil, an operator must obtain licenses from federal, state and municipal entities, the applications for which can take years to be analyzed. Even when a concession is granted, a federal agency does not guarantee an operator his safety, thus leaving the area highly susceptible to invading garimpeiros. Operators can also fall victim to fines or closure claims, incurring costs and difficulties for his defense, even in situations when he operates according to the law. Unlawful competitors are not burdened with most, if not all of the aforementioned challenges.

5. Examples of mining environmental management in Brazil

As mining is an important industrial activity in Brazil, it is important that it begins to operate more efficiently, so it can best meet the needs of a large and growing population, and increase export revenues. In doing so, it is equally crucial that mining environmental issues receive increased attention. Some important strides have already been made in Brazil to improve environmental protection in the mining industry. One major accomplishment has been the work of The Ministry of the Environment, which has developed a work program for the application of the Agenda 21 principles to mining in Brazil, the results of which are presented in the ‘Environmental Guidelines for the Mineral Sector’ [9]. These guidelines seem highly effective and applicable, since support is provided to the technicians and companies that abide by them. The guidelines are as follows [13]:

1. Maintenance of agile, integrated and efficient legal, normative and institutional mechanisms for licensing, monitoring, and environmental fiscalization in the Mineral Sector.
2. Internalization of modern concepts of Environmental Administration and of environmentally compatible technologies in the processes of extraction, processing and use of mineral resources.
3. Maintenance of the knowledge base, formation and conscientization of human resources that make possible environmental planning and administration in the mineral sector.

Although these guidelines appear well thought out, the following should be noted:

- Their execution will demand coordination between
several levels of government and the private sector itself. This need for coordination is confirmed by the total absence of references to mining in the most recent document produced by the Ministry of the Environment concerning Agenda 21.

- Sources of financing have not been declared for their implementation.
- It reveals a disposition to deregulate the extraction of sand, which would be disastrous for urban areas in close proximity to sand mines.
- During the process of elaborating the guidelines, the academic community was not consulted.

Rational working of mineral deposits, increased evaluation of ore bodies, and efficient environmental control the reclamation of the disturbed areas all lead to environmental improvements.

Small-scale miners have suffered more from environmental regulations because they simply lack the technological and managerial means to improve environmentally. They have communicated this difficulty to both local and state governments, and have requested that they meet, amongst other things, the following demands [14, 15]:

- a better understanding among the agencies that support mining activities;
- to provide more detailed geological information;
- improved access to public funds during phases of geological risk;
- provision of capital with subsidized interest rates;
- revisions to the Brazilian mining taxation scheme;
- acceptance of the mineral deposit as collateral security for financing;
- increased access to the official laboratories and research centers to obtain technological support during exploration, extraction and processing;
- that the Government finances infrastructure development — roads, communications and water supply;
- that the Government constructs schools for training in human resources.

Associations of producers have carried out a number of promising education- and remediation-related initiatives, each of which has important environmental implications. Primary examples include [2]:

- improved environmental control and reclamation along the margins of the Jacuí and Ribeira rivers, where sand mining is widespread;
- the establishment of parks in areas with closed quarries (e.g. Vila Velha and Curitiba);
- establishment of quarries in the degraded areas of Juiz de Fora and Biguacu; and
- establishment of centers to support the reclamation of degraded mined areas (e.g. Paraiba River Valley).

In each of these cases, there is combined participation from mining companies, the state, national associations and public agencies.

These efforts, however, have had limited impact, and there are a number of opportunities for further improving the industry’s environmental performance. The next section of the paper prescribes a series of recommendations for further improving the environmental conditions of the Brazilian non-metallic small-scale mining industry.

6. Recommendations and conclusions

To further improve the environmental performance of the Brazilian non-metallic mining industry, a number of initiatives must be undertaken, most of which will help to improve conditions in the Brazilian mining industry as a whole. A fundamental first step is to improve coordination among public entities responsible for the control of the mining sector. This is the key to establishing an effective, integrated licensing procedure for mining projects; developing compatible criteria and norms to evaluate the environmental aspects of mining activities; avoiding an overlapping of actions and responsibilities at the institutional level; and promoting more effective environmental control at mining sites. Once institutional parties are working toward a common goal — improved environmental protection in the mining industry — pertinent legislation must be rationalized and more effectively enforced. As already indicated, Brazilian mineral law is highly complex overall, and the difficulty with meeting existing legislative requirements is sufficient incentive for operating illegally. This is particularly significant for resident non-metallic small-scale miners, who are not only perceived as being unimportant, but also tend to lack the requisite funds to comply with existing legislation and meet registration demands. It is therefore imperative that these and other resource-strapped mine operators are informed of key environmental issues, and that pertinent legislation is unraveled and made more efficient and appealing.

Increased reclamation is important in this segment of industry because, as already explained, there is a significant number of operations scattered throughout Brazil, and few operators effectively reclaim or re-grade pit-ted regions. Specific legal mechanisms must therefore be created to help assure that effective rehabilitation of mine-degraded areas is carried out. These new mechanisms should replace the existing methods, which are merely administrative without enforcement characteristics. Real warranties to cover the cost of reclamation of disturbed areas should be established as part of mine licensing documents. The value foreseen for such costs should be part of a performance bond, with the resources immobilized used as warranty and returned to the miner after each phase of reclamation is completed; the remain-
Table 2
Strategies for facilitating environmental improvements in the Brazilian small-scale non-metallic mining sector

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Role, impact or potential contribution</th>
<th>Organization responsible for implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To improve coordination among public entities responsible for the control of the mining sector</td>
<td>To avoid duplication of effort and prevent incoherent actions. To develop compatible norms</td>
<td>Legislative bodies, ministries and state departments</td>
</tr>
<tr>
<td>To establish real warranties for environmental management and reclamation</td>
<td>To assure minimal impacts and the reclamation of disturbed mined areas</td>
<td>Legislative bodies, at federal, state and municipal levels</td>
</tr>
<tr>
<td>Research and diffusion of mining and environmental technology</td>
<td>To develop efficient procedures for environmental control and reclamation for small-scale operations</td>
<td>Universities, research centers, mining associations, councils and committees</td>
</tr>
<tr>
<td>To develop licensing procedures for small-scale mines</td>
<td>To reduce informality in the small-scale sector</td>
<td>Legislative bodies, ministries, state departments, mining associations</td>
</tr>
<tr>
<td>Review of environmental impact evaluation and enforcement procedures</td>
<td>To assure that environmental documents contain reliable field data, and that the plans propose feasible activities, whose execution should be enforced</td>
<td>Legislative bodies, governmental departments, federal and state environmental departments</td>
</tr>
<tr>
<td>To improve regional land use planning</td>
<td>To assure mining activities in areas with high mineral potential</td>
<td>State and municipal planning departments, mining associations</td>
</tr>
<tr>
<td>Adequate financing and technical assistance to support the implementation of new environmental technologies</td>
<td>To encourage the adoption of environmental management measures and technologies at small-scale mines</td>
<td>Legislative bodies, governmental departments, universities and research centers</td>
</tr>
<tr>
<td>Political action</td>
<td>To spread environmental information to the Government, the mining community and the general voting public</td>
<td>Mining and professional associations, universities and technical schools</td>
</tr>
</tbody>
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small-scale mining research must also increase. It is recommended that in the Brazilian case, there should be increased participation from commissions representing government agencies, academic and technical institutions, mining companies and organizations, and environmental and political organizations. It would also be worthwhile tapping into the experience of former groups such as the Council for Geology and Mining in the State of São Paulo, and the expertise of existing organizations such as the Watershed Committees and the Foundation for Support of Research of the State of São Paulo.

The aforementioned initiatives deal very much with the organizational aspects of environmental protection. More specifically, these changes, if made, would help to establish a sound regulatory framework that would enable individual initiatives, which target the more specific aspects of environmental management, to be more effectively carried out. Once these and related changes have been made, the environmental regulations and procedures for small-scale mining can be reviewed.

A pressing need is to develop individual licensing procedures for small-scale mines. Environmental and administrative requirements for licensing should be simplified, taking into account the particularities of some mining enterprises (low technical capacity, small production, etc.). This would help to reduce the occurrence of informal mining in Brazil.

A second important initiative is the reviewing of the enforcement of environmental impact studies (EIS) in the sector, which simply requires a thorough review of existing environmental impact evaluation procedures. There is also a need for enforcement and orientation activities to assure that environmental documents (e.g. EIS and environmental control plans) contain reliable field data that can be used for regional-scale studies, and that the plans propose feasible activities.

There is also a need for improved regional planning, as can be discerned from the earlier discussion. At present, the non-metallic small-scale mining industry is not heavily prioritized, and there is an obvious need to improve regional planning to accommodate such mining activities. The use of Master Plans for land use (zoning) of the municipal territory would be highly practical, which would help to guarantee that the mining sector competes fairly with municipalities and other industries for land, and to ensure cohabitation between parties. The efforts made in the state of São Paulo should be drawn from. Here, specific zones have been allocated for mining activities. Moreover, the State has in place a Master Plan of Mining for the Metropolitan Area of São Paulo (1978), which was developed by EMPLASA (a metro-
recycling of minerals, particularly those operating informally. In addition, the implementation of new environmental technologies. Subsidies should be provided to micro-miners, particularly those operating informally. In addition, the recycling of minerals — particularly building materials — should be encouraged, as it is a means for reducing the impact of mineral extraction and global consumption of non-renewable resources.

Resident universities and research centers can work with miners to implement technologies and further promote improved environmental practices. These organizations can also work to help educate operators, particularly those of the small-scale mining sector, about key environmental issues in the industry, and the importance of natural resources conservation and protection. Table 2 provides an overview of the proposed initiatives for further improving the environmental performance of the Brazilian non-metallic small-scale mining industry.

In order to be effectively carried out, each of the above-mentioned initiatives requires political motivation. As this, in all likelihoods, will not happen spontaneously, conscious professionals must lobby to communicate environmental information to the Brazilian Government and the general public. Although this paper has largely documented the environmental impacts of the non-metallic small-scale mining sector, with the appropriate political will, many of the recommendations made could serve to improve the environmental performance of the industry as a whole.

References