Prioritization of Reclamation Criteria during Mines Closure, in Iron Mines of Golgohar, Sangan, Chadormalu

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Expanded Abstract
Introduction

Development of natural resources and mining activities are prerequisite for economic and industrial growth in many countries. In some cases, such mining areas lie within residential or agricultural lands or natural habitats. These are intensifying the contradiction between land use and environmental protection.

Different components of mining activities including exploration, extraction and processing impose extensive physical, chemical and biological impacts on the environment due to nature and characteristics of the activities. Nowadays, mine owners are strongly urged to do their activities in line with environmental standards and regulations. Therefore, in the contemporary world with increasing knowledge of environmental impacts of projects, development of mining industries must be accompanied with welfare as well as effective and continual protection of the environment and of human and financial resources. Implementation of environmental management for mines to minimize the adverse effects of mining activities and mining wastes on the environment as well as planning for reclamation of mine sites after completion of mining activities is of great importance.

Materials and Methods
Reclamation and environmental characteristics

In general, reclamation refers to the activities carried out for the preparation of mined out lands for re-use and rehabilitation of the lands. Such activities do not necessarily restore the land to its former or original form and conditions (prior to mining). Reclamation activities cover different parts of the mining area including pit, waste dumps and tailing dams. In fact, reclamation is not considered as an activity separated in design, planning and mining, but it is regarded as a component of mining activity. It begins from design and planning stage and continues to mining stage.

The major objectives of mine reclamation are risk mitigation and safety enhancement, rehabilitation of lands (affected by mining activities) and water resources, environmental impact mitigation, ensuring the protection of environmental and socio-economic resources of the area after completion of mining activities, creation of new land-uses, stimulation of the proper use of energy resources, and ensuring sustainable exploitation of mines.

In this research, Golgohar, Sangan and Chadormalu as the three largest iron mines in Iran are located in Sirjan, Khaf and Bafgh, respectively. These mines were selected for definition of reclamation criteria. These three large mining-industrial complexes are located in arid warm regions with similar ecosystems.

Study Areas
Golgohar Mine

Golgohar deposit in the form of six separate anomalies lies in Kerman Province at longitude 55° 19′ E and latitude 29° 7′ N. Golgohar orebody is located over an elevated pastureland within a semi-arid area surrounded by mountains with an elevation over 2500m. There is no perennial stream over the area. Dry and arid climate has caused extensive fluctuations in temperature during different seasons and during daytime and nighttime.

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Sangan Mine

Sangan iron ore mine lies in Khorasan-e Rasavi Province, Khaf town at longitude 60° 16′ E and latitude 34° 24′ N with three anomalies. The project site is located over a semi-arid area with predominant warm and dry climate.

Chadormalu Iron Mine

Chadormalu Mine lies in Yazd Province, at longitude 55° 30′ E and latitude 32° 17′ N . Due to vicinity to Markazi and Lut Desert, the area has warm and dry climate with an average temperature of 20.8°c.

Methods

As it mentioned, three large iron mines in Iran named Golgohar, Sangan and Chadormalu were selected for this research. Since the reclamation criteria were qualitative, using mathematic models was impossible. To utilize the collective opinions and existing experiences, Multi-Criteria Decision-Making (MCDM) system and Fuzzy Delphi Analytical Hierarchy Process (FDAHP) were used. Reclamation criteria were defined based on the studied documents, type of ecosystem of the study area, and advice of mining and environmental specialists and executives. Up to 40 criteria and sub-criteria were defined and tabulated for collection of the opinions of professors and specialists in three categories including natural, social and economic environments as bellows:

A) Natural Environment including:

Criteria	Sub-Criteria
Topography and Landform	Slope and land relief
Vegetation	Density, composition, economic value, medicinal value, cultivation method and final land use
Water	Drainage pattern, quality and quantity
Climate	Precipitation, temperature, wind and humidity
Soil	Texture, water retention in soil, pH, organic matter percentage, nutrient percentage, physical and chemical properties, fertility, solubility and erosion
Mine Location	Remoteness from residential areas, protected areas, sensitive ecosystems and historical heritage, former land uses, access roads and the extent of destructed land

B) Social Environment including native inhabitants, immigration, land ownership, employment, values of inhabitants' properties, safety, sanitation and health

C) Economic Environment including losing jobs, income, improvement of individual skills, and cost

After collecting the completed criteria tables, the required data were extracted and the criteria were prioritized based on Delphi Fuzzy Methods.

Result and Discussion

We distributed some questionnaires among the experts. Up to 20 questionnaires out of the total 30 questionnaires were filled out by the experts. The information received through these questionnaires were extracted, classified and used as the input data for FDAHP method. The Fuzzy pair-wise comparison matrix was computed, and the given value to each criterion was compared between different experts; then, the Minimum, Geometric Mean, and Maximum of each criterion were calculated. In the next stage, the relative weight of parameters were computed and shown as fuzzy weight and non-fuzzy weight and the criteria were classified based on their priority.

Based on conducted investigations, reclamation criteria priority has been shown in below table:

In the next step, considering the frequency and distribution of the criteria, another classification was made in terms of different expert groups and the given preference. Ultimately, 16 criteria were selected out of 40 criteria and sub-criteria with the highest preference and priority in iron mine reclamation for the purpose of compilation of reclamation model and instruction. The selected criteria are as follows:

- In topography and landform category: slope and relief
- In vegetation category: vegetation density and vegetation composition for cultivation
- In water category: water quality and drainage pattern
- In climate category: wind blow and precipitation
- In soil category: soil erosion and soil pH
- In mine location category: extent of destructed area and access roads
- In social environment category: indigenous inhabitants of the area, and safety, sanitation and health
- In economic environment category: reclamation cost and income

The results of the research indicate that 16 criteria have priority over other criteria in iron mine reclamation in

Iran. The prerequisite for preparation of an executive plan for iron mines reclamation based on the criteria studied in this research depends on mining method and mine decommissioning and mine closure plan.

Conclusion

The investigations revealed that due to diversity and multiplicity of reclamation criteria, Multi-Criteria Delphi-Fuzzy Decision-Making Method could be applied for defining the priorities of the criteria. In this research, 16 sub-criteria were selected out of 40 sub-criteria with the highest preference and priority in reclamation of the mined out area in the iron mines of Golegohar, Sangan and Chadormalu. These prioritized sub-criteria provide a suitable framework to prepare the reclamation program. This method can be applied for prioritization of reclamation criteria for all mines. However, it should be noted that time restriction, cost, available facilities and equipment as well as ecosystems of the mining areas define the order of priorities of the criteria for reclamation programming. In fact, the reclamation program should be compiled in the form of an integrated management plan taking all criteria into consideration at the same time.

Therefore, reclamation of mining areas is significant for policymakers and authorities of the country due to extensive use of natural resources in mining activities. The rules and regulations related to reclamation of mining areas have not been standardized and administrated in Iran and the duties and commitments of the owners and beneficiaries have not been properly defined. The quantitative and qualitative development of the mines reclamation program should be properly planned.

Keywords: mine reclamation, prioritization, reclamation criteria.