# Water use management in the mining industry: a comparison based on company size

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**Abstract**
The study seeks to identify the association between company size and water use management in the Brazilian mining industry. The results are indicative of significant differences between these enterprises with respect to water use management, suggesting that smaller firms adopt less advanced management practices.

**Keywords:** Water Use Management, Company Size, Mining Industry

## INTRODUCTION

Awareness of corporate sustainability, combined with economic prosperity, social responsibility and environmental concerns, poses a challenge to managers in a context where management of scarce resources and concern for social issues are required (Savitz, 2007, Elkington, 1998). In the context of the mining industry, sustainable development is an even greater challenge. It is known that mining has great economic importance and is crucial for the development of many industries, However, it is an essentially extractive activity that uses natural resources and has an intense relationship with the environment.

The mining industry is located at the base of several supply chains that are essential to modern life. It is an important source of energy and has significant participation in the Brazilian economy. According to data from the Brazilian Mining Institute, the industry account for 3% to 5% Brazil's gross domestic product, with significant participation in the trade balance, with a trade surplus of 38.4 billion dollars and a total value of record production of about 50 billion dollars in 2011 (Ibram, 2012). According to the Ministry of Development, Industry and Foreign Trade (2011), ores have been one of the main Brazilian exports in recent years.

Despite its importance in the economic context, environmental impacts and social issues involved in this activity are known. Discussion about the extraction of non-renewable resources, changes in environmental landscape and issues involving health and working conditions of miners are some of the impasses to be addressed. In environmental terms, disturbance happens in the soil, e.g., changes in soil composition and erosion; in the waters, as regards the amount of water consumed and waste discharges into water bodies; and in the air, for example, pollution caused by mineral processing (Azapagic, 2004, Hilson and Murck, 2000, Mclellan et al., 2009).

According to a study of the National Water Agency and the Brazilian Mining Institute (Ana and Ibram, 2006), it can be stated that the mining industry is one of the largest water users in Brazil and has the most particular aspects. Those involved in mining activities range from large enterprises that cause high environmental impact but have modern and efficient management of such impact, to small miners that exploit small mines but have poor environmental plans and controls. According to the National Department of Mineral Research (2010), 70% of Brazilian mines are small, 25% are medium-sized and 5% are large, which illustrates the very diverse profile of these enterprises.

Therefore, assessment of water use management by Brazilian mining enterprises is extremely important. Especially in view of the diverse profile of these enterprises, it is crucial to understand the differences in water use management as regards the size of enterprises in the Brazilian mining industry. Within this context, this study aims to identify how company size affects water use management in Brazilian mining enterprises.

To achieve this purpose, the study is divided into five sections, including this introduction. The next section discusses water use management in enterprises of the mining industry from a theoretical point of view. The third section describes the research method and the technical procedures used for the research. The fourth section presents the analysis of the results and, finally, final remarks are made in the fifth section.

## WATER USE MANAGEMENT IN THE MINING INDUSTRY

There is a broad consensus among those involved in mining that the water-mine relationship is dichotomous. On the one hand, it is extremely necessary in various activities and processes of this industry; on the other hand, it is the source of many problems and involves additional costs. These problems arise because mining usually takes place in the water table, and directly affects surface waters. This requires mining areas to be drained, thereby producing important hydrological, environmental and economic effects, and leads to the need for proper management of such waters (Ana and Ibram, 2006).

Another problem is the intensive use of water in the grinding, sieving, dedusting, rinsing operations as well as in the reagent mixture. According to the authors, flotation, which is a separation procedure commonly used in mining, may require from 1.9 to 3.0m³ water per ton of ore, on average (Gunson et al., 2011).

In this sense, it is crucial to control mining water quality through the effective management of this resource through methods of prevention, correction and active and passive treatments. Thus, the success and viability of the mining activity are highly dependent on the water-mining interaction, and this requires knowledge of the hydrological context and appropriate interaction not only in the phases of exploration, operation, closure and post-closure of mines, but also in the treatment of ores (Ana and Ibram, 2006).

Fennel (2012) consider that water use management is one of the biggest challenges to safe economic development in mining. This author states that an integrated, holistic approach to water management is needed, taking into account scientific, engineering and regulatory aspects in order to ensure sustainable development and use of innovation opportunities in water use management.

According to Braga et al. (2008) the principles that guide the actions of the national water policy can be summarized as follows: (1) recognition of water as a public good with economic value; (2) guarantee of multiple water use; (3) priority of use of water resources in shortages for human and animal consumption; (4) adoption of the river basin as the unit of planning and water management: decentralized management; (5) participation of different levels of government, users and civil society in the decision-making process: participative management.

According to Lambooy (2011), as far as corporate water use is concerned, it is difficult to determine the boundary where public accountability gives rise to corporate responsibility, because: (1) legislation and water management policies vary greatly between countries; (2) different types of industries have different impacts with regard to water; (3) it is difficult to relate environmental impacts directly with water consumption of a given enterprise; (4) various complications occur involving multinational companies in weak governance zones.

Ceres (2010) developed the study in order to evaluate and rank statements and practices with regard to water management in 100 public companies. The statements were assessed using a framework developed by Ceres, in consultation with members of the Investor Network on Climate Risk, based on a review of the Global Reporting Initiative (GRI) indicators, with flexibly to the reality of diverse industries. Thus, the model proposed by Ceres comprises five dimensions analysis divided into subcategories, which form a 100-point scale. The dimensions proposed by the study are: (1) Water accounting, (2) Risk assessment, (3) Direct operations (4) Supply chain and (5) Stakeholder engagement.

This is in line with the studies of Lacy et al. (2010), which showed managers' increasing awareness of sustainability. In research conducted with CEOs from several countries, it was observed that sustainability is now considered as a decisive factor for business success, and it is increasingly incorporated into strategic decisions of companies. The study also points out differences in expectations between managers of small and large companies. According to the study, most CEOs of large enterprises expect sustainability to be already incorporated into business issues within the next 10 years. Small enterprises, by contrast, believe that this integration will occur more slowly, over a period of more than a decade.

In fact, studies show that challenges to sustainability are different in companies with different profiles. In a study conducted in mining, forestry and oil and gas companies, Bansal (2005) found differences in companies' engagement to sustainable development, and identified positive association of factors such as company size and international experience. Sharma and Henriques (2005) point out that larger enterprises perform better in certain sustainability practices, such as pollution control, eco-efficiency and recirculation of materials, as compared with smaller companies. The findings of Hourneaux Junior (2010), which show greater concern of large enterprises with their stakeholders and greater presence of environmental controls when compared with smaller companies, are in agreement with this reality.

Expectations about regulation also appear to be different, depending on company profile. According to Lacy et al. (2010), managers of larger enterprises believe that in the coming years, external pressure, in terms of legislation, will be even bigger and they are less receptive to them,

compared with managers of smaller companies, who expect lower external pressures, but are more receptive, however.

The mineral industry is inserted in this context of integrating sustainability into operations. Although sustainable development is crucial in the economy, it is a major challenge to such industry in social and environmental terms, given the nature of mining activities (Azapagic, 2004).

Brazilian mining industry is among the country's largest water users, with several particular aspects. This is because companies involved range from large enterprises with high environmental impact, but with modern and efficient management of such impact, to small miners that exploit small mines with poor environmental controls (Ana and Ibram, 2006). According to the National Department of Mineral Research (DNPM, 2010), 70% of Brazilian mines are considered small, 25% are medium-sized and 5% are large. This also confirms the high diversity in the profile of these companies.

According to McLellan et al. (2009), the mineral industry has advanced in the search of alignment and commitment to sustainable development, for example, by reducing the impact caused by the production process. Azapagic (2004) states that this industry has been engaged in the sustainability debate, and developed strategies to face the challenge of sustainable development.

Hilson and Murck (2000) consider that the key issue is how to align the concepts of sustainable development with the reality of the mining industry so that this can be applied to the mining sector. The literature of sustainable development does not precisely propose how mining can contribute to sustainable development by integrating environmental and socioeconomic aspects. This integration requires a commitment to continual environmental and socio-economic improvement, from mineral exploration, through operation, to the end of the chain. McLellan et al. (2009) corroborate the importance of planning for the implementation of sustainable development in the mining industry, by both small and large enterprises.

In view of the challenges and the concepts presented, the following hypothesis was formulated for this study: H1- There is an association between company size and water use management.

Thus, the hypothesis was tested in order to confirm the association between company size and water use management practices in the study companies. The research method used in the development of this study was aimed at achieving such goals.

## METHOD

This section addresses the classification of the study and the adopted methodological procedures. In order to achieve the proposed objectives, a descriptive, quantitative research study was developed, and conducted through a survey.

The survey was targeted to industries belonging to the Brazilian mineral sector, linked to the Brazilian Mining Institute, considering that this is the largest organization representing companies and institutions working in this sector. For composition of the target population of this study, the following inclusion criteria were adopted: (1) The enterprise has to be a member of the Brazilian Mining Institute or another association linked to this institute. (2) The enterprise develops extraction, transformation or processing of any mineral goods.

All companies that fitted the inclusion criteria were contacted. The sample was composed of companies that actually received, filled in and returned the data collection instrument. A total of

260 questionnaires were sent and 50 of them were returned, yielding a response rate of 19%. The number of returned questionnaires allowed the implementation of statistical tests in order to achieve the objective of the study. However, it does not allow the results to be extrapolated to a larger universe of analysis, because it is not a representative sample of this population. Data collection was performed between October 2011 and October 2012.

In order to identify business practices in water use management, the model proposed by Ceres (2010) was used. It considers five dimensions of analysis by means of 19 variables. In this sense, aspects are evaluated as regards: (1) water accountability, (2) risk assessment, (3) direct operations, (4) supply chain, and (5) stakeholder engagement. A 10-point interval measurement scale was used, where the respondent could indicate the degree of agreement with the practices carried out by the company.

Data analysis was made by means of statistical analysis, with the support of Microsoft Excel and SPSS v.18 software. Data normality was tested by means of the Kolmogorov-Smirnov and Shapiro-Wilk tests. According to Fávero et al. (2009), the Kolmogorov-Smirnov test consists of comparing the observed cumulative distribution with an expected normal distribution. In both tests, it was found that the collected data did not have normal distribution. The Kruskal-Wallis test was used to compare and identify differences in means between groups, according to company size. This non-parametric test is recommended by Pestana and Gageiro (2003), for replacing the One Way Anova test, when the assumptions of the latter are not met, e.g. normality. It is used to test the hypothesis of equality between groups with regard to the location of the observed distribution. When hypothesis H0 is rejected, it is stated that there is a group that differs from the central tendency.

## RESULTS

The first results presented in this session are about the characteristics of the industrial enterprises in the sample. Then, descriptive results about water use management are presented. Finally, the influence of company size on water use management is analyzed.

The enterprises have been operative in the market for 37 years, on average. Two classifications were used for company size: number of employees (Table 2) and gross operating revenues in 2010 (Table 3).

*Table 2 - Company size - Number of employees*

| Company size - Number of employees | Frequency | (%) |
|---|---|---|
| Micro and small enterprises (up to 99 employees) | 17 | 34.00 |
| Medium-sized enterprises (100-499 employees) | 17 | 34.00 |
| Large enterprises (over 500 employees) | 16 | 32.00 |
| **Total** | **50** | **100.0** |

*Table 3 - Company size - Gross operating revenue (2010)*

| Company Size - Gross Operating Revenue (2010) | Frequency | (%) |
|---|---|---|
| Micro and Small enterprises (up to 16 million reais) | 21 | 42.00 |
| Medium-sized enterprises (16 to 300 million reais) | 16 | 32.00 |
| Large enterprises (more than 300 million reais) | 11 | 22.00 |

| | | |
|---|---|---|
| Did not answer | 2 | 4.00 |
| **Total** | **50** | **100** |

As for gross operating revenues, there is a predominance of micro and small enterprises, which represent 42% of the sample, followed by medium-sized enterprises (32%). This distribution is in line with the profile of the mineral sector, which according to the DNPM (2010), is composed mostly by small enterprises. The sample is diverse as for type of extracted mineral: 17 different types of minerals were identified among the study enterprises.

*Table 4 – Water use management - descriptive statistics*

| Variables | Mean | Standard Deviation | Coefficient Variation (%) |
|---|---|---|---|
| **1 Water accountability** | 0.56 | 0.30 | 53.53 |
| Data on water withdrawal/consumption | 0.68 | 0.36 | 52.13 |
| Data on wastewater discharge | 0.70 | 0.36 | 52.00 |
| Data on the water footprint of suppliers | 0.31 | 0.37 | 119.68 |
| **2 Risk assessment** | 0.77 | 0.30 | 39.02 |
| Disclosure of physical risks | 0.79 | 0.32 | 41.23 |
| Disclosure of reputational risks | 0.80 | 0.30 | 37.63 |
| Disclosure of regulatory risks | 0.76 | 0.35 | 46.30 |
| Disclosure of litigation risks | 0.72 | 0.35 | 48.14 |
| **3 Direct Operations** | 0.67 | 0.31 | 45.59 |
| Description of water-related policies and management systems | 0.70 | 0.37 | 52.65 |
| Information on non-compliance, violations, or penalties associated with water use or wastewater discharge | 0.73 | 0.39 | 53.15 |
| Qualitative description of company efforts to reduce water use (corporate level and operations) in water-stressed regions | 0.78 | 0.29 | 37.23 |
| Qualitative description of company efforts to reduce wastewater discharge corporate level and operations) in water-stressed regions | 0.75 | 0.33 | 44.41 |
| Quantitative targets to improve corporate or site-level water withdrawal or consumption | 0.55 | 0.42 | 75.38 |
| Quantitative targets to improve corporate or site-level wastewater discharge | 0.54 | 0.43 | 79.01 |
| **4 Supply Chain** | 0.32 | 0.30 | 95.02 |
| Description of efforts to assess, evaluate, or train suppliers on water management | 0.35 | 0.35 | 102.18 |
| Description of eff orts to gather and track data on suppliers' water impacts | 0.29 | 0.33 | 114.34 |
| Quantitative targets to reduce water impacts in the supply chain | 0.33 | 0.36 | 110.24 |
| **5 Stakeholder Engagement** | 0.48 | 0.35 | 74.12 |
| Collaboration with local and national governments and international institutions on issues (drinking water and sanitation) | 0.52 | 0.37 | 71.71 |
| Collaboration with local and national governments, businesses, NGOs, andcommunities on watershed management or restoration | 0.47 | 0.40 | 84.59 |
| Consultation with local communities and NGOs on water impacts when siting or expanding operations | 0.44 | 0.40 | 90.33 |
| N = 50 | | | |

[1]The averages refer to the level of agreement with the companies on the implementation of these practices on a scale with range 0-1, where 1 is the highest level of agreement.

[2]The means of each dimension were calculated from the arithmetic mean of its variables.

The analysis of water use management aims to present the main business practices adopted by the surveyed mineral enterprises. Table 4 shows the results found in each of these dimensions and their respective variables.

The results show a prevalence of 'risk assessment' practices as regards water use. This dimension is associated with knowledge of the enterprises of the various water-related risks to which they are exposed. The companies in the mining sector had high means for risk assessment, especially physical and regulatory risks, compared with companies in other sectors. This is due, according to Ceres (2010), this activity, which is highly dependent on water availability on a large scale (physical risks) and subject to increasing pressure from legislation (regulatory risk).

The means in the 'operational' dimension, referring to direct operations, are worth of notice. This dimension is related to water use management at the operational level in the enterprises and it is also associated with water management policies and systems, in compliance with water-related regulations and efforts and quantitative targets for reducing water use and wastewater discharge.

The third dimension with higher means in water use management refers to 'water accounting'. This category considers companies' control of water footprint, wastewater discharge and water footprint of suppliers, in quantitative data.

Finally, the two dimensions with the least relevant results: the dimension 'stakeholder engagement', which considers the involvement of companies with stakeholders, and the dimension 'supply chain', which assesses the degree of commitment of companies to suppliers, as regards water use, confirming the thought of Hilson and Murck (2000), who highlighted the need for greater integration between mining enterprises and their stakeholders.

According to the gross operating revenues, significant differences were found in the three dimensions of water use management. (Table 5).

*Table 5 - Management of water use in accordance with the gross operating revenue*

| Dimensions | Company Size - Operating Revenue (in millions of reais) | Observ. | Means of sizes | Chi-square test | Sig |
|---|---|---|---|---|---|
| **Water accouting** | Micro and Small enterprises | 21 | 18.62 | 6.667 | **0.033*** |
| | Medium-sized enterprises | 16 | 29.31 | | |
| | Large enterprises | 11 | 28.73 | | |
| **Risk assessment** | Micro and Small enterprises | 21 | 22.33 | 1.948 | 0.385 |
| | Medium-sized enterprises | 16 | 24.03 | | |
| | Large enterprises | 11 | 29.32 | | |
| **Direct Operations** | Micro and Small enterprises | 21 | 17.52 | 9.482 | **0.009**** |
| | Medium-sized enterprises | 16 | 30.19 | | |
| | Large enterprises | 11 | 29.55 | | |
| **Supply Chain** | Micro and Small enterprises | 21 | 23.74 | 0.117 | 0.929 |
| | Medium-sized enterprises | 16 | 24.94 | | |
| | Large enterprises | 11 | 25.32 | | |
| **Stakeholder Engagement** | Micro and Small enterprises | 21 | 18.14 | 8.731 | **0.013*** |
| | Medium-sized enterprises | 16 | 31.66 | | |
| | Large enterprises | 11 | 26.23 | | |

N = 48

[1]Kruskal-Wallis test with significance obtained by the Monte Carlo method. * Sig p<0.050; **Sig p<0.01
[2] Micro and Small enterprises (up to 16), Medium-sized enterprises (16 to 300) and Large enterprises (more than 300), [3] Did not answer = 2

The data presented showed that smaller companies, considered as micro and small enterprises, have lower means in the dimensions 'water accounting', 'direct operations' and 'stakeholder engagement', compared with other companies.

According to the number of employees, significant differences were found in the three dimensions of water use management: 'water accounting', 'risk assessment' and 'direct operations'. The mean in each of the categories and the significance of the statistical analysis are shown in Table 6 below. It can be seen that companies with fewer employees have lower means in the dimensions 'water accounting' and 'direct operations'. In the dimension 'risk assessment', medium-sized enterprises have the lowest rates.

Accordingly, it can be seen that the water use management practices are influenced by company size, both in terms of operating revenue and number of employees.

*Table 6 - Water use management and number of employees of companies*

| Dimensions | Company size - Number of employees | Observ. | Means | Chi-square | Sig |
|---|---|---|---|---|---|
| Water Accounting | Micro and small enterprises | 17 | 18.53 | 7.474 | **0.019*** |
| | Medium-sized enterprises | 17 | 26.06 | | |
| | Large Enterprises | 16 | 32.31 | | |
| Risk assessment | Micro and small enterprises | 17 | 28.56 | 6.301 | **0.043*** |
| | Medium-sized enterprises | 17 | 18.56 | | |
| | Large Enterprises | 16 | 29.63 | | |
| Direct Operations | Micro and small enterprises | 17 | 19.79 | 7.741 | **0.020*** |
| | Medium-sized enterprises | 17 | 23.74 | | |
| | Large Enterprises | 16 | 33.44 | | |
| Supply Chain | Micro and small enterprises | 17 | 21.68 | 2.911 | 0.221 |
| | Medium-sized enterprises | 17 | 30.06 | | |
| | Large Enterprises | 16 | 24.72 | | |
| Stakeholder engagement | Micro and small enterprises | 17 | 21.00 | 4.849 | 0.090 |
| | Medium-sized enterprises | 17 | 24.03 | | |
| | Large Enterprises | 16 | 31.84 | | |

N = 50

[1]Kruskal-Wallis test with significance obtained by the Monte Carlo method. *Sig p<0.05; **Sig p<0.01
[2] Micro and small enterprises (up to 99), Medium-sized enterprises (100-499) and Large Enterprises (over 500)

It is evident that water use management practices, in most cases, are more incipient in smaller companies, compared with large companies, which adopt more efficient practices.

These results are in line with the information provided by ANA and IBRAM (2006), which cite, as a specific aspect of the mining industry, the fact that the industry makeup ranges from large enterprises, which have high potential for environmental impact, but have modern and efficient management of such impacts, to small miners that exploit small mines with poor environmental controls and planning. Thus, given the profile of the Brazilian mineral sector, which according to the DNPM (2010) is composed predominantly of small enterprises (70% of the mines), there are high water-related risks in the mining activity in Brazil, because smaller

companies adopt less advanced management practices, as compared with larger companies. Such findings corroborate the claims of Hourneaux Junior (2010), which show that larger companies are more concerned with their stakeholders, and have better environmental controls when compared with smaller companies. These data also show greater commitment and integration of SMEs to sustainable development, corroborating the results of Bansal (2005) and Lacy et. al (2010).

## CONCLUSIONS

This research made it possible to achieve the purposes of its application, in that it identified the use of water management practices in the surveyed mining industries as well as described the differences on these aspects in view of the size of the companies surveyed.

From this analysis, it was found that the main practices adopted by the mining sector for water use management are the evaluation and understanding of the risks and practices at the operational level in order to decrease water footprint. It was also evident that greater integration is needed between enterprises and their stakeholders and the supply chain, through integrated and collaborative management in order to improve water use management outcomes.

The results presented confirmed an association between company size and gross operating income after analysis of water use management practices in three dimensions: 'water accounting', 'direct operations' and 'stakeholder engagement': smaller companies have lower means in these dimensions. According to the number of employees, significant differences were found in the dimensions 'water accounting', 'risk assessment' and 'direct operations'.

These findings are in agreement with the information provided by Ana and Ibram (2006), whereby controls of the impacts of water use vary according to company size. Thus, the hypothesis of this study was confirmed (H1: there is an association between company size and water use management).

The limitations of this research should be noted, however. Given the scale of the Brazilian mineral sector, the results cannot be extrapolated to other Brazilian mining enterprises, since it is not a representative sample of this population. A suggestion for future research is to further analyze these relations in a broader set of companies in the industry. It is also suggested that the results can be compared with companies in the mining sector in other countries, as well as in other sectors of the Brazilian economy which are also impacted by the challenges of water use management.

Finally, there are contributions of this research to the academic advancement of social and environmental management. The results presented reflections and allow the discussion of aspects of water use from the perspective of business management. It was verified, through a holistic and integrated perception of aspects of water use, that there is an association between these practices and the size of the companies studied. It is noticed that smaller companies adopt less advanced management practices, as compared with larger companies. Thus, water use management poses a challenge to the industry, given that, in most cases, it is made up of small enterprises.

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