JME

Journal of Mining & Environment,
Vol.3, No.2, 2012, 69-77.

Environmental impact assessment of coal washing plant (Alborz- Sharghi –Iran)

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Received 11 October 2011; received in revised form 23 June 2012; accepted 21 October 2012
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Abstract
This paper utilises the modified Folchi method to assess the environmental impact of coal washing plant, Alborz Sharghi, North-east Iran. In this study, the number of factors designed in the method was slightly modified by focusing on the environmental impact of coal washing operations. In addition, few other factors were designed and added to the previous factors. Then, twenty-one values of environmentally impacting factors from the study area and a case with standard amounts of effects were calculated. This method was conducted by forming an assessment matrix in which one dimension is the environmental components and the other one is impacting factors to estimate the environmental problems arising from the impacting factors of both cases. Comparison of the results of two cases shows that the amount of contamination produced by the plant, especially for components including air quality, agriculture and area landscape is significant.

Keywords: *Modified Folchi method; impacting factor; environmental component; Alborz-Sharghi.*

1. Introduction

Active coal washing plant like other mineral processing plants can create major problems for the environment due to the nature of coal mineral and using chemical materials during the washing operations. Tailings dams and effluents from the plant often comprise the main part of these problems.

Nowadays environmental impact assessment (EIA) and using the necessary measures for industrial and mining activities are essential in preventing or controlling environmental problems. In fact, the purpose of the EIA program is the identification of the harmful effects of an industrial or mining activity and all of affected components from them to reduce long-term effects (Weaver et al. 1996).

Several studies have assessed the adverse effects of mining and related industries on environment and ways to estimate these effects (See White (1991), Pain et al. (1998), Tadesse (2000), Gobling (2001), Haupt et al. (2001), Sare et al. (2001), Folchi (2003), Koca and Kıncal (2004), Driussi and Jansz (2006); Wang et al. (2006), Bozkurt et al. (2008), Hansen et al. (2008), Mouflis et al. (2008), Dhakate et al. (2008), Kuitunen et al. (2008), Mirmohammadi et al. (2009), Monjezi et al. (2009), Ijäs et al. (2009). Among these studies, Gobling (2001) evaluated the environmental impact of a copper mill plant using an entropy method. Koca and Kinca (2004) investigated geo-environmental impacts of the stone quarries in around the Izmir city in Turkey. Wang et al. (2006) expressed that EIA problems need to be modeled and analysed using methods that can handle uncertainties and designed the evidential reasoning (ER) approach. Mouflis et al. (2008) assessed the ecological, landscape and visual impacts of marble quarries on the island of Thasos, NE Greece by employing remote sensing, geographical analysis and landscape metrics. Dhakate et al. (2008) investigated impact assessment of chromite mining on groundwater by geophysical, hydrogeological, hydro-chemical and aquifer modeling studies data in Sukinda chromite mining area, Orissa, India. Kuitunen et al. (2008) have shown how the results of environmental impact assessment (EIA) and Strategic Environmental Assessment (SEA) could be compared using the Rapid Impact Assessment Matrix (RIAM) method. Monjezi et al. (2009) employed Folchi method to evaluate environmental impact of four open pit mines in Iran.

One of the environmental assessment methods is quantitative method of assessment of environmentally affected components from impacting factors using matrix assessment. Environmental components include social, physical and biological environment components such as human health, social issues, surface and ground water, ecology, etc.

The matrix method in environmental assessment can be very useful for its simplicity and comprehensibility of its algorithm. The first matrix method of environmental assessment "as Leopold matrix" designed by Leopold et al. (1971). In this matrix, one dimension contains environmental factors and the other one represents activities of the project. The elements of Leopold matrix indicate the magnitude and importance of the impact of each activity on each environmental factor. Interpretation of results in Leopold matrix is a difficult process (Mirmohammadi et al. 2009) often according to qualitative interpretation.

In order to achieve more understandable results, Folchi method has been developed by Folchi (2003). Initially, the Folchi method was used to evaluate environmental impact of a simple surface mine. It was then employed by other researchers in order to assess the environmental impacts of open pit mines. In Folchi method, the number of impacting factors was approximately limited to technical and operational aspects of mining activities. Furthermore, the magnitudes of impacting factors had small range and were lack of perfect scenarios to obtain them in Folchi method.

Mirmohammadi et al. (2009) presented a comprehensive algorithm in order to take into account more impacting factors comprising positive impacts of mining activities on social issues like domestic, employment, population, social and cultural development and to obtain comprehensible wide range scenarios to cover the issues related to each impacting factors. These researchers modified Folchi method by increasing impacting factors and affected environmental components from them. In this modified method, a reliable scenario was designed as list of questions to each impacting factors to evaluate its magnitude for surface mining projects. In addition, they employed this algorithm to evaluate environmental impact for imaginary cases of mine and mill by considering standard values of magnitude for impacting factors.

In this paper, the environmental impact of Alborz Sharghi coal washing plant, North-east Iran (Figure 1) was evaluated by the slight modifications made on the Folchi algorithm previously modified by Mirmohammadi et al. (2009) and development of its impacting factors.

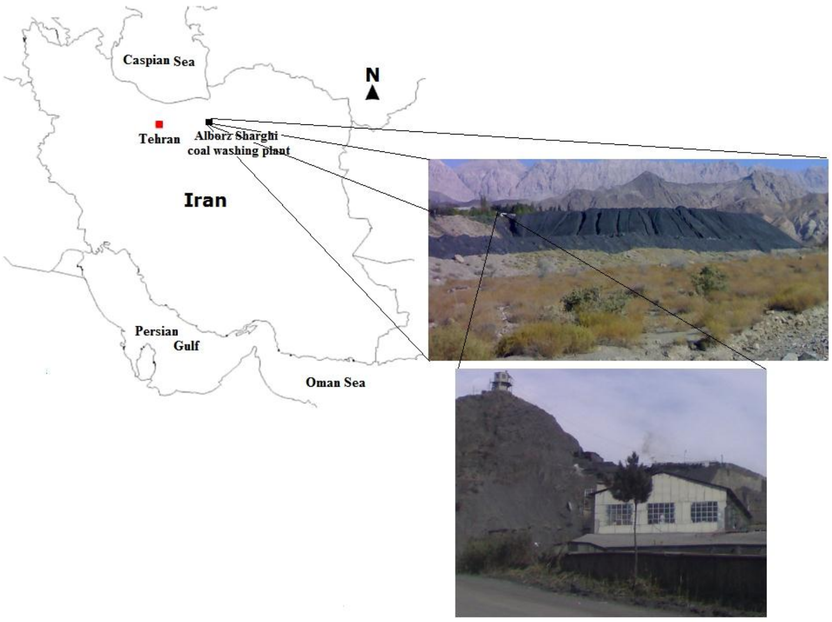

Figure 1. Location of the study area (Alborz-Sharghi coal washing plant, North-east Iran).

In present work, by focusing on coal washing operation, plant effluents, tailings dams and coal waste dumps, some additional impacting factors were considered and added to the pre-impacting factors. Furthermore, due to the importance of the agricultural activity in the study area, this factor was also considered as another environmental component affected by the plant.

Based on the environmental investigations made by Doulati Ardejani et al. (2008), it is understandable that the climate, topography, the method used for coal washing and type of the geological formations in the area are the main factors affecting the pollution generation and discharging pollutants to the receiving environment. In addition, the necessary considerations should also be taken into account on the environmental components to prevent the impact of the auto coal burning phenomenon in the tailings dumps depending on the coal washing method is being used. Then, based on the research presented by Mirmohammadi et al. (2009), the amount of each impacting factor has been determined using related scenario. The influence of ‘‘Impacting Factors’’ (IFs) on the ‘‘Environmental Components’’ (ECs) has been finally obtained.

2. Methodology

The method considered here is based on the Folchi method modified by Mirmohammadi et al. (2009). However, some slight modifications have been done to increase the number of impacting factors. Furthermore, a few changes have been made to use pre-impacting factors according to the case study is being used.

In this method, IFs were first identified and the magnitudes of these IFs were then obtained according to the relating scenario of each IF and studied case. Subsequently, in order to consider the effect of these IFs on environmental components, the influence weight of each IF on each environmental component were defined as nil, minimum, medium and maximum. Table 1 gives environmental components (ECs), IFs and the effect of IFs on ECs. This table represents the matrix in which each element indicates affecting weight of an IF on an EC. The elements of this matrix are quantified by defining maximum effect is twice the medium effect and medium effect is twice the minimum effect and the sum of these coefficients for each EC equals to 10. Therefore, Eq. 1 is used to calculate the effect of IFs on each EC (Mirmohammadi et al., 2009):

$$[C]=[F][M] \qquad (1)$$

where, C represents a (1×12) matrix in which each element represents the amount of overall effect on each EC. Due to the nature of method, this effect is as a fraction of 100 and is expressed by percent. F denotes a (21×1) matrix in which elements represent values of IFs, and M is the quantitative matrix obtained from Table 1.

As mentioned above, environmental studies in the study area indicated that the climate, topography and type of geological formations are the main factors affecting the release and rate of pollutants transportation in the area. In addition, the method of coal washing in the generation of pollutants and some necessary considerations required to prevent the auto coal burning in tailing dumps are significant to be considered as impacting factors.

According to these investigations, five new IFs were added to the pre-IFs that have been presented by Mirmohammadi et al. (2009), and their related scenarios were designed and shown in Table 2 through Table 6. It can be suggested that wet climate condition and rainfall have an important role in pollutants release to the environment. It is clear that an increase in the rate of rainfall increases the rate of emission of pollutants to the surrounding environment.

The magnitude of topography factor depends on the situation of tailing dams and low grade waste dumps, and the situation of waste water effluents from the plant. Locating such sources of pollution on the places with rough topography increases the rate of the pollutants release to the receiving environments. The scenario related to the type of geological formations factor was designed according to the permeability of rocks in the area and their geochemical potential in releasing heavy metals (Hasani Pak, 1991), as well as the results of consulting made by authors with experts. The designed scenario for the factor of coal washing method was normally established based on the chemical materials which are used during washing process. The scenario related to the necessary considerations of auto burning of coal in the tailing dumps was designed according to the necessary standards in coal washing plants in order to prevent this phenomenon in the tailings dumps (Rezai, 2001). To obtain amount of influence of new IFs on ECs (Table 1) according to the methodology, the results of consulting with more than ten experts were collected and average amount of them for each factor has been considered in Table 1.

Table 1. Influence of impacting factors (IFs) on environmental components (ECs) (modified from irmohammadi et al., 2009)

Impacting Factors	**Environmental Component**											
	Human health and immunity	**Social issues**	**Surface waters**	**Underground waters**	**Air quality**	**Area usage**	**Ecology**	**Agricultural**	**Area landscape**	**Quietness**	**Economical issues**	**Soil of the area**
Changing the usage of the area	Med	Min	Med	Med	Nil	Max	Min	Max	Max	Min	Max	Max
Exposition of the plant and the tailing area	Nil	Min	Nil	Nil	Nil	Med	Nil	Nil	Max	Nil	Min	Nil
Interference of input feed with surface water	Max	Nil	Max	Max	Min	Med	Max	Max	Max	Nil	Min	Max
Waste water from plant	Max	Min	Max	Max	Med	Med	Med	Max	Med	Nil	Nil	Max
Increase in the traffic of the area	Max	Max	Nil	Nil	Min	Nil	Min	Nil	Min	Med	Min	Nil
Dust emission	Max	Nil	Med	Nil	Max	Min	Min	Med	Med	Nil	Min	Med
Toxic pollutants and substances emission to air	Med	Med	Med	Nil	Max	Med	Max	Med	Nil	Nil	Max	Nil
Noise pollution	Med	Max	Nil	Nil	Nil	Nil	Med	Nil	Nil	Max	Min	Nil
Land vibration	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Min	Nil
Material existed in the tailing	Max	Med	Max	Max	Max	Med	Med	Max	Nil	Nil	Max	Max
Tailing discharge considerations	Max	Med	Max	Med	Max	Max	Med	Max	Max	Nil	Max	Max
Domestic employment	Nil	Max	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Max	Nil
Population control	Min	Max	Nil	Nil	Nil	Med	Nil	Nil	Nil	Min	Max	Nil
Social and cultural development	Med	Max	Nil	Nil	Nil	Min	Nil	Min	Nil	Nil	Med	Nil
Environmental arrangements	Max	Med	Max	Max	Max	Min	Min	Min	Max	Max	Max	Med
Light	Max	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Med	Nil
Climate of the area	Min	Nil	Max	Med	Nil	Med	Min	Med	Nil	Nil	Nil	Med
Topography of the area	Nil	Nil	Max	Nil	Nil	Nil	Min	Med	Nil	Nil	Nil	Med
Type of geological formations of the area	Min	Nil	Max	Max	Nil	Min	Min	Max	Nil	Nil	Nil	Med
Method of coal washing	Med	Nil	Med	Med	Med	Min	Min	Med	Nil	Nil	Min	Med
Necessary considerations of auto burning of coal in the tailing dumps	Min	Nil	Nil	Nil	Med	Min	Med	Min	Min	Nil	Nil	Nil

Table 2. Climate of the study area (climate conditions affect the pollutants release in the area)

Scenario	Magnitude
Dry climate with very low annual rainfall	2
Dry climate with low annual rainfall	4
Temperate climate with an average annual rainfall	6
Temperate climate with a high annual rainfall	8
Humid climate with a very high annual rainfall	10

Table 3. Topography of the study area, in particular, on waste dump and tailings dams

Scenarios	Magnitude
The surface of the area is completely smooth so that water from precipitation transports pollutants very slowly in the area.	2
The surface of the area is moderately smooth so that water from precipitation transports pollutants slowly in the area.	4
The surface of the area has moderate slope so that water from precipitation transports pollutants moderately in the area.	6
The surface of the area has significant slope so that water from precipitation transports pollutants with considerable rate in the area.	8
The surface of the area is completely high slope so that water from precipitation transports pollutants with high speed in the area.	10

Table 4. Type of the geological formations of the area

Scenarios	Magnitude
Clay and marl	2
Siltstone and clayey limestone	4
Limestone, dolomite, dolomitic limestone and alluvial	6
Sandstone	8
Igneous rocks	10

Table 5. Method of coal washing

Scenarios	Magnitude
Jig and shaking table methods	2
Spiral, reichert cone and hydrocyclone methods	4
Magnetic and electrostatic methods	6
Heavy media method	8
Floatation method	10

Table 6. Necessary considerations to prevent auto coal burning in tailing dumps (number of positive answers to following questions minus number of negative answers is the magnitude of this factor)

1. Have vegetations been eliminated on the area of the tailing dumps at least in 15m distance from the dumps?
2. Have burning materials such as fragments of coal or wood, waste paper, oil, etc. been eliminated in around the tailing dumps?
3. Have the tailing materials been stored as systematic method so that does not cover wide domain?
4. Should to be prevented sudden oxidation of tailings bearing pyrite those are exposed to the air about two weeks.
5. Have the tailings been stored as compact layers?
6. Are crushed the fragments whose size more than 100 mm before storing?
7. Is decreased slope of tailing dump and is smoothed it?
8. Is covered tailing dump by a layer of clay material?
9. Have been passed safety programs by workers and staff to prevent making fire in the vicinity of tailing dumps?
10. Has been constructed fence around the tailing dumps (like as constructed channels) to prevent progressing of the fire?

3. Study area and measurement of impacting factors

Alborz-Sharghi coal washing plant is located in North-east of Iran and has a history about 30 years (Figures 1). The area has temperate climate. It is mountainous with cold winters. Amount of input coal to the plant is about 600,000 ton per year and its recovery rate is approximately 50 percent. Therefore, half of this input coal is dumped as wastes in a close distance of the plant. The input feed was stored in adjacency of the plant before entering the washing operation thereby it can make some environmental problems. Since the process of coal washing is being used in the plant, about 80 percent of the total wastes are produced from the washing operation by Jig machine and the rest is resulted from the floatation process.

Quantity of sulphide in the input coal including native sulphide, sulphate and pyrite is about 3 percent that of the pyrite is the major part. The tailings are dumped in five distinct areas around the plant with respect to their type and history. Moreover, the floatation tailings are discharged into two tailings dams for drying before dumping process.

In the present work, the environmental data related to the above case study were collected and then using the extended method, each of the coal washing plant activities which affects the environment was evaluated. Furthermore, using the magnitude ranges defined in the related scenarios (some of them are in the Mirmohammadi et al., 2009, and the others were extended in this work), each impacting factor of the proposed coal washing plant activity was assessed. Table 7 gives the calculated magnitudes of IFs of the plant with respect to the related scenarios. Standard or allowable values of these magnitudes were also given in this Table.

Table 7. Magnitude of impacting factors for a standard case of coal washing plant and the Alborz-Sharghi coal

Impacting Factors	Standard Magnitudes	Magnitudes for the Alborze Sharghi Plant
Changing the usage of the area	2	5.1
Exposition of the plant and the tailings site	2	8
Interference of input coal with surface water	0	7
Wastewater from the plant	0	10
Increase in the traffic of the area	1	10
Dust emission	0	7
Toxic pollutants and substances emission to air	0	10
Noise pollution	5	5.5
Land vibration	0	5
Material associated with the tailings	1	8.5
Tailings discharge considerations	1	8
Domestic employment	0	-5
Population control	0	-4
Social and cultural developments	0	-3
Environmental arrangements	0	6
Light	5	2.5
Climate of the area	2	5
Topography of the area	2	4
Type of geological formations of the area	2	2
Method of coal washing	2	3.6
Necessary considerations of auto burning of coal in the tailings dumps	0	0

4. Results and discussion

Results of the method used in this study are shown in Figures 2 and 3. Figure 2 shows the standard amount of the overall effect of IFs on each EC. Figure 3 shows the amount of overall effect of IFs caused by the plant. By comparing two sets of results (Fig. 2 and Fig. 3), it is clear that the amount of pollution for most of environmental components is considerable and the plant has a significant role in generating pollutants in the study area. Hence, based on the obtained results, controlling and reducing these undesirable effects using necessary considerations is almost unavoidable.

Most of the environmental components such as human health, surface and groundwater, air quality, ecology, area landscape, agricultural, quietness and soil of the area are considerably being affected of adverse environmental effects from the plant. Therefore, through these results, it can be seen that the Alborz-Sharghi coal washing plant is somewhat harmful for the environment.

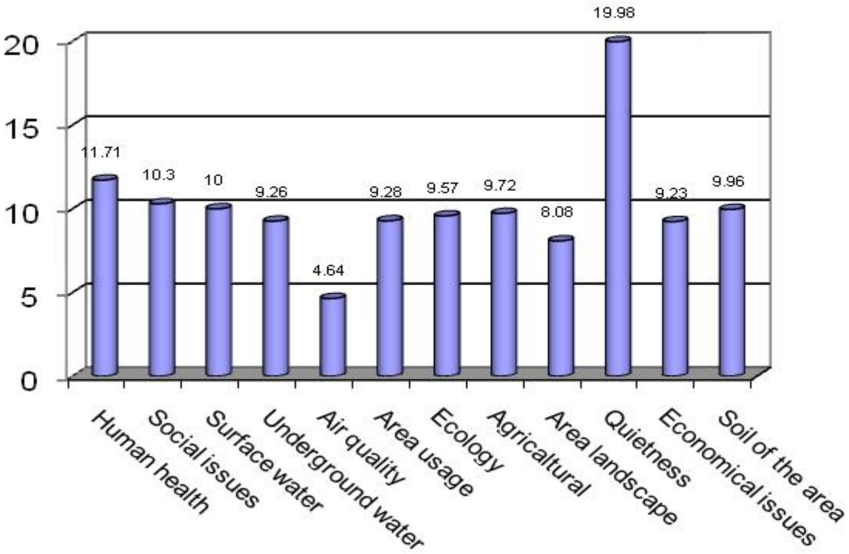

Figure 2. The standard amount of overall effects of impacting factors on each environmental component.

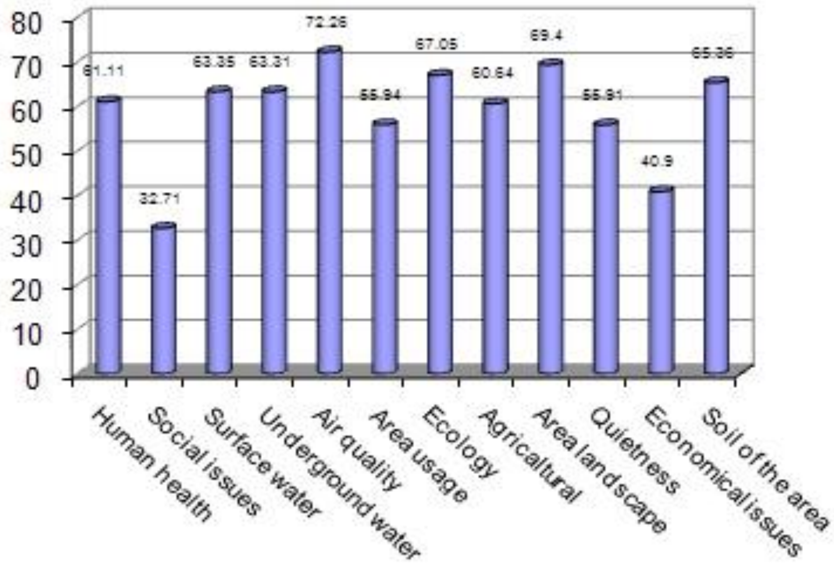

Figure 3. The amount of overall effects of impacting factors on each environmental component for the Alborz-Sharghi coal washing plant.

5. Conclusion

Assessment of the environmental impact arising from mines and mineral processing plants alike other industrial projects is very important in order to control environmental problems. Among the environmental assessment methods, the matrix method, as modified Folchi method, is a valuable technique due to its capability in quick estimation. In this study, almost all of impacting factors on environmental components were considered. These factors include climate of the area, topography of the site, type of geological formations and the coal washing method and also some necessary considerations to prevent auto burning of coal in the tailings dumps, associated with designing the related scenarios. Moreover, required environmental impacting factors were obtained for the Alborz-Shrghi coal washing plant together with their corresponding standard values. In addition, the results of environmental impact assessment of the Alborz-Sharghi coal washing plant were presented by calculating the influencing matrix of impacting factors on environmental components and according to the methodology.

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