ABSTRACT

Environmental issues have become increasingly important in mining business in Brazil and abroad. This means that the sustainability paradigm must be part of the mining project from the exploration throughout the mine opening, operation and closure. Sustainability implies the use of clean technologies, minimisation of raw materials and energy demand, reduction of emissions and effluent discharge into the environment and maximisation of social benefits. In order to measure positive and negative changes in the environment associated to the use of a particular technology by industry, indicators must be used. Within this context this paper presents and discusses the process of building environmental indicators at the business level particularly for the mineral industry. It also addresses how these environmental indicators can be used to make environmental decisions.

INTRODUCTION

Some of the methods of what is presently called environmental performance evaluation - EPE of an organization may be identified in North American and European studies carried out by chemical and petrochemical companies back in the eighties and by mining companies in the nineties of the last century (Scott, 200; Hope C. et al 1992). The methodology however, was fully developed to its present status from in the second half of the last decade. This period of time coincides both with attempts to standardise analytical tools that could be applicable to different organizations and with the publication in 1999 of the first set of ISO 14030 standards on environmental performance.
The most important tool of an environmental performance evaluation - EPE is the indicator. The choice of the indicator should address multiple demands. At the management level it should support the decision making process as to the environmental consequences of a project strategy or production technology. At the consumer level it may orient informed consumer decisions when environmental issues are to be considered. This is the case when the purchase of a product is decided taking into account the fact that it incorporates environmental concerns in its project such as reusing or recycling. Indicators may also be used to communicate the environmental performance of an organization to the stakeholders as shareholders, suppliers, NGOs and government enforcement agencies.

The main roles of the indicator within an environmental performance evaluation are as follows:

- Follow up of long term changes of environmental performance
- Detection of opportunities for improvements;
- Identification and definition of environmental targets;
- Comparative evaluation of environmental performance amongst organizations ("benchmarking");
- Tool for performance communication;
- Tool to inform and motivate employees and partners;
- Subsidise implementation of environmental management systems EMS.

Some key methodological elements, to select and develop indicators that address these multiple functions are presented and summarised in the following items, taking as basis the ISO 14031:1999 standard.

ENVIRONMENTAL PERFORMANCE EVALUATION

Within an EPE, indicators should be selected to reflect the most relevant environmental aspects of the activity of the organization and those which, being under the organization’s management control, may be influenced and measured. They should also be able to detect modifications introduced by preventive or corrective actions over a period of time. In other words they should relate to the organization’s business objectives and strategy.

Classification systems may be used to orient the process of selecting indicators that are more suitable to a particular organization. The academy, industry and international organizations such as the International Organization for Standardization - ISO or the Eco-management and Audit Scheme – EMAS propose different classification systems (Scott 2000; ISO, 1999; EEC, 1993).

The ISO system this paper deals with, takes the so-called operational system as basis for classification. Within this classification, the indicator is part of an EPE that follows a PDCA (Plan - Do - Check - Act) cycle. This cycle, in fact, mirrors a process that is characteristic of the implementation of a quality management system.

According to the PDCA cycle the EPE and the selection of indicators start by the planning step (Plan). The systematic work of assessing environmental aspects of an organization is the essence of this step. The assessment of aspects is also an important part of the implementation of an environmental management system (EMS). If the organization has already implemented an
EMS it should be easy to address this task. If it is not the case the EPE must necessarily start by surveying environmental aspects and impacts.

The planning step should be complemented by an identification of the environmental constraints of the organization. Both internal (management goals, shareholders’ expectations, etc) and external (laws, regulations, action of NGOs, etc) constraints should be taken into account at this stage.

Data collection is the next step as well as converting data into indicators and comparing these indicators with pre-established targets (Do). The standardization of collection methods and the quality of the data are crucial to the work at this point.

Conversion of data into indicators involves a standardization step that may be done basically by normalization or aggregation (Olsthoorn et al 2001). These methods facilitate the comparison of indicators over a period of time or amongst organizations of the same type that operate in different locations. If the water consumption of a plant is, for instance, $x$ cubic meters, the associated environmental performance indicator (EPI) standardized by normalization will be equal to $x/y$, where $y$ is the output of the plant in tons per unit of time.

Aggregation, on the other hand, tends to reveal a less detailed picture of the operation. An example of aggregation is given by the calculation of indicators that measure the effect of greenhouse gases emissions from fossil fuel combustion. The calculation of these indicators usually takes the amount of methane and carbon dioxide, weight them by specific factors that reflect the contribution of each one to the greenhouse effect and aggregate them into a single number.

After the analysis of results - indicator levels - should be communicated internally and externally to the organization. Internally, the information should be conveyed to the management level as well as to the members of the staff at the operational level so that informed decisions as to corrective actions can be taken. Externally it should be reported to public.

Finally, improvement opportunities of the environmental performance analysis - EPE are assessed by comparing expected results to those effectively obtained (Check). At this stage some indicators previously selected might need adjustments whereas others might be included or even abandoned (Act). The PDCA cycle re-starts with a new planning stage.

The process can be represented by the scheme in Figure 1.
INDICATORS IN THE CONTEXT OF THE ENVIRONMENTAL PERFORMANCE EVALUATION

General characteristics

The indicator is mainly a tool for evaluation and communication of the impacts of activities of a fully operational organization on the environment. It is also a way to measure how far the organization is from its environmental objectives. In this sense a set of indicators must be able to reflect the results obtained by an organization in the management of its environmental aspects that, in other words, is the organization environmental performance.
A set of indicators may be part of an environmental management system - EMS that establishes standards against which the environmental performance should be measured. However, the pre-existence of an EMS is not mandatory to the use of indicators.

The ISO 14031 standard points out the criteria to support the selection of indicators as part of an EPE. Firstly indicators should be comparable which means they should be able to measure changes in the environmental performance over time or amongst different geographical locations or organizations. Secondly they should be continuous which facilitates the comparison at different times. Thirdly they should be frequent. Their periodicity should be such as to give the management a chance to act and change the performance of the organization. Indicators should also be balanced as to reflect both positive and negative aspects of the operation and finally, they should be comprehensible and driven by the sense of utility which means they should satisfy the needs of the stakeholders and bring useful information about aspects under control of the organization's management.

The process of data collection for calculation of indicators involves costs therefore it should be designed to be compatible with size and type of the organization.

**Types of indicators**

The ISO system suggests that indicators developed as part of an environmental performance analysis can be classified according to three general categories. The first encompasses indicators of environmental management of the organization, the second those which refer to the operational area and the third, indicators that reflect the environmental state or condition of the area influenced by the organization.

The environmental management indicators (EMI) should bring information about the management elements of the organization as to the environment and the achievements towards a goal previously established. Investments to improve environmental quality, policies, procedures as well as registration of the number of fines, documentation on contingency plans, corrective actions and stakeholder consultations are part of this category.

Operational environmental performance indicators (EPI) refer to the mass and energy balances of the organization. These balances, as mentioned before, are of primary importance to the environmental performance evaluation, since they tend to reflect the interface between the organization and the environment.

The environmental indicators - EI, describe environmental strains and impacts and reflect aspects such as quality of water and air, soil contamination as well as conditions of the biota in the area influenced by the operation of the organization. Risk analysis studies can contribute to the selection of EIIs by helping, for instance, to identify regions within the area of influence of the organization where exposition to effluents are deleterious to human health and to the environment.

It is important to mention that indicators of each category mentioned above are strongly related to each other. This makes difficult to avoid always some redundancy on the information they express to the stakeholders.
Each ore deposit and mineral processing operation demands a specific survey of environmental aspects that support the environmental performance evaluation and selection of indicators at the management level, as well as at the operational level and at those on state of environment. Some characteristics however, may be taken as common to a number of different mining and mineral processing operations and illustrate the process of selecting indicators.

It is also correct to assume that usually operations such as exploration, vegetation removal, overburden disposal, mining, mineral processing, waste disposal and decommissioning of facilities and equipments as well as reclamation may occur simultaneously in different locations at the same mine site.

The mineral exploration phase usually requires vegetation removal with consequent loss of vegetal species and impact on the animal habitat in addition to erosion, emission of particulates to air and water, etc. Indicators selected in this phase should reflect such alterations. The number of trees cut down per hectare during exploration would be a possible indicator in the operational category. The goal of reducing the number of trees removed in future operations may be a management indicator. On the other hand an environmental indicator may reflect the number of hectares of natural forest lost as a consequence of the exploration.

Overburden removal usually implies changing the landscape, the natural habitat of wild species, the water quality in both surface and ground water bodies and air emissions among other effects. In a mechanized operation for removal and trucking of the overburden, operational environmental performance indicators may reflect for instance the air emissions due to fossil fuel combustion. Management indicators may capture the investment on reducing energy consumption of this phase. Environmental indicators may refer to the air quality in the working area.

The mining phase may have many features in common with the overburden removal phase such as generation of aqueous effluents, increase of suspended solids in water bodies changes in water quality of aquifers, dust, noise, aesthetic changes in the landscape, loss of pastures or farming land, changes in the biota, etc. The number of hectares of farming land lost may be one of the possible environmental performance indicators of this phase. The investment to reduce changes in the aquifer level that are expected to result from dewatering of the mine may be an environmental management indicator. The number of complains of local farmers about lacking access to good quality groundwater is another possible indicator at the management level. An environmental indicator of this phase may reflect alterations in the aquifer level in the neighbourhood of the mine site.

In the mineral processing phase, environmental aspects are generally associated with consumption of water and energy, generation of aqueous effluents, air emissions, soil contamination, noise, dust, tailings generation, etc. The production of solid residues usually means an important environmental aspect of this phase since they represent potential changes in landscape, contamination of water bodies, dust, risks to animal life and populations downstream of the mine site. Indicators should capture these aspects. The concentration of contaminants in the aqueous effluents of the ore processing plant is an example of environmental performance indicator of this phase. Management indicators may set goals for reduction of emissions to water and air. On the other hand, the concentration of soluble metals in the water body where the processing plant discharges effluents at a point downstream of the mine site may be an environmental indicator.
The decommissioning phase encompasses dismantling of buildings and equipment that are no longer necessary and will not have other use, as well as, preparation for closure of facilities that are not removable. Environmental performance indicators of this phase may reflect the generation of solid residues that result from demolishing of buildings and the destination of debris. Therefore, a possible indicator of operational environmental performance would be the amount of material (debris or equipment) converted into goods for sale. On the other hand the investment on finding destination for reuse or recycling of solid debris and equipment may be a management indicator. The number of hectares of land given back to the community after decommissioning would be an environmental indicator.

Ideally, the reclamation phase occurs simultaneously to the mining and mineral processing so that many of the indicators related to environmental aspects of these phases such as solid waste and effluent generation may also be used in mine reclamation. An example of environmental performance indicator of this phase is the number of hectares of land resurfaced and revegetated after an open pit mining operation. The investment on re-vegetation may be an environmental management indicator. The state of the environment may be reflected by an indicator that refers to the number of wild animal species living in the area subsequently to the reclamation.

Table I shows some of the possible indicators selected in a process of environmental performance evaluation assuming the characteristics previously mentioned.

**FINAL REMARKS AND CONCLUSIONS**

The selection of environmental indicators may fall under some general principles but it must always follow a detailed assessment of the environmental aspects of the organization. This assessment stimulates the analysis of the interactions of the organization with the environment and helps the implementation of procedures to improve its environmental performance.

The use of performance indicators based on the EPE type of approach is an important step towards the assessment of the sustainability of the mineral industry.

At the business level the use of indicators may be used to the dissemination of information to the stakeholders and society and it may also contribute positively to the public image of the organization.

In a broader level, the application of EPE and performance indicators in the mineral industry may be incorporated in a national project of a database of indicators that may be instrumental to the development of governmental policies on environment.

Some mining companies have recently included economic and social aspects in their environmental performance reports that reveal a trend towards publication of sustainability assessments (van Huyssteen, 2003). This approach involves the analysis of additional aspects in the interface between mining business and community such as quality of life, employment levels, education and health & safety. The use EPE and indicators as presented in this paper is key to this type of approach.
Table I: Examples of indicators of a mining and mineral processing facility in the context of environmental performance analysis (adapted from CETEM, 2001)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Environmental management indicator (Management)</th>
<th>Environmental performance indicator (Operational)</th>
<th>Environmental indicator (State of the environment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>% Reduction of the number of trees removed</td>
<td>Number of trees removed</td>
<td>Number of hectares of forest lost</td>
</tr>
<tr>
<td>Overburden Removal and disposal</td>
<td>Investments in reduction of energy consumption</td>
<td>Air emissions of particulates and gases</td>
<td>Quality of air in the operation area</td>
</tr>
<tr>
<td>Mining</td>
<td>Investments to reduce impacts on aquifers</td>
<td>Hectares of pasture or farming land lost</td>
<td>Change in the local level of aquifers</td>
</tr>
<tr>
<td>Mineral processing</td>
<td>% Reduction of water consumption</td>
<td>m³ of water per ton of ore processed</td>
<td>Local reduction of water supply</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>% Reduction of contaminants in the effluents</td>
<td>Concentration of contaminants in effluents</td>
<td>Concentration of contaminants downstream</td>
</tr>
<tr>
<td>Decommissioning</td>
<td>Investments to sale equipments and debris</td>
<td>Number of equipments for sale</td>
<td>Land returned to other uses after decommissioning</td>
</tr>
<tr>
<td>Reclamation</td>
<td>Investments in reclamation</td>
<td>Revegetated area</td>
<td>Number of animal species living in the area</td>
</tr>
</tbody>
</table>
REFERENCES


EEC Council regulation nº 1836/93 29/06/1993


