Volume : 3 | Issue : 2 | February 2014 • ISSN No 2277 - 8179

Natural Resources Sustainability of Iron Ore Mining

Earth Science

KEYWORDS : Sustainability, iron, energy, CO2 emissions

Dr.Chinnaiah

Department of Earth Science,University of Mysore Manasagangotri,Mysore-6

ABSTRACT

In the present article, a new tool to determine environmental sustainability, the energy impact index was developed to classify different iron mine projects according to two main parameters including energy consumption and CO2 emissions. The energy impact index considers the characteristics of the mineral such as the quality, size, hardness, iron ore grade, reducibility, mineral/waste rate, and type of deposit, mining processes type of exploitation, ore processing, available technology, and transportation.

Introduction

Mining sustainability has been of significant interest to the mining industry. Currently, mining companies have different tools to show their commitment to the values of environmental sustainability studies on mineral efficiency, life-cycle assessment, cost/benefit analysis, mining sustainability indicators, and environmental accounts, protocols on the safe use of mineral raw materials, risk analysis, ecological footprint, best available technologies, and sustainability reports. In the present study, a new environmental sustainability classification tool was created by constructing the energy impact index. The scope of the proposed tool includes various processes such as iron extraction and transformation into blast furnace raw material of ore processing and transport.

The main parameters are explained. Afterwards, several iron-mining projects are analysed to explain the behaviour of the tool.

Parameters

Mineral deposits can be identified and classified according to their environmental sustainability by determining the characteristics of the deposit and its exploitation, the present study, including energy consumption and CO2 emissions. From an environmental perspective, an underground mine is more energy-efficient than an open pit mine. Best available technologies, appropriate equipment and successful site locations with good infrastructures can improve energy efficiency. Mineral characteristics also affect energy efficiency, including the type and physical properties of the ore (hardness, grain size, magnetic susceptibility, and friability). The size of the site clearing, mineral/ waste ratio, and ore processing method must also be considered. Other parameters related to the mineral including the quality, end-use, ore grade and type of gangue, must be determined.

Different parameters can be used to determine the environmental sustainability of a mineral deposit. However, the following factors are critical for the energy impact index tool:

Energy consumption, including the energy required for the mining and processing of iron ores. Such processes as blasting, ripping out, loading, and transporting ore to treatment plants, as well as the treatment and transportation of the product to the market, consume significant amounts of energy. Units of MJ/ton of ore are often used. The total amount of energy consumed in the aforementioned processes is not immaterial.

Stage	Consumption	Units
Perforation	1.8	MJ/t
blasting	3.1	MJ/t
Loading	6.7	MJ/t
Transport to treatment	53.7	MJ/t
Primary crushing	0.83	MJ/t
Coarse screening	0.04	MJ/t
Secondary crushing	2.2	MJ/t
Grinding	69.7	MJ/t
Magnetic separation	3.6	MJ/t
Fines screening	0.72	MJ/t
agglomeration	1.5	MJ/t
Transport to port	1.2	MJ/t
Transport to market	0.003	MJ/t

Table 1 shows the energy consumption of mining, processing, and agglomeration. In particular, agglomeration was included in the table because pelletisation is performed near the mine, while coarse fines are sent to sinter plants (but already sold). Filtering, pumping, community consumption and other operations that consume energy were not included in the table because these processes are of minor importance, and differences between exploitations are not significant.

CO2 emissions in mining and ore processing (units of kg CO2/t). Energy consumption and CO2 emissions are closely related because the energy required by a particular process is directly related to CO2 emissions. Therefore, carbon dioxide emissions cannot be analysed as a single parameter in the index. CO2 emissions are dependent on the energy source used (coal, oil, natural gas, or renewable sources); therefore, the efficiency of energy consumption and the source cannot be defined using a single parameter. Similarly, an operation cannot be environmentally assessed using only energy consumption data. Depending on the energy source, the operation may emit so much CO2 into the atmosphere that it can be transformed from an energy-efficient exploitation to an environmentally deleterious process

Stage	Energy source	Kg Co2/t Mineral emissions
Perforation	diesel	0.1
blasting	explosive	0.3
Loading	diesel	0.05/km
Transport to treatment	diesel	Acc country
Primary crushing	electricity	Acc country
Coarse screening	electricity	Acc country
Secondary crushing	electricity	Acc country
Grinding	electricity	Acc country
Magnetic separation	electricity	Acc country
Fines screening	electricity	Acc country
agglomeration	Coke/ electricity	125
Transport to port	diesel	0.06/km
Transport to market	Fuel oil	0.02/km

Influence of reducibility

The effects of selecting an appropriate iron ore are relevant when the ore is reduced in a blast furnace. Although hematite possesses a higher ratio of oxygen (O/Fe = 1.5) than does magnetite (O/Fe = 1.33), hematite is more easily reducible than magnetite because magnetite is crystalline (is less reactive and displays a lower ability to reduce than hematite).

Thus, the benefits achieved when pre-reducing iron ore must be introduced into the index. The use of pre-reduced ore as a raw material in a blast furnace effectively reduces energy consumption. This favourable effect was introduced into the energy impact index by applying the energy efficiency parameter μR. Although the efficiency of pre-reduced ore occurs downstream in the blast furnace, this efficiency is reflected in the EII calculation. The value calculated by the proposed tool is based on the processes and characteristics of the mineral ore (even the reducing conditions).

As an example, a quality lump ore only requires minor crushing and screening prior to transportation to the bulk carrier. The ore must observe with certain chemical and physical characteristics. Non-agglomerated ore represents 25 % of the iron used worldwide, and iron pellets represent another 25 %. Sinter covers the remaining 50 %.

Due to the use of pre-reduced ore in the blast furnace, the rate of reducing agents in the blast furnace decreases, which saves energy. Whether significant energy savings can be achieved when the entire hot metal process is considered, including pre-reduced ore production processes must be determined.

Natural lump ore has a lower degree of reduction than do iron pellets. Some authors suggest that this effect may be due to the greater porosity of the pellets.

The degree of reduction has been studied in detail. Specifically, the time required to secure a 90 % degree of reduction at a temperature of 880 ºC is approximately 120 minutes, whereas the time to secure a 60 % degree of reduction at the same temperature is 20 minutes. The productivity rate at a 60 % degree of reduction is approximately six times greater than that of a 90 % degree of reduction.

As a result, the unit energy consumption of the blast furnace decreases by 0.97 GJ/t pig iron or approximately 6 %. After taking into account the energy required to produce pre-reduced ore (0.94 GJ/t pig iron) and considering the reduction in energy required to transport the ore by sea to Japan (0.02 GJ/t pig iron), the decrease in energy consumption is 0.05 GJ/t pig iron or approximately 0.3 %.

Although is the aforementioned facts are widely accepted, the author concluded in another article that blast furnace processes are not negatively affected by the substitution of natural lump for iron pellets.

Therefore, when iron ore is pre-reduced, the reduction parameter (μR) should be used to decrease the energy consumption value of the EII. This reduction coefficient reaches a maximum value of 0.97.

Due to the fact that the real savings are produced upstream in the blast furnace (approximately 80 % of the total energy consumption), the introduction of this energy efficiency into early calculation stages can be considered to be a reward for saving energy when the furnace is fed with pre-reduced iron ore.

Chemical composition and mineral grade
According to the chemical composition and iron grade, mineral ore influences the energy requirements of blast furnaces used for the production of pig iron. The amount of slag is affected by the iron content (and gangue composition) and the amount of lime and limestone necessary to achieve adequate slag basicity.

The chemical composition and iron grade must be determined to modify the blast furnace energy demand (approximately 1–2 GJ/t).

The energy needs of a blast furnace depend on the quality of the ore. As the metal content increases, the energy required for the production of iron decreases. A lower metal content results in more slag, as well as greater limestone additions and higher energy use. Variations in the chemical composition of ore can lead to 10–15 % differences in blast furnace energy use. The use of prepared burden (sinter and pellets) substantially reduces the coke ratio. Data for European blast furnaces suggest that the coke ratio increases from 330 to 410 kg/t as the prepared burden ratio decreases from 95 to 65 % (Lacroix, et al., 2001). However, the impact on the total blast furnace balance is less evident. Chinese research indicates that if the iron content of the feedstock improves by 1 %, coke use decreases by 1.5–2 % (Yu, 2003; Wei 2006).

Effect of the iron ore grade
Among industrial iron ores (magnetite, hematite, limonite and siderite), high-grade ores contain more than 55 % iron, while ores with iron contents below 25 % are considered economically non-exploitable (cut-off grade). The effects of the iron grade are more evident in the energy consumption of mining than the opportunities lost when a higher grade ore is not used (not to mention the improvement in product price and, approved break even iron grade, and the easier supplier differentiation).

When the iron grade is too low to transport the ore, the ore must be agglomerated which demands a considerable amount of energy (1,500 MJ/ton of ore during pelletisation.

Because the energy demand depends on the iron grade, a magnetite with an iron content of 72 % can be compared to a hematite with an iron content of 62 %. For global processes involving iron ore, G1 hematite demands 9,978 MJ/ton of ore, while G2 magnetite requires 11.542 MJ/ton of ore. The energy difference is equal to 10 %; therefore, the energy demands of the ores are similar.

The energy impact index considers the ore grade by applying a function that reflects the relationship between the iron percentage and CO2 emissions. The energy used to release low-grade iron ore is greater than the demands of a DSO. Nevertheless, at times, DSO does not have a high grade after mineral processing.

Therefore, an exponential function was adjusted to reflect the relationship between CO2 emissions and iron ore grade. This curve allows us to understand how energy consumption and emissions increase for lower iron ore grades (do not forget grinding limitations). When the grade is equal to 100 % iron, consumption decreases exponentially as the amount of CO2 decreases.

Environmental impact Assessment:
The Environmental Impact Assessment categories, including global warming (CO2, CH4 and NOX), acid rain, eutrophication, natural resource depletion, waste, indoor air quality and water intake, habitat alteration, smog, ozone depletion, ecological toxicity and human health. This score, along with economical considerations, is used to obtain a global impact score.

Following the characteristics of iron mining was introduced, environmental impact was related to energy consumption (with fossil fuels as the main source) and CO2 emissions (which are derived from the energy demand and, include global warming hazards). Iron ore depletion is not considered a relevant impact, despite the growth in mineral consumption.

Building for Environmental and Economic Sustainability, an environmental software creator was selected from different environmental impact assessments to develop the Environmental impact categories can be classified according to their weights: 5 % impact for smog, ozone depletion and acid rain, 10 % impact for eutrophication, water intake, habitat alteration and ecological toxicity, and 30 % for global warming. After global warming, the most relevant contributor is fossil fuel depletion, which has a 10 % impact followed by air contamination.

The most relevant contributors are global warming (30 %) and fossil fuel depletion (10 %). Considering only these impacts, new percentages were proposed. The percentages supported by hierarchists (human health = 70 % and resources = 30 %) were sufficient to infer the new weights. As a result, the impact of CO2 emissions was (global warming) equal to 70 %, while the impact of fossil fuel depletion was set to 30 %.

The proposed distribution originates from human concerns on global warming, which led to a higher weight for CO2 emissions than energy consumption (industrial emissions accounted for 14 % of human production, not considering a change in land use, agriculture and waste. Of that proportion, 4 % was attributed to mining. Moreover, from the global mining share, 2 % was derived from iron ore extraction; however, with energy consumption, the biggest problem could be the depletion and substitution of fossil fuels).

Energy resource substitution (due to oil depletion) leads to the adoption of different sources with various green house gas emissions, depending on the source of energy (percentage of different electric power generation technologies) from every country. For instance, in countries with large hydraulic resources, the omission of oil would improve the environment, because a non contaminating source would replace oil emissions; however, in countries (e.g., China) with a high percentage of coal power plants, oil replacement would not be positive from an environmental point of view.

Mineral use and ore processing.

Pelletising and sintering consume significant amounts of energy and emit large volumes of CO_2, due to transport and blast furnace feed requirements.

Depending on the end-use of the iron ore (pig iron, sponge iron, commodities such as cement, etc.), different mineral properties are required.

Iron ore is subjected to several processing stages to increase the iron content and reduce the amount of mineral impurities, depending on its end use. Ore processing is affected by the type of deposit and profit requirements. High-grade ores are treated to obtain a homogenous product, remove fines and reduce impurities. However, lower grade ores require mineral beneficiation to obtain a concentrate ore that can compete with high grade ores in international markets.

CONCLUSIONS

Therefore, energy consumption, CO_2 emissions and processes that transform ore into blast furnace feedstock are the main characteristics affecting the sustainability of iron ore and mineral deposit mining.

The aforementioned information was properly weighted, and an iron deposit evaluation that can be used to develop a sustainability classification was obtained by introducing other related parameters note that the results are relative values with regard to other mines and global circumstances.

Thus, energy consumption and CO_2 emissions are merged into the new index, which assesses the energy required to perform essential processes according to the type of exploitation, technology applied, type of deposit, mineral/waste ratio, iron grade and other mineral features. The optimisation of the aforementioned parameters will lead to higher energy efficiencies (fossil fuel depletion is taken into account). CO_2 emissions reflect the energy consumption and main energy sources used during mining (both of which are included in the energy impact index), which are the most significant issues, due to their impact on the environment. Other parameters that assess mineral and process characteristics are included in the index to an equal extent.