A METHOD FOR COAL WASTE DISPOSAL SITE SELECTION FOR PREVENTION OF ENVIRONMENTAL IMPACTS

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Abstract
Acid mine drainage is one of the most important environmental pollutions, that produces many environmental problems. As a result of the development of mining activities in Iran, more acid mine drainage is generated. Coal is considered to be a major source of acid mine drainage and is a main cause of long-term poor water quality. In this study, the pollution problems associated with the coal waste produced in Alborz Sharghi coal washing plant, in Iran, was investigated. Based on the results obtained from field investigations, numerical simulation and geophysical modelling, an appropriate disposal site for coal wastes containing reactive pyrite was selected to minimise environmental effects arising from both active and abandoned coal waste dumps.

Introduction
Coal mines have made considerable contribution to Iranian mining industry and the national economy. The coal produced by mining activity should be washed in order to raise its quality and remove any impurity. The waste produced by coal washing plant often contains pyrite which may be oxidized and produce acid mine drainage (AMD) if it is exposed to the atmosphere.

The groundwater pollution problem is the adverse effect, which may be caused by the pyrite oxidation, AMD generation and subsequence pollutant leaching from the coal washing waste dumps.

Despite many research works have been done to quantify the mechanisms that control the rate of pyrite oxidation and the subsequent leaching of the reaction products related to waste rock dumps (Cathles and Apps, 1975), open cut mines (Jaynes et al., 1984a, b; Doulati Ardejani et al., 2004; Singh and Doulati Ardejani, 2004) and mine tailings (Elberling et al., 1994), no attempt has been made to design an appropriate disposal site for coal wastes containing reactive pyrite to minimise pollution problem associated with coal washing waste dumps. Hence, this paper presents a method for selecting an appropriate disposal site for coal wastes using field investigations, mathematical modelling and geophysical studies. Designing a waste disposal site for a coal washing plant would facilitate the development of a waste dump rehabilitation and environmental management plan during the design stage of a coal washing plant.

Figure 1 shows a schematic diagram of waste dump site which is located in Mehmandoost region at about 400 km north-east of Tehran in Semnan province.

Geology of the study area
The study area is a part of Tazareh coal region and is located in geological sheet 1:100,000 of Shahrood. From geological point of view, the area consists of sandstone, thin bedded coaly shale of Shemshak formation, new alluvial deposits and old alluvial fan with gravel marl and quartz.

Coal in the region is mined by the Alborz-Sharghi coal company. Alborz-Sharghi coal washing plant has being worked for 30 years. The coal extracted from Tazareh, Gheshlagh and Tabas coal deposits are washed in this plant. The processed coal is then being transported to Isfahan and is used in steel company. The input feed of the washing plant is 600,000 ton per year. The coal recovery in the plant is 50%. The rest of the input feed is dumped as waste around the plant. Depending on the method is being used for coal washing, two kind of wastes are produced and dumped in distinct places. These are the waste produced by jig machine and that produced by flotation process. It has been expected that the amount of the coal waste in the study area is about 3 million ton.

Field measurements
Samples were taken from different depths at three points on the waste dump in order to investigate pyrite oxidation process. The samples were analysed using an AA–670 Shimadzu atomic absorption to determine the percent of pyrite remained within the waste particles. The results are given in Table 1.

Mathematical modelling
A one-dimensional mathematical model was presented to simulate long-term pyrite oxidation within the spoils of the coal waste dump and subsequent pollutant generation. The pyrite oxidation reaction is described by the

shrinking-core model (Levenspiel, 1972). Gaseous diffusion is considered to be the main mechanism for the transport of oxygen through the waste (Jaynes et al., 1984a, b; Elberling et al., 1994; Doulati Ardejani et al., 2004). It was assumed that the oxygen is the only participant in the oxidation of pyrite.

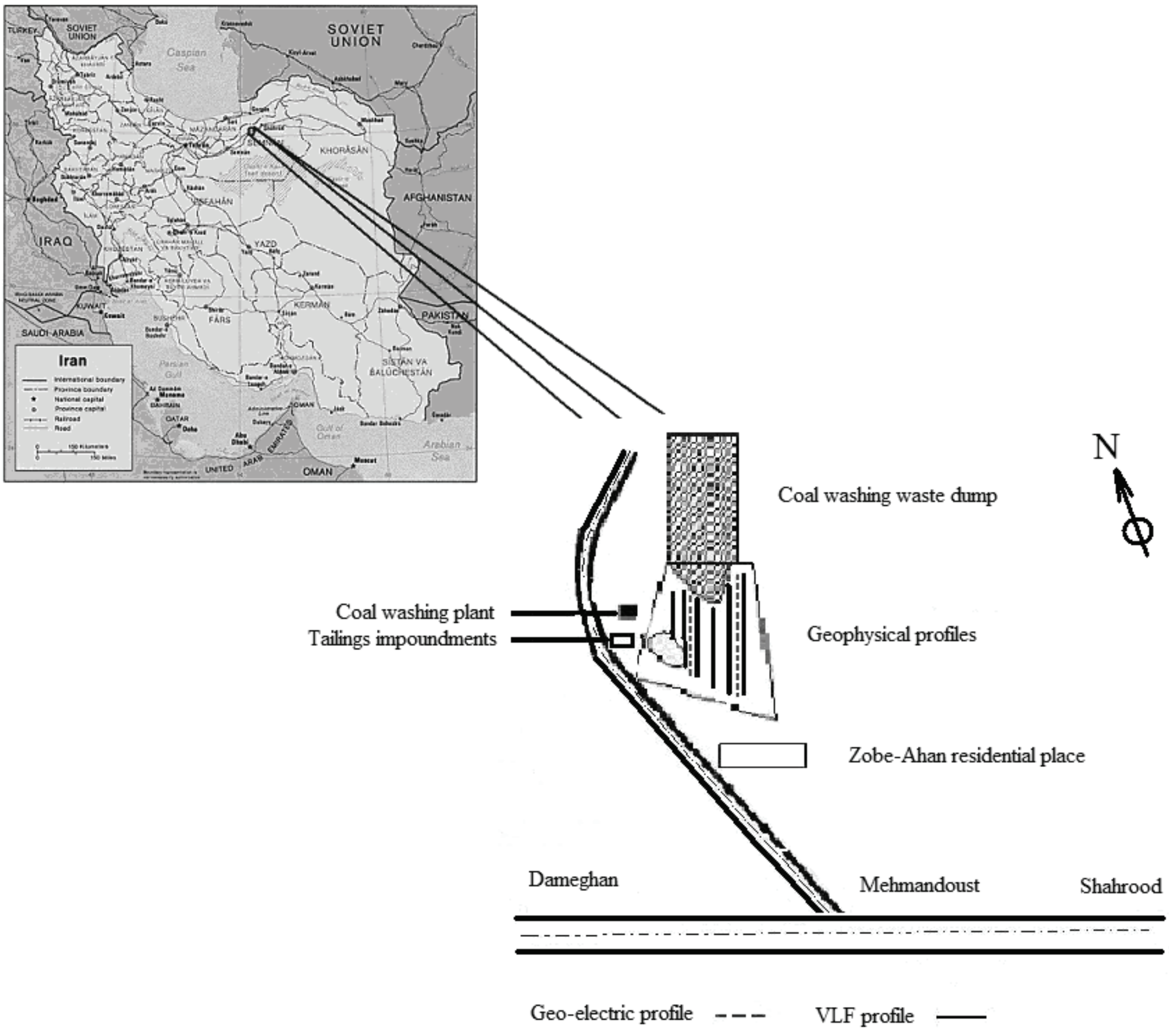

Figure 1. Schematic diagram of coal washing waste dump site.

Table 1. Experimental results for the percent of pyrite remained within the spoil particles.

Sample point No. 1		Sample point No. 2		Sample point No. 3	
Depth (m)	Percent of pyrite remained	Depth (m)	Percent of pyrite remained	(m) Depth	Percent of pyrite remained
Dump surface	1.0	Dump surface	0.87	Dump surface	1.65
0.2	1.32	0.2	1.1	0.2	1.64
0.5	1.53	0.5	1.41	0.55	1.42
1.1	1.6	1.1	1.46	1.1	1.81
1.5	1.62	1.5	1.64	1.5	1.73
-	-	1.6	1.64	1.75	1.75

To solve the mathematical equations describing long-term pyrite oxidation and oxygen diffusion through the pore spaces of waste dump, a numerical finite volume model called PHOENICS (Spalding, 1981; CHAM, 2006) was slightly modified.

Modelling results

Figure 2 compares the model predictions (solid line) and field measurements (data points, Table 1) for the percent of pyrite remained in waste particles of the entire spoil column. This comparison is for the sampling point No. 2 over the waste dump. As it is clear, the agreement between modelling results and field data is somewhat close. Both simulation results and field observations showed that the rate of pyrite oxidation decreased sharply at lower depths up to 0.5 m where oxygen concentration (not given here) decreased rapidly. For an effective diffusion coefficient of $5\times10^{-8}\ m^2/s$ and a simulation time of about 1 year, pyrite oxidation decreased gradually for depths between 0.5 - 1.2 m and for deeper layers (below 1.2 m) where no oxygen is available to oxidise pyrite, the pyrite oxidation reaction was completely ceased. One can conclude from Figure 2 that pyrite oxidation process takes place in the study area. It means that the coal waste dump in the area can be considered as a source of pollution.

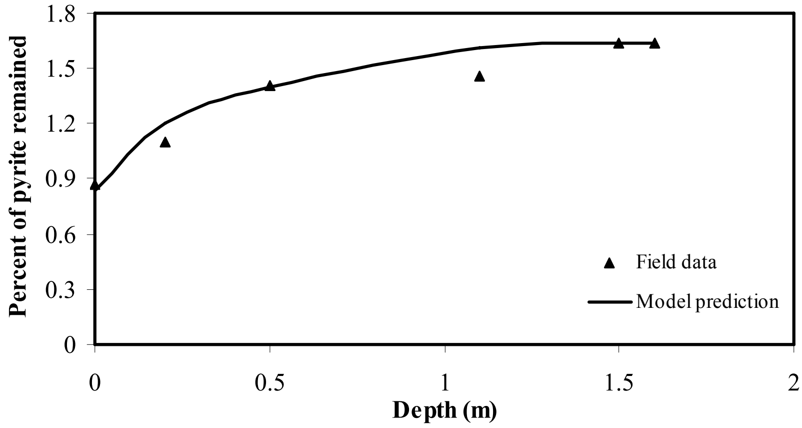

Figure 2. Comparison of the field data and modelling results of the percent of pyrite remained within the waste particles as a function of depth for sample No. 2.

Geophysical investigations

A geoelectrical survey incorporating dipole-dipole array was carried out in order to determine the subsurface layers and investigate the likely transportation process of pollutants leached from the waste dump. A computer software called RES2DINV (Lock, 1999) was used to perform an inverse modelling on the measured geoelectrical data. The results of inverse modelling of resistivity data for the western profile are depicted by Figure 3. The RMS error was 3.25% indicating a good correlation between field data and the obtained model response. As it is evident from the figure, the upper layers are recognised as a series of resistive layers with resistivity greater than 150 ohm.m and average thickness of 35 m. The field measurement of the water penetration into the ground on two locations around this profile show that the rate of water penetration varies from 0.3 to 0.4 mm/hr indicating that qualitatively the permeability of the surface material is very low. Hence this zone of the study area which is located in the south of the newly dumped wastes can be considered as a suitable waste disposal site due to the considerable thickness of surface layers and their low permeability.

Conclusions

This paper presents a method for the selection of an appropriate disposal site for coal wastes using field investigations, mathematical modelling and geophysical studies. The results of a numerical model using PHOENICS package were compared with the field data for the percent of pyrite remained within the pyrite containing waste particles. Both model and experimental data revealed that the pyrite oxidation takes place in the waste dump site of the study area. So, the coal waste dump is noted as a potential source for pollution generation. Although not given here, both numerical model and geophysical inverse modelling results are agreed in the identification of pollutant transport originated from the waste dump. The results of an inverse modelling of the resistivity data proposed a suitable waste disposal site based on the considerable thickness of the surface layers and their low permeability. The amount of pollutants produced in waste dump sites can be reduced by using efficient reclamation techniques during the operation of coal washing plants and also after cessation of washing operations. However, the assessment and development of best reclamation and management techniques in order to minimise the effect of waste dump site on the hydrology and hydrogeology of the area is a long-term and expensive procedure. Selecting a waste disposal site for a coal washing plant would facilitate the development of a waste dump rehabilitation and environmental management plan during the design stage of a coal washing plant.

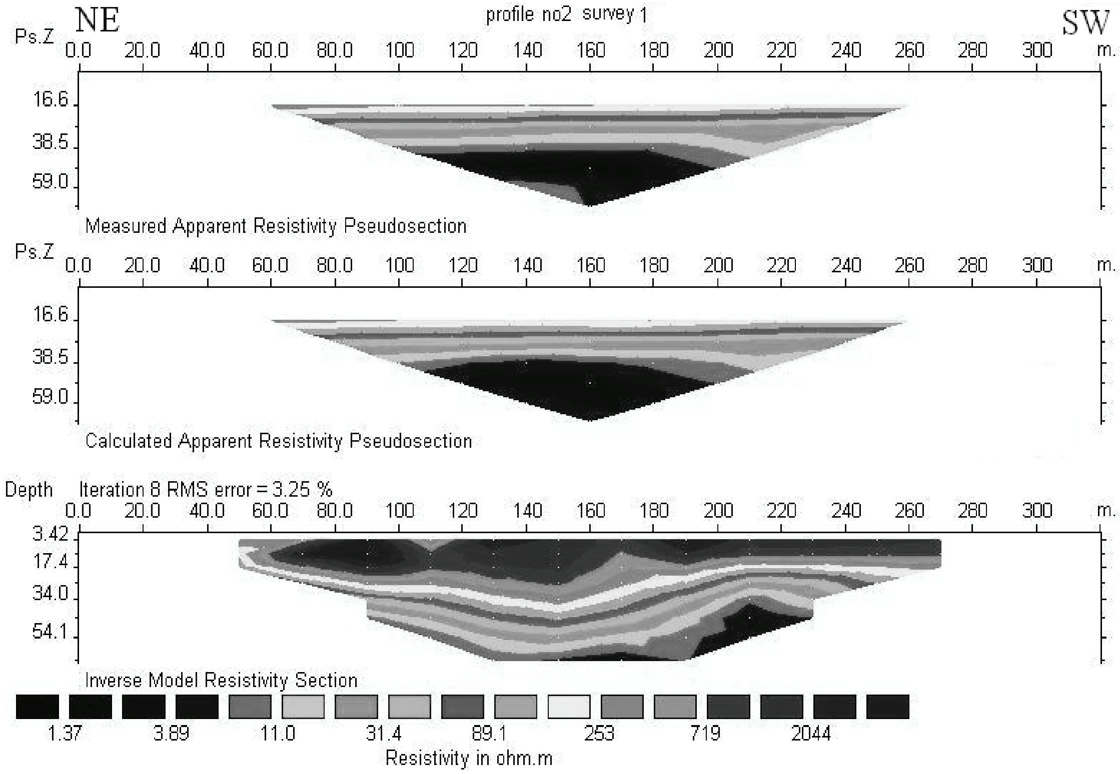

Figure 3. Inverse modelling results for geoelectrical data indicating measured apparent resistivity pseudosection, calculated apparent resistivity pseudosection and inverse model for profile number 2.

Acknowledgements
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References
Cathles L.M., Apps J.A. (1975). A model of the dump leaching process that incorporates oxygen balance, heat balance and air convection. Metallurgical Transactions B 6B, 617-624.
CHAM (2006). The PHOENICS On-Line Information System, http://www.cham.co.uk/phoenics/d_polis/polis.htm .
Doulati Ardejani F., Singh R.N., Baafi E.Y. (2004). Use of PHOENICS for solving one dimensional mine pollution problems. The PHOENICS Journal: Computational Fluid Dynamics & its applications 16, 23p.
Elberling B., Nicholson R.V., Scharer J.M. (1994). A combined kinetic and diffusion model for pyrite oxidation in tailings: a change in controls with time. Journal of Hydrology 157(1), 47-60.
Jaynes D.B., Rogowski A.S., Pionke H.B. (1984a). Acid mine drainage from reclaimed coal strip mines, 1, Model description. Water Resources Research 20 (2), 233-242.
Jaynes D.B., Rogowski A.S., Pionke H.B. (1984b). Acid mine drainage from reclaimed coal strip mines, 2, Simulation results of model. Water Resources Research 20 (2), 243-250.
Lock M.H. (1999). Electrical imaging surveys for environmental and engineering studies. A practical guide to 2-D and 3-D surveys, 58p.
Singh R.N., Doulati Ardejani F. (2004). Finite volume discretisation for solving acid mine drainage problems. Archives of Mining Science 49 (4), 531-556.
Spalding D.B. (1981). A general purpose computer program for multi-dimensional one- and two-phase flow. Mathematics and Computers in Simulation 23(3), 267-276.