Environmental Aspects and Impacts of a Diabase Quarry in an Urban Area

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Abstract

The concept of environmental performance has been used as a way of revealing the relationships of a company with its environment and community, and is a parameter of its posture in addressing social and environmental questions. Evaluation of the environmental impacts generated by a certain activity is one instrument of environmental management. We present a case study of a diabase quarry located in an expanding urban area in the Municipality of Campinas, State of São Paulo, Brazil. Several aspects and impacts of the different stages of production in the quarry, as well as its administrative facilities, were evaluated. The most significant adverse impacts were related to the extraction of ore of which affected the soil, water, and air, and disturbed the neighborhood. Among the ameliorative actions that could be initiated by the company are improvement of community relations and pro-active attitudes, mostly related to prevention of negative impacts, environmental preservation, and reclamation of the quarry site, as a reactive posture.

Introduction

Knowledge and divulging of the environmental aspects of a commercial business meets the expectations of an improvement in environmental performance (ISO 14.031, 1999; DE JORGE, 2001; ABNT, 2004b). With prior knowledge of the problems associated with the establishment and operation of the business, through instruments for environmental impact and planning, one can adopt measures to lessen or avoid these impacts, thus reducing environmental damage and consequently the costs involved in their remediation or correction.

To identify and assess the environmental aspects and impacts associated with a particular business, one must initially seek to identify all of the activities, products, and services related to the producing activity, so as to isolate as many as possible of its environmental impacts, be they real or potential, beneficial or adverse, resulting from each aspect identified, always considering whether or not they are significant (SÁNCHEZ, 1989, 2001).

According to De Jorge (2001), the complete process of evaluating environmental performance, if carried out continuously, systematically, and periodically, allows businesses to evaluate whether their objectives are being reached. This process also provides a mechanism to investigate and present reliable and verifiable information, including financial information, which can be reported to interested parties, for example, activists, stakeholders, financial, regulatory, and environmental organizations.

The present study identifies these aspects and evaluates the environmental impacts generated by a diabase quarry which is used as an aggregate material in construction. The quarry is located in an urban area in the Municipality of Campinas, State of São Paulo. Crushed stone is used for a variety of purposes, including concrete aggregate, road sub-base and black-top (road surface).

Environmental Impacts of Diabase Exploitation

According to Worsey (2004), with increasing prosperity has come the encroachment of development on mining operations. Some may say that encroachment is inevitable if careful planning is not done. The reasons for encroachment may be quite varied, depending on the type of mining carried out and the geographic location. The majority of these quarries are located in the vicinity of major population concentrations, i.e., their market. Because of the low cost of the product versus high transportation costs, the quarries are often initially sited on the edge of cities, to gain a competitive edge.

The geological factors linked to the natural location of the deposit and to the large volume of the reserves, althoug they may provide a long and useful life to the businesses, are rigid and immutable factors that make it impossible to relocate the extraction sites.

Inevitably the cities prosper and grow outwards towards the quarries, in many cases eventually surrounding them. The standard of living is always rising, which equates to the construction of larger, newer houses and the migration of people away from town centers to new suburbs. On one hand this in advantageous for existing quarries, because new markets are opened up on their door- steps, and haulage distances are far less than for new operations which are now much farther from the population centers. This makes existing quarries more competitive. On the other hand, their proximity to residential areas produces problems with complaints about blasting (WORSEY, op cit.).

The consumption of aggregates is an important indicator of the economic and social situation of a country. Whereas the U.S.A. annually consumes about 7.5 t, and Western Europe from 5 to 8 t of aggregates per capita, in Brazil consumption is slightly above 2 t. Even within Brazil, the levels of consumption of aggregates differ considerably. Consumption in the State of São Paulo reaches 4.5 t/person/year, whereas in Fortaleza and Salvador it is less than 2 t/person/year. This shows that consumption of crushed stone has a clear relationship to per-capita income (VALVERDE, 2001).

Generally, the environmental effects of mining are associated with the different phases of exploitation: mine opening (vegetation removal, excavations, earth-moving, and modification of the local landscape); blasting (air blast, ground vibration, flyrock, fumes, dust, noise); transport and rock crushing (dust and noise). All these affect the water, the soil, and the air, as well as the neighborhood.

Study Area

The study area included the diabase quarry and a 1-km radius around it, in the northeast of the Municipality of Campinas, São Paulo (Figure 1), within the urban expansion grid. A community has grow up east and northeast of the quarry. The nearest commercial construction is located 250 m northeast of the pit, and the nearest houses of the Vila Boa Vista residential community are about 800 m from the pit.

Identification of the Environmental Aspects and Impacts

The activity of the diabase quarry consists of stripping, blasting, loading, and transporting the rock and then processing it, to produce crushed stone and rock dust.

In identifying the environmental aspects and impacts generated by the industry, we considered the production of the ore (extraction, transport, and crushing) the administrative facility, the maintenance plant and, the dining hall.

In accordance with Braga et al. (1996), the environmental aspects considered in this study were erosion; silting; surface- and groundwater contamination; flora and fauna impacts; instability of the slopes and landslide; earth movement; air, noise, and visual pollution; flyrock; ground vibration and air blast.

Tables 1, 2, 3 and 4 show the aspects and impacts identified in the different activities of the quarry. Among the different impacts identified, the most obvious are associated with the blasting (air blast, ground vibration and noise), because these cause discomfort for the quarry neighborhood.

The main sources of air blast in blasting are, according to Worsey (2004): first displacement of the ground, a direct result of physical movement of the rock, causing air displacement similar to a subwoofer speaker in an audio system; second, premature release of gas pressure from the blasthole, as a result of inadequade confineament, when gases escape with ejection of the plug, and through the fractures of the rock mass; and third, from the detonation of unconfined explosives such as surface detonating cords.

The displacement of the ground generally results in low-frequency noise, which is difficult to hear but rattles dwellings, whereas the high-velocity release of explosion gases, usually at supersonic velocities, causes intense noise in the audible range, often startling neighbors. Because the pressure waves in the air cause residential structures to flex and the air to move within them, they are often confused with the effect of ground vibrations by the occupants. In fact, in many cases complaints of excessive blasting vibrations can be attributed to air blast rather than ground vibrations (WORSEY, 2004).

The effects of sound waves in the study area are reflected in the civil structures through vibration of the walls, windows, and objects inside the residences. The residents' perception is expressed much more in their startlement at the moment of detonation, than through interference with their daily activities. Some residents interviewed were unable to express their feelings precisely, but all of them were apprehensive of the blasts.

In Brazil the generally accepted limit for air blast is 134 dB using modern equipment, according to NBR 9653 (ABNT, 2004a).

Air blast rarely damages structures, yet is very startling and can be the cause of much anxiety for residents. The first type of structural damage to occur is the breaking of windows, which starts at about 143 dB for large or poorly seated glass of low quality. The 134 dB limit was chosen by ABNT because higher levels, although non-damaging would be intolerable.

The number-one cause of excessive air blast levels is the premature venting of explosion gases, which represents the loss/waste of energy in a blast. Unusually high air blast levels are virtually always linked to inefficiencies in blasting, which are realized as higher mining operating costs. The four causes of premature venting are, according to Worsey (2004): weak seams, through the blast hole collar due to inadequate and inappropriate stemming material, overburdening of blast holes and poor delay timing. Unnecessarily annoying neighbors with excessive air blast costs the mining operator more for every ton that is mined, and this is a key fact that is not understood by many mining operators.

Ground vibrations are an inevitable byproduct of any blasting. These vibrations are the result of energy lost from the blast which is distributed in the form of vibration waves through the ground away from a blast. Ground vibrations are caused by the detonation of the explosives, the breaking of the rock and displacement of the rock (for example rock falling onto the bench from a highwall). The latter two causes are difficult to control because they are usually the effects that we want in the majority of mining operations. The efficient use of energy liberated from the detonation of explosives is, however, something that we can largely control.

Ideally, all the blast energy should be used in rock fragmentation, and none wasted by loss into the surrounding ground to annoy neighbors.

Fragmentation is composed of both fracturing and the disassociation of rock fragments, and their movement away from the standing face into a muckpile out on the bench or pit floor.

According to Worsey (2004), factors which result in poorer fragmentation, increased mining costs and increased blasting vibrations are: low powder factor, improper delay between holes, improper delay between rows, the improper functioning of explosives within a hole, and, again inadequate stemming.

In the diabase quarry studied, the ground vibrations are caused by blasting to break up and move the rock and by improper delay between holes, causing overlapping of waves and increasing ground vibrations.

The effects of the ground vibrations on the civil constructions appear as cracks and fissures in the walls, and as ground tremors. The residents feel the vibration of the floor and walls, and confuse the effects of the ground vibration with those of the air blast .

The noise from blasting can be heard in the residential neighborhood. Although blasting takes place only once or twice a week, it is one of the impacts causing discomfort, because it frightens people during their daily activities. The continuous noise from rock crushing also has some effect, although it is local.

The nearby houses sustained no structural damage during the period of seismic monitoring. However, all the residents interviewed complained of discomfort at the moment of blasting.

Air pollution is caused as much from the blasting, which generates fumes, gases, and dust, as from the transport and rock crushing. Fumes are an unavoidable fact of blasting. The majority of fumes come from improper combustion of the explosives for a variety of reasons including poor loading conditions, ground-water, improper priming, improper selection of explosives and explosives that are incorrectly formulated or have deteriorated. The amount of fumes generated under ideal conditions depends on the oxygen balance of the formulation.

No matter how the explosive is formulated, there will always be some fume generation (WORSEY, 2004).

Although the impact of air pollution was not quantified, it is local and limited to the immediate area of the quarry. The impacts from the administrative and workshop installations are also local.

Blasting can be a substantial source of liberation of dust for short time periods. Dust can also be generated by loading and transporting the rock, and in the crushing operation.

Excessive flyrock can be devastating to a mining operation. Being hit by rock from a blast when it is intentionally initiated is the leading cause of blasting fatalities (D'ANDREA et al.; in WORSEY, 2004). Not only government mine safety authorities assesses financial penalties, but also expensive and time-consuming lawsuits generally ensue, and the mining operations may be temporarily or permanently halted. In addition, flyrock can cause extensive and expensive damage to equipment and plant, and stoppages in production. Rock thrown an excessive distance from a blast is a hazard to equipment tires and can necessitate unnecessary extensive and time-consuming clearing up. The three major causes of flyrock are insufficient burden, insufficient stemming, and weak layers or seams. Other contributing factors include poor blast design and insufficient delays between rows (WORSEY, 2004).

Flyrock was not observed during the monitoring period. Because of the blasting routine used, this type of impact is unlikely to occur in the blast area.

Discussion and Conclusions

The different environmental aspects and impacts of the diabase quarry were assessed. These can form a basis for future evaluation of the environmental-practices of the company.

The most significant adverse impacts are related to the blasting. These impacts can extend to areas beyond the control of the quarry, and affect mainly the residential neighborhood of Vila Boa Vista, about 800 m distant from the quarry faces, northeast of the pit.

The company has not yet developed an environmental management system or a performance evaluation system. Nevertheless, certain measures were taken to evaluate the impacts, by monitoring the ground vibrations and air blast. The different quarry faces were monitored for one year, during which 28 blastings were recorded and 146 measurements were done (BACCI, 2000).

The results of monitoring showed that ground vibration measured at the residences did not exceed 2 mm/s, at frequencies of 50 Hz or above. The air blast reached about 100 dB, a level which causes the local population great discomfort (BACCI and LANDIM, 2001). These results were below the levels established under Brazilian regulations for this type of activity, by NBR 9653 (ABNT, 2004a) as well as state standards D7.013 (CETESB,1992), and also under international regulations (BACCI et al., 2003a, 2003b). Blast vibrations do not offer risk of damage to the local civil structures, although they cause discomfort to the community. It was established that a large part of the complaints recorded was related to the residents' lack of knowledge of the actions and measures taken by the company to minimize the impacts.

Proactive items which are extremely effective include blast monitoring, keeping good blast records, active programs to decrease ground vibrations and air blast, public relations, the use of blasting specialists or consultants, and pre-blast surveys.

As a result of the monitoring, certain ameliorative measures were adopted to lessen the effects of the blasting, such as:

- Changes in the direction of the quarry faces (from northeast to east and southeast) and abandonment of the faces oriented toward the residential area (north);
- An increase in the time period for blasting, with introduction of additional 42 ms delays between rows, and adjusting the time delay between holes, thus avoiding overlapping of consecutive charges and a consequent increase in the ground vibration;
- Maintaining fixed blasting design, and warning the local population by a sound signal.

In addition to the seismograph monitoring, proactive actions could be taken by the company in order to improve its relations with the community and avoid conflicts.

- Maintaining continuous monitoring of the blasts;
- Maintaining active programs to decrease ground vibration, air blast, and noise;
- Keeping complete records of the blasts, as much to establish that the company maintain control over the use of explosives, as to be able to show the records to interested parties;
- Use of inputs in blasting, to minimize environmental impacts such as air blast, noise, fumes, and dust;
- Training blasters and other personnel to plan the blasting design to minimize environmental effects;
- Training at least one employee of the company to operate the seismograph;
- Maintaining good relations with the community through contracting consultants and experts, preferably third parties, to ensure blasting compliance, minimize blasting effects both on and off the property, increase safety, and minimize operational costs.
- Maintaining public relations with the community and establishing records of complaints, with the name, address, and, telephone of the complainant.
- Reporting the environmental-monitoring activities and their results whenever requested by the community, in order to establish the seriousness and transparency of the business's activities to prevent damage and preserve the environment, reflecting its social responsibility.

According to Worsey (2004), education is one of the best tools that can be used. Both regulatory and public officials and local residents should be informed of what the company is doing, how it cares about public protection, that there are regulated or acceptable vibration limits that it must meet, how it uses seismographs to stay well below those limits and to document the blasts, and, most important of all, not to worry. In addition, how blasting may rattle residences for a second or two but it is only for a miniscule amount of time and several international studies have conclusively shown that weekly changes in temperature and humidity put far more stress on their houses for long period of time in comparison. Be open with people; arrange tours and demonstrations, and show them that the company have nothing to hide. Blasting can be an extremely interesting subject for the public, and knowledge goes a long way to dispel fear.

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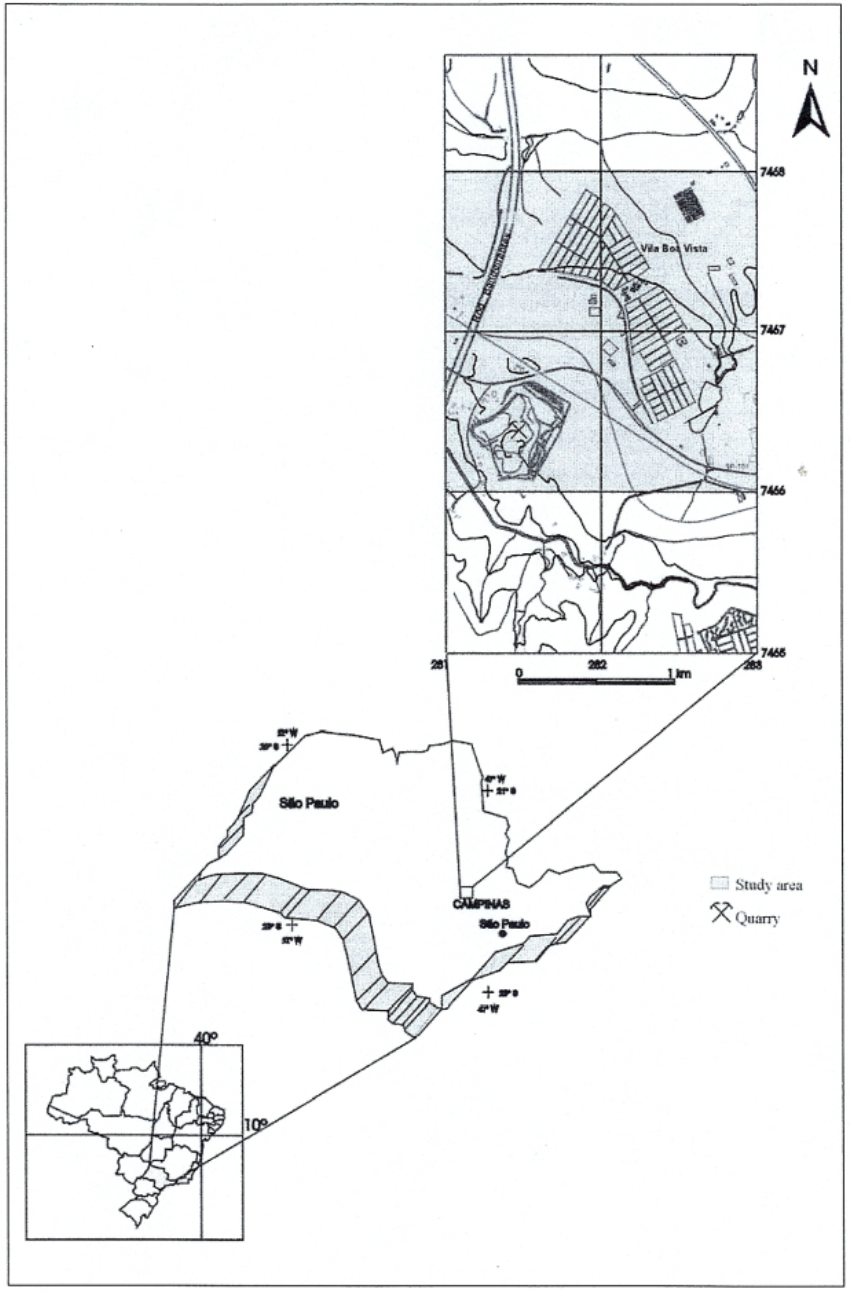

Figure 1: Location map of study area.

Table 1: Primary environmental aspects and impacts in the open pit mine.

ACTIVITIES	ASPECTS	IMPACTS
Stripping, involving soil removal, damage to superficial vegetation, land placement (muck pile disposal).	Erosion, earth movement, silting of local drainage Landscape, flora and fauna damage	Exhaustion of natural resources
		Frighten of wildlife
		Modification and damage on natural vegetation and landscape
Drilling of benches	Noise and dust	Noise pollution Human health damage or risk Occupational exposure to workers
	Use of personal protective equipment (mask, gloves, boots, ear plug)	Decrease of accident hazards and occupational exposure to workers
Loading of holes with explosives	Accidents hazard	Explosion hazards Human health damage or risks
	Keeping good geological and structural knowledge of the mine and exploitation area	Reduction of environmental impacts (landslide, etc.)
	Training and capacitating of technical employers	Reduction of accident hazards
Blasting	Ground vibration and air blast	Potential of damage in civil construction Human health risks Annoyance to local community
	Flyrock	Potential damage in civil construction Health and death risk to workers and local community
	Noise and toxic gases	Noise pollution Occupational exposure to workers and local population Accidents and intoxication hazards
	Landslide outside the mine area	Fatal and non-fatal accidents hazards
	Maintaining correct blast design, use appropriate explosive charges and delays	Reduction of ground vibration and air blast, no occurrence of flyrock, reduction of gases and ideal rock fragmentation Decrease of community complaints Decrease of potential damage in civil construction
Storage of explosives and accessories in magazines	Explosion hazards	Fatal and non-fatal accidents hazards Air pollution
	Keeping a good and correct storage of explosives and accessories, in ideal conditions of temperature and complying federal and local laws	Reduction of accident hazards and health risks
Environmental monitoring	Keeping control of ground vibration and air blast levels, complying federal and local regulations	Decrease of community complaints Decrease of potential damage in civil construction
Loading and transport of ore to crushing facility	Dust, noise and gases emission	Air and noise pollution Occupational exposure to workers
	Leakage of fuel oil grease	Soil and superficial drainage potential of damage
Opening new roads in mine area	Erosive process and input of sediment to local drainage	Soil and superficial drainage potential of damage Compromising use of natural resources
	Noise, dust and gases emission produced by equipment	Air and noise pollution Occupational exposure to workers
	Leakage of fuel oil and grease	Soil, superficial and ground-water potential of damage
Mine drainage	Generation of liquid effluents, input of sediment to local drainage	Superficial and ground-water contamination Superficial drainage potential of damage
	Energy consumption	Use of natural resources
Moisturizing roads in mine area	Water consumption	Use of natural resources, reduction of airbone

Table 2: Primary environmental aspects and impacts in the crushing installation.

ACTIVTIES	ASPECTS	IMPACTS
Ore Discharge	Noise and dust	Air and noise pollution Occupational exposure to workers
Crushing	Noise and dust	Air and noise pollution Occupational exposure to workers and health hazards (lung disease)
	Health hazards	Fatal e non-fatal accidents hazard, occupational exposure to workers
	Energy consumption	Use of natural resources
	Equipment vibration	Lost of efficiency , accidents hazards
	Use of personal protective equipment (mask, gloves, boots, ear plug)	Decrease of accident hazards and occupational exposure to workers
Conveyor belt moisturizing	Water consumption	Use of natural resources Reduction of airbone
Loading and haulage	Escape and lost of rock material	Fatal and non-fatal accidents hazard, depending on the diameter of the block
	Noise and dust	Air and noise pollution, occupational exposure to workers
Storage of ore	Noise, dust and, gases produced by equipment	Air and noise pollution, gases intoxication, occupational exposure to workers
	Lost of rock material	Superficial water contamination and local drainage silting

Table 3: Primary environmental aspects and impacts of the maintenance place.

ACTIVITIES	ASPECTS	IMPACTS
Circulation of trucks, vehicles and machines	Gases emission and escape of fuel oil	Air pollution Soil, superficial and ground-water contamination Occupational exposure to workers
Storage of diesel oil	Leakage of diesel oil	Soil, superficial and ground-water contamination
Vehicles combustible supply	Explosion hazard	Potential of damage in civil construction Fatal and non-fatal accidents hazards Intoxication hazard Air pollution
Maintenance work (lubrication, oil change of trucks and equipment)	Leakage of fuel oil and grease	Soil, superficial and ground-water contamination
	Disposal of solid waste (oil packaging)	Reduction of contamination risks
	Material recycling	Less exploration of natural resource
	Manufactured recover of lubricants	Less exploration of natural resource
	Periodic support of motors, trucks and vehicles	Less exploration of natural resource Reposition and recycling of material Decrease of gases emissions
Wash of trucks, vehicles and equipment	Generation of liquid effluents	Environmental pollution Soil, superficial and ground-water contamination
	Generation of solid waste and discard packaging	Environmental pollution Soil and superficial drainage contamination
	Water consumption	Use of natural resources
	Energy consumption	Use of natural resources
	Installation of fuel oil, greases and, liquid effluents collected box	Prevention of soil, superficial and ground-water contamination
Local housekeeping	Generation of liquid effluents	Environmental pollution Soil, superficial and ground-water contamination
	Water consumption	Use of natural resources
	Energy consumption	Use of natural resources
	Generation of solid waste (packaging)	Environmental pollution Soil and superficial drainage contamination
	Installation of tank draining or liquid effluent collected boxes	prevention of soil, superficial and ground-water contamination

Table 4: Primary environmental aspects and impacts in administrative facility and dinning hall.

ACTIVITIES	ASPECTS	IMPACTS
Administrative facility and dinning hall	Electric Energy Consumption	Use of natural resources
	Water consumption	Use of natural resources
	Liquid effluents and sanitary effluents	Superficial and ground-water contamination
	Waste and discard and perishable products	Environmental pollution
Housekeeping	Electric Energy Consumption	Use of natural resources
	Water consumption	Use of natural resources
	Liquid effluents	Environmental pollution
	Generation of residues and packaging	Environmental pollution