

Environmental sustainability in the mining sector. Evidence from Catalan companies

Abstract

This paper examines the adoption of environmental practices in small and medium sized companies in the surface mining industry in Catalonia (Spain). To fulfill this aim, a survey of 41 items concerning environmental management systems and environmentally sustainable practices has been conducted. Results show that companies have committed themselves to environmental and sustainable issues. The majority of companies claim to understand the effects of their activities on the environment and they care for responsible access and management of natural resources. Restoration plans and the annual waste declaration are mandatory in Catalonia, and rational resources exploitation practices have been adopted by a high percentage of mines. Finally, some examples of good environmentally sustainable practices are introduced.

Keywords: Environmental management; sustainability; mining industry; Catalonia

1. Introduction

Mining activities have important economic, environmental, labor and social repercussions on local and global scales (Escanciano et al., 2010). While the sector provides vital raw materials and energy for a large number of industries, its activities are still commonly considered as a threat to the natural surroundings, with environmental effects on the air, water and soils. In this sense, the first decade of the 21st century in particular has seen a renewed debate about mining and its sustainability (Mudd, 2010) owing to public concern about the current degradation of the environment (Hilson and Murck, 2000). Examples of potentially serious environmental impacts of

mining include chronic soil erosion, heavy metals overloading and acid mine drainage (Hilson and Nayee, 2002). Hence, the main challenge for the sector is to demonstrate that it contributes to the welfare and well-being of the current generation without compromising the quality of life of future generations (Azapagic, 2004).

Nowadays, enterprises are expected to respond positively to these challenges by assuming responsibilities in local and national development. They must adapt existing strategies or adopt new strategies to attend to these demands and to deal with the compatibility between the productive activity and environmental (Claver et al., 2004) and social protection (Wheeler et al., 2002). Companies have to comply with the law currently in force and have to satisfy the demands of external stakeholder groups.

There is evidence in the literature that since the early 1990s, the mining industry has shown increasing interest in social and environmental issues and it has been seeking ways to integrate the challenges of sustainability into its core business practices (Hilson and Murck, 2000). Sustainable development has been included in the agendas of the mining industry (Cowell et al., 1999), and various national and international initiatives have developed frameworks for sustainability. For instance, the European Union (CEC, 2000) has promoted priorities based on four broad pillars (environmental protection, economic issues, social performance and employment, and research and technological development). The Mining Association of Canada (MAC) has developed an initiative called “Towards Sustainable Mining (TSM)” to enhance the sector’s reputation by improving its environmental, social and economic performance (Ford, 2005). Another instance is that the International Council on Mining and Metals (ICMM) has formulated 10 basic principles of good practice, including ethical management and sustainable development (ICMM, 2005).

Environmental management includes a wide variety of practices to be adopted, both mandatory (i.e. rehabilitation of mining sites and payment of taxes) and voluntary (i.e. environmental management systems and life cycle assessment). Nevertheless, different obstacles may difficult the implementation of such practices as for example the short-run compliance costs and low levels of environmental awareness by staff (Nikolaou and Evangelinos, 2010).

The adoption of environmentally responsible practices (Driussi and Jansz, 2006; Kapelus, 2002) may assist companies to minimize their negative impacts on the environment and also to improve their accountability in environmental issues. Several mines worldwide have implemented a comprehensive environmental management system (Hilson and Nayee, 2002), which has helped them to anticipate environmental problems and secure the support of local communities. Other mines have adopted codes of conduct and internal policies. For example, many Spanish companies, especially the largest ones, have introduced ethical and sustainable policies, and the adoption of green business practices is increasing (Fernández et al., 2005). Sustainability is also encouraged by the European Union (European Commission, 2011).

Under this context, this work aims to explore environmentally sustainable practices by focusing in the aggregate mining industry and the ornamental stone quarrying in Catalonia (Spain). Environmental sustainability may be defined as the maintenance of natural capital (Goodland, 1995), that is the maintenance of the factors and practices that contribute to the quality of environment on a long-term basis.

In the next section, the paper introduces a brief description of the current discussions on sustainability and environmental practices in the mining industry. The research

methodology is then introduced. Next, the results obtained from a descriptive statistical analysis are presented. Discussions and conclusions follow.

2. Literature review

The study of environmental and sustainable issues in the mining industry has gained importance within the academic community during the last few years. There are several studies regarding the extensive interest on this topic which explore strategies of companies on sustainable issues (Sinding, 1999; Cowell et al., 1999; Warhurst and Noronha, 2000; Hilson and Murck, 2000; Warhurst, 2001; Hilson and Nayee, 2002; Newbold, 2006; Suppen et al., 2006; Van Zyl, 2007; Enríquez and Drummond, 2007; Mudd, 2010; Fonseca, 2010 and 2011; Dutta et al., 2012; Hassan and Ibrahim, 2012). While different authors have depicted the positive impacts that mining activities can have (Mikesell, 1994; Walker and Howard, 2002; Wheeler et al., 2002), the link ‘sustainable development and mining’ seems to be still somewhat controversial. A major argument against the mining sector contributing to sustainable development is that mineral resources are finite and non-renewable (Cowell et al., 1999) and therefore the opportunities for future generations to access these resources are reduced (WCED, 1987). Moreover, the main environmental disasters that have increased public concern over the last 40 years have mainly taken place in the mining and petroleum industries (Warhurst, 2001).

Other academics argue that mining operations have an important effect on their surroundings and on local communities (Hilson and Murck, 2000; Jenkins and Yakovleva, 2006; Blinker, 2009). Morphological changes in the exploited areas, noise, dust, and surface and groundwater pollution are the main environmental hazards produced by mining operations. These, together with the risk of professional diseases and accidents in mining activities have contributed to a questionable reputation for

social responsibility (Lambert, 2001). On the other hand, primary examples of positive contributions of mining to sustainable development include caring for the country, people and culture (Howitt, 2001).

From an environmental perspective, the debate is now centered on the enterprise-environment relationship (Banerjee, 2002) both at the global and national scales. For instance, Warhurst (2001) has concentrated on sustainability issues, and Jennings and Zandbergen (1995) have analyzed institutional approaches to sustainability through different aspects including the construction of social and organizational contexts, the value assessment of organizational sustainability, the introduction of sustainability in regulative rules, and the diffusion of sustainable practices. Different authors have conducted case studies of mining companies in different countries. For instance, Macedo et al. (2003) have analyzed the historical and present conditions of the Brazilian non-metallic small-scale mining industry in relation to environmental practices. Ghose (2003) has analyzed the environmental management plans in the small-scale mining industry in India. Evangelinos and Oku (2006) have examined the corporate environmental management of Greek mining companies and the process of gaining permission to operate. Berkel (2007) has defined an eco-efficiency framework for the Australian mining industry. Das (2009) has compared the environmental and sustainable performance of public and private mining companies in India. Nikolaou and Evangelinos (2010) have conducted a SWOT analysis of the Greek mining industry in adopting sustainable practices. And Jia et al. (2013) have defined an evaluative framework using the Fuzzy AHP model to assess a cleaner production in the vanadium extraction industry.

In fact, literature seems to indicate that mining companies have increased their environmental consciousness and they start to adopt cleaner production and

environmental management systems (Zhu et al., 2010). Hilson and Murck (2000) point out that the mining industry can contribute to sustainable development by minimizing the environmental and social impacts throughout its lifecycle. Gibson (2000) suggests that any negative effect should be immediately remediated, which would improve the reputation of mining. And Barbara-Sánchez and Atienza-Sahuquillo (2010) suggest that environmental strategies focusing on energy conservation, waste reduction, pollution prevention, recycling and ecological product design lead to improvements in product quality, manufacturing cost reduction and entrance into new markets. Similarly, Driussi and Jansz (2006) state that some specific management practices such as environmental management systems, pollution prevention technologies and environmental training may assist companies to improve their accountability in relation to environmental issues.

Other authors have studied the connections between environmental degradation and conflict, and have analyzed the relationships between environmental and social variables (resource scarcity, population growth, resource abundance, democracy, and poverty). They concluded that those countries undergoing important economic and political transitions (Esty et al., 1999), and those with limited economic and political resources (Timura, 2001), are more prone to internal violent conflicts. As Walton and Barnett (2008) state, environmental conflicts in developing countries are basically the result of unequal distribution of outcomes arising from environmental degradation and its related causes.

Environmental issues have increasingly more influence on business strategies and therefore, in strategic decision-making (Rugman and Verbeke, 2000). Companies may seek only to comply with the law currently in force, or they may go further and adopt

more proactive environmental practices that allow for sustainable competitive improvements (Barba-Sánchez and Atienza-Sahuquillo, 2010).

3. Environmental management practices in the mining sector in Catalonia

Catalonia is located in the northeastern part of the Iberian Peninsula. It is one of the most industrial communities in Spain and it is also one of the regions with a high mining production. In 2011, it became the second autonomous community in mining production in Spain, specifically the 16.3% of the total production (statistics of Ministry of Industry, Energy and Tourism of the Spanish government). The economic value of the production was around €526 million in 2011, and it employed about 2865 direct workers. Amongst the different minerals, quarry products, including ornamental stone, were the second sector in marketable production in Catalonia with about 31% (€164 million) of the total regional production. More detailed data can be found (in Spanish) on the General Directorate of Mining website (<http://www.mityc.es/energia/mineria>).

The Catalan mining industry provides primary materials to a great number of national and local businesses (ceramics, building, electronics, metal, paper, plastics and others). However, there is still some kind of troublesomeness with the link “sustainable development and mining” (Cowell et al., 1999).

To overcome this problem, both the Catalan government and the Spanish government have enacted mandatory measures and voluntary schemes to take a leader role in sustainable responsibility. For instance, Law 26/2007 (Environmental Responsibility) defines the terms for the accomplishment of prevention and restoration requirements of environmental impacts. Another instance is Law 3/1998 (Integral intervention of the Environmental Administration), which surpasses to the internal classification of

Catalonia the Council Directive 96/61/EC concerning integrated pollution prevention and control.

Specific regulations for the mining sector have also been enacted to deal with the environmental effects of mining operations. In Spain, and also in Catalonia, the mining regime is regulated by the Mines Act (Act 22/1973), of July 21st, and by Royal Decree 2857/1978, of August 25th. These two regulations already referred to environmental protection in their content. More recently, other regulations concerning environmental issues in the mining sector have been approved. For example, Royal Decree 975/2009, of June 12th (Waste management in mining and quarrying and protection and rehabilitation of areas affected by mining activities) combines several existing environmental decrees and ministerial orders related to mining, and it transposes the European Directive 2004/35/EC on waste management in extracting industries into national law. Under this decree, companies engaged in mining are required to present an environmental restoration plan to explore or exploit mining sites.

Moreover, some companies have voluntarily implemented environmental management systems, such as the International Standard ISO 14001, and the European Eco-Management and Audit Scheme EMAS. Other companies have adopted sustainable mining schemes such as UNE 22480 (a Spanish norm for sustainable management in mining activities).

4. Methodology

The basic information of this work comes from a more extensive study that analyses quality, environmental, occupational health & safety, and corporate social responsibility management in the aggregate mining industry and ornamental stone quarrying in Catalonia.

The primary data for this study was collected during fieldwork in January – April 2010. The research was initiated with the design of a questionnaire, which was the main source for data collection. A pilot-test was conducted within a small number of Catalan mining companies in order to prove viability and to detect difficulties in the interpretation of questions.

The final version of the questionnaire comprised 41 items concerning environmental management systems and environmentally sustainable practices. To validate the reliability of the questionnaire, the Cronbach's alpha coefficient was calculated (Yang and Green, 2011; Cronbach, 1951). The Cronbach's alpha coefficient is a statistical measure of internal consistency estimate of reliability of test scores for a given sample. It is defined as [equation 1]

$$\alpha = \frac{K}{K-1} \left[1 - \frac{\sum_{i=1}^K \sigma_{Y_i}^2}{\sigma_X^2} \right] \quad [1]$$

where K is the number of components (items or variables), σ_X^2 is the variance of the observed total test scores, and $\sigma_{Y_i}^2$ is the variance of component *i* for the sample. Thus, $0,8 \leq \alpha < 0,9$ indicates a good internal consistency and $\alpha \geq 0,9$ an excellent internal consistency. The obtained overall Cronbach's alpha coefficient value for the aspects evaluated, $\alpha = 0.962$ (> 0.80 and very proximate to 1), demonstrated a high degree of internal consistency and reliability.

The target population was identified in the 'Register of Catalan Mining (year 2008)' published by the General Directorate of Mining of the Spanish Government. Although a

single company may operate in more than one location, the unit of analysis for this research was the company. The population considered amounted to 202 companies.

All questionnaires were sent by electronic mail and by post and were addressed to the Management Systems Manager or to the Business Manager. A cover letter explaining the purpose of the study and a self-addressed and stamped envelope accompanied the survey questionnaire. To increase the response rate, companies were previously contacted by telephone. After all this process, the deficiencies detected in the answers were rectified through telephone calls or electronic mail.

A total of 60 completed responses were received (29.7% response rate), which reached the targeted overall response rate for a valid assessment since [Ortega \(1990\)](#) observes that response rates of 20% are common and considered satisfactory for post surveys in Spain, and [Malhotra and Grover \(1998\)](#) suggest a response rate over 20% for a positive assessment of mail survey results.

With the data obtained, a descriptive statistical analysis on sustainable and environmental practices in the aggregate and ornamental stone mining industry of Catalonia has been performed using Minitab v.15 and Microsoft Excel v. 2011. Table 1 shows the technical record of the study.

INSERT TABLE 1

Similar studies about how companies adopt environmental practices have been published in the literature ([Deegan and Rankin, 1996](#); [Newbold, 2006](#); [Gonzalez and Gonzalez, 2008](#)). Most of these studies are centered in the analysis of environmental management systems and the contents of environmental and sustainable reports published by companies, more than in statistical analyses of environmental practices adopted by companies. In fact, the published research about mining and sustainability

has mainly analyzed national, project or corporate-level policies but not individual policies (Hilson and Murck, 2000; Fonseca, 2010). The research presented in this paper tries to fill this gap by analyzing environmental and sustainable practices in individual mining companies. The literature on the topic of sustainable mining has increased during the last years, but there is still a long way to go and more studies from different countries are necessary. In this sense, the literature on environmental and sustainable practices in the mining sector in Spain (and also in Catalonia) is not very extensive so far. Hence, the work presented in this paper aims to contribute to the field by analyzing the current situation in a sample of mining companies of Catalonia.

5. Results and discussion

5.1. The companies' profile

Around 90% of the analyzed companies are medium or small sized firms according to the European Union Recommendation 2003/361/EC. These companies mainly concentrate their commercial activity at national scale.

The distribution of the sampled companies by mineral type (aggregate and ornamental stone mining) is indicated in Table 2.

INSERT TABLE 2

The literature suggests that larger firms are more likely to be under public scrutiny (Liu and Anbumozhi, 2009) and are generally capable of having superior resources (Spence, 1999). Nevertheless, the study conducted shows that medium and small companies have also undertaken various environmentally responsible actions (we refer the reader to subsequent sections).

5.2. Environmental management systems

About 22% of the companies participating in the study have an ISO 14001 environmental system implemented, and 78% of those that do not have an environmental system said to be in the process of implementing it or to intend to do it. In fact, data on the application of environmental practices (see next section) seem to indicate a business approach to a friendly environment for ISO 14001.

The core motivations to apply for an environmental system are mainly linked to image and reputation in 85% of the companies. Sustainability, social responsibility and a clean company hallmark are the principal motives. This high percentage could be attributed to the fact that mining has traditionally been considered as a dangerous activity due to its adverse environmental and social impacts (severe land disturbance, off-site impacts, community displacement, and health and safety problems) (Hilson and Murck, 2000; Sánchez, 1998). In this respect, some of the companies admitted in the questionnaire that the most perceived threats from mineral extraction activities were the high impacts on the environment:

“Land degradation, loss of local biodiversity, leakage of chemicals from mining processes, and noise and visual pollution are high impacts that mining activities may have on the environment. Therefore one of the main reasons to implement an environmental management system is the pressure from society for a cleaner and sustainable environment” (observation made by a respondent in one of the questionnaires).

The figure of the project and site manager, mandatory for mining companies, performs environmental management tasks in 31% of the analyzed companies. On the other hand, most of the companies (69%) assign environmental tasks to the responsible of

management systems in front of the assignment of tasks to the responsible of environmental issues. This last result fits with previous studies (Salomone, 2008; Zheng et al., 2008; Escanciano and Iglesias, 2012) that show the existence of an increasing tendency to integrating environmental, quality and occupational health and safety areas.

5.3. Environmentally sustainable practices

Results show that companies have committed themselves to environmental and sustainable issues (Table 3). Around 75% of the companies have implemented at least three different environmentally sustainable practices and 12% have applied six or more.

INSERT TABLE 3

Restoration plans and the annual waste declaration are mandatory in Catalonia, thus these practices are adopted by 100% of the companies. Since the 1970s decade, the legislation currently in force in the mining sector in Spain and in Catalonia eludes the need for the control of environmental risks (Mines Act 22/1973 and Royal Decree 2857/1978). Other national and regional norms regulate waste management (Law 15/2003 amending Law 6/1993, introduced by the Catalan Government) and landscape protection and restoration (Law 12/1981, also introduced by the Catalan Government).

Energy sources consumption control and mining source reduction are commonly adopted practices, too. Around 50% of the companies have adopted them. These two practices can be linked to rational resources exploitation (Vintró and Comajuncosa, 2010) as they care for responsible access and management of natural resources.

Meanwhile, procedural practices such as environmental goals definition and environmental emergency protocols are adopted by a smaller percentage of companies (about 20%). Similarly, the percentages of internal and energetic audits are not very high, which could be attributed to the fact that companies without an environmental

management system implemented do not usually perform these audits. The lowest percent (2%) corresponds to cooperation with environmental non-governmental organizations.

Results seem to indicate that companies with an environmental management system implemented adopt more sustainable practices compared with companies without an environmental system. This can be attributed to the fact that implementing an environmental system involves the introduction of several practices inherent to the system itself. That is, to develop an environmental management system, companies must establish mechanisms to identify, measure, and control their environmental effects, define environmental policies and objectives, document procedures related to environmental management and define responsibilities in all the areas (González-Benito et al., 2011). All these issues are integrated through restoration plans in mine closure, annual declaration of waste, energy sources consumption control, environmental goals definition, environmental emergency protocols, and internal audits, as well as documentation of all environmental issues, which are practices adopted by all companies with an ISO 14001 system.

Companies claim to understand the effects of their activities on the environment, and they are aware of the need to implement sustainable working criteria in their business policies. As Ottman (1995) states, the enterprises that target the sustainable aware consumers can take advantage of being the first to offer less contaminated products, and therefore, these may facilitate the entrance into new markets. In the eyes of one manager, companies want to observe the law and collaborate with both internal and external stakeholders, reasons for which they implement several environmental practices:

“Currently, we (all companies) need to identify our key stakeholders and incorporate their issues into the way we do business where possible. Society is increasingly environmentally responsible, thus we have to take this into account and we have to redefine our processes so that they are respectful with the environment.”

Another respondent indicated that:

“We take account of possible effects of our activities, and we adopt a variety of measures to control work and develop periodic plans for restoring the initial conditions. We understand that environmentally responsible practices can provide a competitive advantage because they meet the environmental needs of our customers”.

Aggregate mining companies accounted for higher percentages of procedural practices and non-profit practices, whereas they accounted for similar percentages of rational resources exploitation practices compared to ornamental stone quarrying companies.

In order to analyze the perceived utility of environmentally sustainable practices, respondents were required to assert whether these practices were contributing to improve business results or whether they were not. Variable “perceived utility of environmentally sustainable practices” was measured with a five point (1-5) Likert scale. Around 33% of the companies (35% aggregate mines and 27% ornamental stone quarries) perceived a positive impact (punctuations 4 or 5 in the Likert 1-5 scale). The mean 3.216 (slightly higher than 3, the central value in the interval) seems to indicate that the null hypothesis can be rejected ($H_0: \mu=3$; $p\text{-value}>0.05$), thus the average perceived utility of environmentally sustainable practices is positive. Results are detailed in Table 4.

INSERT TABLE 4

A Kruskal-Wallis one-way analysis was used in this study to explore the relationship

between the implementation of environmental management systems and the usefulness of environmentally sustainable practices to business results. Results show a positive association (Kruskal-Wallis = 4.77; p-value = 0.029; DF = 1). In fact, environmental management systems like ISO 14001 can help companies introduce sustainable or green practices in their business. Specifically, 77% of the companies with an ISO 14001 system implemented argued that the system improved their business results. For instance, some companies indicated that the environmental management system contributed to reduce operating costs through waste reduction and energy consumption. Others stated that it provided a consistent way to demonstrate competitiveness and to manage the company away from constraints imposed by future regulations. Other benefits may include improved bond ratings and reduced insurance costs. As part of the planning of the environmental management system, companies integrate environmental management into their daily operations through the adoption of several sustainable practices and they regularly perform environmental audits, which help them to identify the areas of their business that impact on the environment and to what extent.

Another issue that was examined was the influence of different management systems implemented in the companies (that is, quality, environmental, and occupational safety management models) on the number of environmentally sustainable practices adopted. Through Kruskal-Wallis analysis we obtained a non-significant relationship since all p-values were higher than 0.05. This result means that having more than one management system implemented does not significantly influence the number of environmental sustainable practices adopted and the perceived utility of such practices. As indicated above, the influencing factor is having an environmental management system implemented.

One indicator that proves the importance of sustainability for companies is the content

of companies' websites in relation to environmental issues. Previous studies have also analyzed the communication of social and environmental issues on websites of mining companies; see [Lodhia \(2012\)](#). We used Content Analysis ([Woodrum, 1985](#)) since it is a "technique for gathering data that consists of codifying qualitative information in anecdotal and literary form into categories in order to derive quantitative scales of varying levels of complexity" .

The categories used concerned (Table 5):

- How companies disclosure environmental and sustainable information, that is whether it is in a report or on the website (Unit of analysis: Html or Pdf) and whether it is in English or other languages (Unit of analysis: Language)
- The indicators that prove their sustainable commitment (Unit of analysis: context): membership into environmental and sustainable networks, adoption of guidelines such as ISO UNE 22480 or ISO 14001, and global environmental concerns.

INSERT TABLE 5

Table 6 is the result of the content analysis/unit analysis.

INSERT TABLE 6

From the 60 companies participating in the study, we analyzed the websites of the companies certified by ISO 14001 (a total of 11 companies). According to the results of the content analysis all companies have a specific heading in the website for sustainability and environmental issues, but only half of them publish the environmental policy on the website. All companies have defined a sustainable strategy but only 5 of them publish their environmental results embedded into their websites. A total of 4 companies have their website available in English, while the others have it only in Spanish.

Another indicator that proves the importance of sustainability for companies is their

participation into environmental networks. Five companies act as members of environmental networks, and perform various activities including knowledge diffusion activities, restoration activities and activities associated with community relations. Most of the companies present their environmental and sustainable strategy under three top priorities: rational resources consumption, stakeholder compromise, and environmental responsible attitude. All companies are committed with the impact of their activities on the environment and manage their processes under global sustainable criteria while trying to act in accordance to environmental ethics.

5.4. Good environmental practices in sustainable mining

During the last two decades, society has become more concerned about environmental and social issues, and this has forced companies to redefine their strategy. The effects of public interest for a cleaner environment, the pressure of groups that have negatively targeted the mining sector at international levels, and the introduction of environmental legislation have contributed to raise overall environmental awareness. Civil society has started to claim for more a practical sustainability that endorses other practices than the simple publication of greenwashing reports and manuals (Bruno, 1992). In this respect, companies have started to redefine their business policies around the selection of a series of environmentally-conscious practices (Sharma and Vredenburg, 1998).

Next, we provide a brief description of some examples of ‘good practices’ adopted by mining companies in Catalonia. We define “good environmental practices” as the ones that help companies to ensure an environmental management in all the activities developed.

Investing in processes for saving energy and natural resources

Natural resources constitute the raw material or energy source for various industrial processes. The management of these resources is essential to reduce potential damage to the environment, by decreasing resource consumption or adapting it to requirements. Several companies have implemented an enterprise-wide program aimed to reduce the levels of consumption of energy, water and raw materials.

For instance, some enterprises have introduced improvements in the design of mining blasting to reduce the consumption of a specific explosive. Others have targeted the reduction of waste through separation, recycling and re-use whenever possible. In this sense, one of the companies has introduced the utilization of recirculated water for the control of dust and the conservation of facilities (irrigation of tracks and stockpiles, spraying in mobile processing units, etc.). This water is obtained from mine drainage of galleries through a system of pumps, pipes and intermediate pools. Another instance is that some companies have developed alternative energy sources such as solar plants.

Reducing greenhouse gas emissions

In line with the Kyoto Protocol, some companies have initiated programs aimed at a significant reduction of greenhouse gas emissions. This includes the conversion of manufacturing facilities to natural gas, the reduction of the use of N₂O and the conversion of electric generators fed by gasoil to power supply.

Improving the safety of the work environment

Beyond the obligation to comply with the law currently in force regarding occupational safety (Law 31/1995 on occupational safety, and Mines Act 22/1973), different companies have undertaken comprehensive risk management programs aimed to promote and increase safety culture at work. One key element that has been introduced in these programs is 'tidiness at work' or the 5S rules (Hirano, 1995). This refers to

effective rules for tidiness that may lead to a cleaner environment, higher safety levels and more discipline, and therefore these would enhance efficient work and quality.

Examples of tidiness rules include:

- Sorting through all the tools, materials, etc., in the work area and keeping only essential items. Tools, equipment, and materials must be systematically arranged for the easiest and the most efficient access.
- Keeping the workplace clean as well as neat.
- Standardizing work and procedures. Everyone knows exactly what his or her responsibilities are.
- Maintaining standards and keeping the facility in safe and efficient order day after day.

Restoring initial environmental conditions

The restoration of mined land consists in returning the land to some degree of its former state. In Spain, the mining legislation currently in force deals with the restoration of degraded land. Companies must submit an initial restoration project to apply for the appropriate operating permit and approval from authorities, and they have to deposit bail in the General Directorate of Mining.

Land restoration includes various activities such as revegetation and soil stabilization.

One of the surveyed companies has converted the exploited terrains to a natural touristic area, with a lake, autochthonous vegetation and itineraries for tourists.

Minimizing the impacts to the environment

One of the surveyed companies has the peculiarity that it is an underground quarry located in a Protected Natural Area. The rock is extracted from inside the mountain and the volume of associated waste is significantly reduced. The company has minimized

the visual impact and the effects on flora and fauna, and has reduced the emissions of dust and noise. One fundamental aim of the company is to reduce the affected soil, especially in surface paths and structures with an esthetic impact.

Another example is the case of a potash mine company. The company has engaged different sustainable strategies aimed to get along with the mining activity and the environment where it operates. For this purpose, it has endowed a Sustainable Mining Chair in Polytechnic Engineering School of Manresa which aims to promote innovation and sustainable issues in the field of mining engineering, through training programs, technical advising, and scientific divulgation. One fundamental activity that has been supported by the Chair is the study of subsidence with topographic measurements. The potash mine company maintains that a profound knowledge on subsidence effects of mining activities is required to improve the mining activity itself.

Measuring the environmental behavior

As [Jenkins \(2004\)](#) states, recent trends show that social and environmental reporting is becoming part of mainstream business, with a significant increase in the number of companies issuing reports of this nature. One fundamental aspect to include in these reports is the measurement of the environmental behavior of the company. For instance, one of the surveyed companies has adopted a proposal of environmental indicators, UNE 22470. Other proposals can be found in the literature, see for example the GRI Mining & Metals Sector Supplement (2005), or the work of [Vintró and Comajuncosa \(2010\)](#).

On the other hand, companies should bear in mind that local communities need to be informed about activities projected or that are being carried out, and about the impacts that these activities may have on the local environment. In this respect, business

transparency and information is required, and one key instrument is the reporting of environmental results. Some companies indicated that they maintain a comprehensive communication with local communities, and that they have included in their yearly objectives the spreading of the new sustainable mining management certificate obtained (UNE 22480) and the presentation of the projected activities of the companies affecting the local community. The number of companies publishing environmental reports has grown during last years, and even though it has not yet been proofed that reporting has a direct effect on environmental performance (Peck and Sinding, 2003), it is undoubtedly an example of efforts made by companies to achieve a more sustainable behavior.

Experiences of sustainable practices in the mining industry in other countries

Similar practices are applied in mining companies of different countries. For instance, Suppen et al. (2006) report the case study of Peñoles industries, one of the most important groups in Mexico oriented towards making beneficial use of non-renewable natural resources. Within their activities they include exploration and mining. The group has adopted different cleaner production technologies: for instance, an automatic monitoring network to check air quality, a bag house adapted to clean combustion gases and a wastewater treatment installation. In 2003, 100 % of the water used in industrial processes in Peñoles industries was recycled water.

Another example is the case of the Lower Caroni mining project in Venezuela analyzed by Sandoval et al. (2006). The authors describe in their work, the potential impacts of the project on natural environment, human health, sustainability of resources and social equity. They also introduce different sustainable practices considered within the project. For instance, adopting well respected standards such as ISO 14001; selecting a high density dredging and pumping system which would reduce the cost of waste water

storage and management; introducing tourism development around the lakes area; and implementing a communication strategy based on transparent policies and practices to ensure long-term economical, environmental and social well-being of local communities.

Other examples can be found in the literature. For instance, the study of [Newbold \(2006\)](#), that analyses ISO 14001 and large-scale mining in Chile, the work of [Milanez and Puppim de Oliveira \(2013\)](#) that analyze sustainable practices in artisanal mining in Brazil, or the work of [Pellegrino and Lodhia \(2012\)](#) that analyze the environmental disclosure practices of the Australian mining industry as a means to respond to climate change.

6. Discussion

6.1. Academic implications

In line with previous studies published in the literature ([Christmann and Taylor, 2006](#); [Driussi and Jansz, 2006](#); [Zhu et al., 2010](#); [González-Benito et al., 2011](#); [Fei-Baffoe et al., 2013](#)), we find empirical evidence that environmental management systems like ISO 14001 can help.

As [Christman and Taylor \(2006\)](#) state, environmental management certification may provide an attraction for firms, but more over, this can help companies better manage the impact their activities have on the environment. In this sense, the results of the study presented in this paper show that the adoption of environmental management systems helps companies integrate environmental management into their daily operations through the adoption of several sustainable practices, and that, facilitates to identify the areas of the business that impact on the environment and to what extent.

As our main contribution, our results indicate that there is a positive association between the implementation of environmental management systems and the usefulness of environmentally sustainable practices to business results, which may improve the image of mining companies and help them accomplish a better environmental balance.

6.2. Practical implications

For business, our study provides information about different environmentally sustainable practices to be adopted in the mining sector, including environmental management systems, and the benefits derived from their adoption based on the experiences of a sample of 60 small and medium sized mining companies from Catalonia.

For public administrations and governments, our findings seem to indicate the need for more strict environmental regulations and for actions to impulse the adoption of sustainable practices by mining companies, so that the negative impacts on the environment get reduced.

6.3. Limitations of the study and further research

Our research has some practical limitations, since it only considered mining companies from Catalonia and two specific mining sectors. Moreover, companies are usually reluctant to give environmental information and even though with strict scientific procedures in the data collection, there is some level of subjectivity inherent to the responses of the questionnaires. In this sense it would be interesting for further research to conduct similar studies in different countries and different mining sectors, to compare results and assess the robustness of the analysis to generate valid scientific knowledge.

7. Conclusions

This paper has examined the environmental sustainability in the aggregate and ornamental stone mining in Catalonia. To sum up, in Catalonia, companies in the surface mining industry are small or middle sized, like most companies in Europe. But this does not stop them from implementing management systems and from adopting environmentally sustainable practices.

The number of registered companies increases (22% of the sampled companies have an environmental management system certified) because of the regulatory pressure in areas such as environmental management. In fact, social and environmental responsibilities are of strategic relevance for mining activities and therefore, it is important that companies have a clear understanding of the issues affecting sustainability in the local communities (Esteves, 2008).

Findings highlight commitment to the environment. Most companies understand the negative impacts of their activities on the environment and they implement different practices. Some of the practices are mandatory in Catalonia for all companies, while other practices become "compulsory" when implementing an environmental management system. As part of the planning of the environmental management system, companies integrate environmental management into their daily operations through the adoption of several sustainable practices. Hence, if more strict environmental regulations were enacted and Public Administration and Governments promoted different actions to favor the implementation and development of environmentally-friendly practices, it would probably enhance companies commitment with the environment and that would lead to an increase in the adoption of sustainable practices.

Results have shown that energy sources consumption control and mining source reduction are commonly adopted practices, while the lowest percent corresponds to cooperation with environmental non-governmental organizations.

Generally, aggregate mining companies accounted for higher percentages of procedural practices (environmental goals definition and environmental emergency protocols) and non-profit practices (cooperation with environmental non-governmental organizations) than ornamental stone quarries, whereas they accounted for similar percentages of rational resources exploitation practices (energy sources consumption control and mining source reduction). Around 33% of the companies perceived a positive impact of environmentally sustainable practices to business results.

Social responsibility and a clean company hallmark are the principal motives to apply for these practices, since mining activities are commonly considered as dangerous activities with environmental effects on the air, water and soils.

The results obtained in the study show a positive association between the implementation of environmental management systems and the usefulness of environmentally sustainable practices to business results. Consequently, we expect that if the diffusion of environmental management systems increases, the adoption of environmentally sustainable practices will increase, and vice versa, and the negative impacts on the environment will be reduced.

In conclusion, several environmentally friendly practices are possible in mining activities, even in small companies. These practices may improve the image of mining companies and help them accomplish a better environmental balance. Although companies that have implemented environmental practices are satisfied with the results,

there is still a long way to go; therefore the support of the government and professional associations seems necessary to impulse the adoption of such practices.

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