Framework of Green and Sustainable Mining: A Case Study

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ABSTRACT – Green mining was proposed to make mining operations more sustainable than in the past as it focuses on resource, environmental, and socioeconomic sustainability. The goal of this study is to develop and implement green mining technologies and processes that improve environmental performance and maintain competitiveness from the start to the closure of mines in Pakistan. A twenty-indicator evaluation index system was developed in this study based on the Driver-Pressure-State-Impact–Response paradigm (DPSIR). Results suggest that green mining has improved, and energy usage and pollutant emissions have been reduced. A strategic framework for green mine construction and mining industry sustainability has been presented.

1. INTRODUCTION

In Pakistan, mineral resource demand has risen in recent years. As a developing country in South Asia, Pakistan is expected to continue the production of coal and other minerals for the market both nationally and internationally. However, the mining industry in Pakistan is confronted with severe environmental pollution and ecological degradation, which limits its long-term sustainability. Because of the weak environmental policies and the unserious image of the mining industry toward green and sustainable mining, the Ministry of Mines and Minerals and the Environmental Protection Agency (EPA) of Pakistan changed the environmental assessment rules and regulations to push the mining industry toward hazard free or green mining.

Green mining has gained popularity, although it is challenging to ensure that mines follow its principles. Developing a mining evaluation index is one technique to overcome this challenge [1]. The evaluation index system facilitates scientific action, plan, or strategy evaluation. The index system in mining industry examines strengths and weaknesses of the system, allowing experts and decision-makers to change or rethink the working/strategic action plan. Due to challenges in rating mines by direct observation, the literature emphasizes green mining evaluation framework [2]. The evaluation index, which is based on DPSIR, helps to ensure that mines are as green as possible.

This study aims to develop a green mining evaluation index. Literature and professional consultation were used to create evaluation criteria and indicators.

The DPSIR model was used for the evaluation index. The principal component analysis (PCA) was used to assess the Makarwal mining area. Finally, further countermeasures to encourage green mining are proposed. This study aims to illustrate the basis for green mining.

2. METHODOLOGY

The DPSIR model is a hierarchical planning and evaluation structure [3]. The comprehensiveness, operability, and integrity of this model are very unique and that's why it is commonly used in indexes. The DPSIR approach was utilized to create a green mining evaluation index, which gives industry experts, researchers, and other stakeholders a scientific basis [4]. Figure 1 depicts the DPSIR framework.

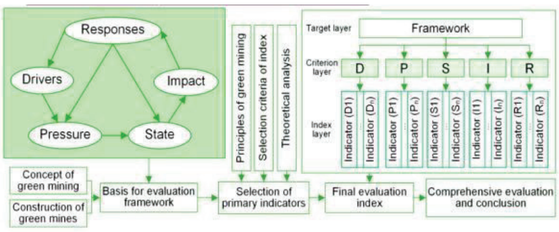

Figure 1 DPSIR framework

In the context of mining, the DPSIR model encompasses socioeconomic growth (driver), environmental pollution and ecological damage (pressure), resources and environmental conditions (state), effects on the environment and society (impact), and solutions (response) to improve efficiency, prevent pressure, recover state, and minimize impacts. The evaluation framework linked the model with green mining and mine construction concepts. Primary indications were picked when the model was postulated. Insufficient evaluation might result from too many or too few criteria. So, scientists chose indicators. Indicator selection took into account resources and the environment in order to examine cause-and-effect relationships more thoroughly and objectively. To better reflect mine conditions, an evaluation index system was devised.

2.1 Data Analysis

This study employed data from mine records and green mine experts. Without compromising information, PCA allows high-dimensional data to be represented in a more manageable manner [5]. PCA can turn numerous variables into principal components. Dimensionality reduction reduces the number of input variables by a high number. The transformed primary components include much of the original data without overlap [6]. Significant components are based on variance contribution ratios above 85%. After dimensionality reduction, compute principal component loading (PCL). In the literature, the key steps of PCA are:

a. First, data were normalized to improve data analysis accuracy and remove dimension influence. Standardizing the data with Eq. (1)

$$X_{ij} \quad \frac{x_{ij}+x_j}{s_j} = \tag{1}$$

b. After normalizing the data, it was checked for applicability to see if any of the samples could be used in PCA. Kaiser Meyer Olkin (KMO) measures the suitability of data for PCA. KMO[0,1] indicates indicator correlation. When KMO is close to 1, all variables are closely correlated, and PCA is appropriate. KMO around 0 makes a sample inappropriate for PCA.

c. In the third phase, R was computed using Eqs. (2) and (3)

$$R = (x_{ij})xp = \frac{z^t + z}{n-1} \tag{2}$$

$$r_{ij} = \frac{\sum z_{kj} \, . \, z_{kj}}{n-1} \tag{3}$$

d. Fourth, based on a variance contribution ratio of more than 85 percent, compute the eigenvalue p of the R-value and identify the number of major components m.

e. Finally, for each principle component (Yp), compute the principal component loading and comprehensive assessment score Eq. (4).

$$F = \sum_{p=1}^{n} a(p) y_p \tag{4}$$

3. RESULTS AND DISCUSSION

Sedimentary rocks ranging in age from the Permian to the Pleistocene. Coal field has served as a source of energy in Pakistan. So far, 25 layers of coal seams have been found, including seven mineable strata. The main mineable seams are 1.36–2.84 m thick and 225–500 m deep. Green mine building in Makarwal has made progress from 2012 to 2015. A linear growth in environmental protection, land rehabilitation, and resource usage was observed. With more safety training, community peace and business culture have improved. This study created a DPSIR-based green mining construction index. All weights were PCA. Green mining has improved. Findings show a developing circular economy, lower energy use, and less pollution. Mining waste reuse benefits the environment. Contamination, gangue accumulation, and ground subsidence hinder green mining buildings. Improve water use, land rehabilitation, the law, and public satisfaction.

The environment is being strained by socioeconomic development, technological innovation, and social idea change. These forces can affect resources, output, and economic rewards. Effective responses can improve driving forces, reduce pressures, get rid of negative effects, and protect the environment. Green mining will advance with innovation and progress. Environmentally sustainable mining requires land reclamation. Green mining demands energy and resource efficiency. Green mining requires a standardized corporate management structure that pursues green innovation strategies to promote green firm culture and communal harmony. Law enforcement, laws that work, and rules from the government help stop damage to the environment and move to "green mines."

4. CONCLUSIONS

Sustainable development depends on green mining. Pakistan prioritizes greens to balance resource expansion and environmental protection. DPSIR is used in this study to evaluate green mining buildings in Pakistan. First, I chose green mining criteria and indicators. PCA assessed them. The green miners' future was envisioned. According to the results, green mining construction has improved with time. Protection of the environment, land restoration, and resource usage have all improved. Concerns remain, such as solid waste utilization, ore processing recovery, and coal washing water reuse. Green mining is a long-term, sustainable solution that can lead to a competitive advantage. To encourage green mining, countermeasures and ideas have been made.

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