Journal of Geology and Mining Research

volume 6 Number 3 April 2014

ISSN 2006-9782

Academic Journals

ABOUT JGMR

The **Journal of Geology and Mining Research (JGMR)** (ISSN: 2006-9766) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as mapping of deformed rock bodies, recovery of natural resources, geotechnical engineering, numerical modelling in geological studies etc.The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JGMR are peer-reviewed.

The **Journal of Geology and Mining Research** (ISSN: 2006-9766) is published twice a month (one volume per year) by Academic Journals.

Contact Us

Editorial Office: jgmr@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/JGMR

Submit manuscript online http://ms.academicjournals.me/

Editors

Prof. D.P. Tripathy
Head, Department of Mining Engineering National Institute of Technology, Rourkela-769008.
India.

Prof. K.C. Tiwari
Department of Geology
The Maharaja Sayajirao University of Baroda
VADODARA - 390 002
Gujarat State – India

Dr. D.S Subrahmanyam
Geotechnical Engineering Division, National Institute of Rock Mechanics,(Govt. of India) ITI Annex Building, Dooravani Nagar Bangalore, Karnataka – 560 016

Journal of Geology and Mining Research

Table of Content: Volume 6 Number 3 April 2014

ARTICLES

Research Articles

academicJournals

Vol. 6(3), pp. 39-45, April, 2014
DOI:10.5897/JGMR14.0202
Article Number: AFBC64C44104
ISSN 2006 – 9766

http://www.academicjournals.org/JGMR

Journal of Geology and Mining Research

Full Length Research Paper

Ranking of coal seams for underground coal gasification (UCG) in Mazino coal deposit, Tabas coal field, Iran

Mehdi Najafi*, Seyed Mohammad Esmaiel Jalali and Reza KhaloKakaie

Faculty of Mining Engeering, Petroleum and Geophysics, Shahrood University, Iran.

Received 12 March, 2013; Accepted 18 April, 2014

The underground coal gasification (UCG) has a potential for converting the world's coal resources into energy, liquid fuels and chemicals. The UCG process involves the injection of steam and air or oxygen into an underground coal seam and igniting and burning of coal *in-situ* to produce the combustible gas. Previous studies showed that many criteria affect site selection of UCG. The criteria include coal seam properties, faulting, discontinuity, properties of hanging wall and footwall of coal seam and hydrogeological regime. In this paper, considering proper UCG site selection criteria, coal seam was ranked and selected for the UCG based on the controlled retraction injection point (CRIP) configuration in Mazino coal deposit. The result of this investigation showed that the M2 coal seam has great advantage (considering the seam thickness and reservoir) related to the other coal seams for the gasification by CRIP configuration.

Key words: Underground coal gasification (UCG), site selection criteria, Tabas coalfield, clean energy.

INTRODUCTION

Coal is the largest fossil fuel resource in the world, with proven reserves that are adequate to meet the expected demand, without much increase in production costs (Couch, 2009). With the depletion in the oil and gas reserves, coal is expected to play an important role in the global energy sector in the near future (BP, 2010).Underground coal gasification (UCG) offers the potential for using the energy stored in coal in an economical and environmentally sensitive way, particularly from deposits that are not mineable by conventional methods (Couch, 2009). Therefore, UCG is a candidate process for converting the world's coal resources into energy, liquid fuels, and chemicals. If the UCG process is developed commercially, it would increase coal reserves by 60% (Sarraf, 2012). The process of UCG eliminates the costs of mining, lowers water consumption and transportation needs, and generates possible sites for CO_2 sequestration, and gasification installation, which are required for traditional surface gasification process (Gregg and Edgar, 1978; Burton et al., 2006). However UCG has some challenges such as process stability, aquifer contamination and ground subsidence. The procedure for *in-situ* gasification of coal is as follows (Figure 1) (Couch, 2009):

*Corresponding author. E-mail: mehdinajafi1362@gmail.com, Tel/ Fax: 0098 273 339 5509.

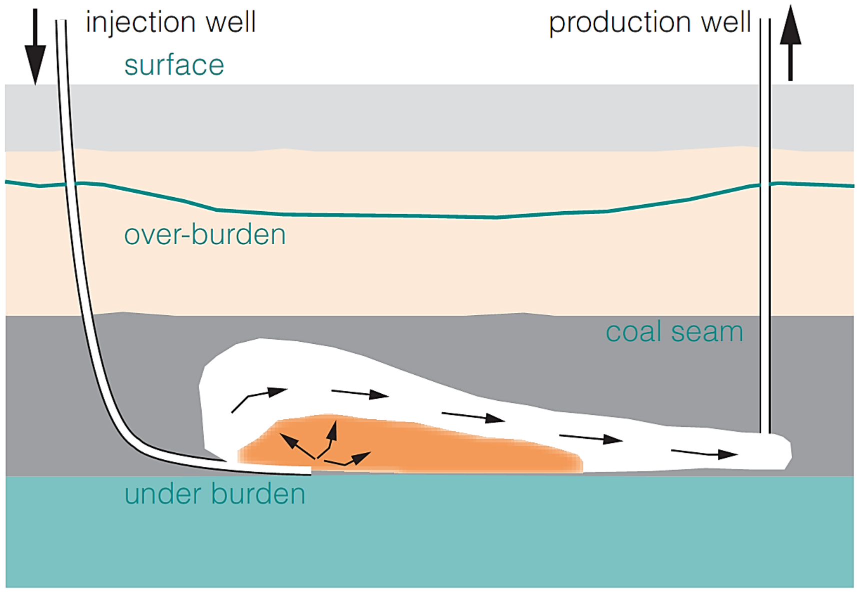

Figure 1. Schematic diagram of the UCG process (Couch, 2009).

(i) Injection and production wells are drilled from the surface to the coal seam.(ii) Injection and production wells are linked together under ground.
(iii) Air or oxygen is sent to the coal seam through the injection well.
(iv) The coal is ignited in a controlled manner.
(v) The gas products, such as H_2, CO, CH_4, and CO_2, flow to the surface through the production well. The gas products are sent to the end users after cleaning. The gas products can be used for power generation or to synthesize chemicals, such as methanol, ammonia, and liquid fuels (Khadse et al., 2007; Daggupati et al., 2011).

The concept of UCG was first suggested by Sir William Siemens in 1868. At about the same time, in Russia, Dmitry Mendeleyev suggested the idea for drilling injection and production wells (Burton et al., 2006). Since the 1930s, more than 50 pilot UCG plants have been conducted worldwide. These developments have been concentrated in the former USSR, Europe, USA, South Africa, Australia and China. The economic attractiveness of a commercial venture depends on a number of factors including socioeconomic conditions and geologic and hydrologic characteristics (Oliver and Covell, 1989). Therefore, the most important factor in success of UCG operation is site selection based on geological and hydrogeological parameters.

Today, based on successes and failures of previous experiments and pilot studies, the site selection criteria are developed (Couch, 2009; Burton et al., 2006; Oliver and Covell, 1989; Ag Mohamed et al., 2012; Irwin et al., 2009; Shafirovich et al., 2008; Białecka, 2009). This criteria take into account the coal rank, coal seam thickness, seam depth, ash content, coal seam permeability, fault density, coal moisture, coal aquifer characteristic, dip and discontinuities. In this study, Mazino coal deposit was selected for UCG site selection in Tabas coalfield, Iran. The aim of the present paper is ranking of coal seams for controlled retraction injection point (CRIP) configuration by considering important criteria in UCG site selection.

CASE STUDY AND METHODOLOGY

Nowadays, it is expected that coal seam energy have a very important in view of government and investors in Iran because of the elimination of fuel subsidy. Tabas coal resources are estimated to be about 2 Gt, which are located in the Parvadeh and Mazino. Mazino is the largest thermal coal deposit in Tabas coalfield and its area is about 8800 km^2. This deposit is located in 85 km west of Tabas, Yazd (Figure 2) (Yazdani et al., 2012). The Mazino formation consists of sandstone, shale, siltstone, and carbonate rocks. A general stratigraphic column at Mazino coal deposit is shown in Figure 3. The thickness of this formation is about 1200 m and gradually decreases in some strata and increases in the other towards the depths (that is, towards Coal-bearing strata in Mazino deposit is within the Middle Jurassic formations. These sediments have been developed across alluvial plain and coastal environment in Tabas coalfield (Yazdiand, 2012). The rank of the Mazinocoal deposit is semi-anthracite and all of the coal seams are formed within the complicated monoclines and synclinal folds dipping to east and have been cut by several faults (Anon, 2002). Several coal seams (75 coal seams) with different thickness are interbedded with these sediments. The coal seams thicknesses are varied from 0.5 to 6 m in different place (Anon, 2002). The overall dip angle of coal seams varies from 6 to 26°. The most important properties of the coal seams are shown in Table 1. It should be noted that total reserve of the coal seams was estimate by Russian geologists (Anon, 2002, 2003). The Mazino area is located far from the populated areas, national parks, wildlife habitat, agricultural fields,

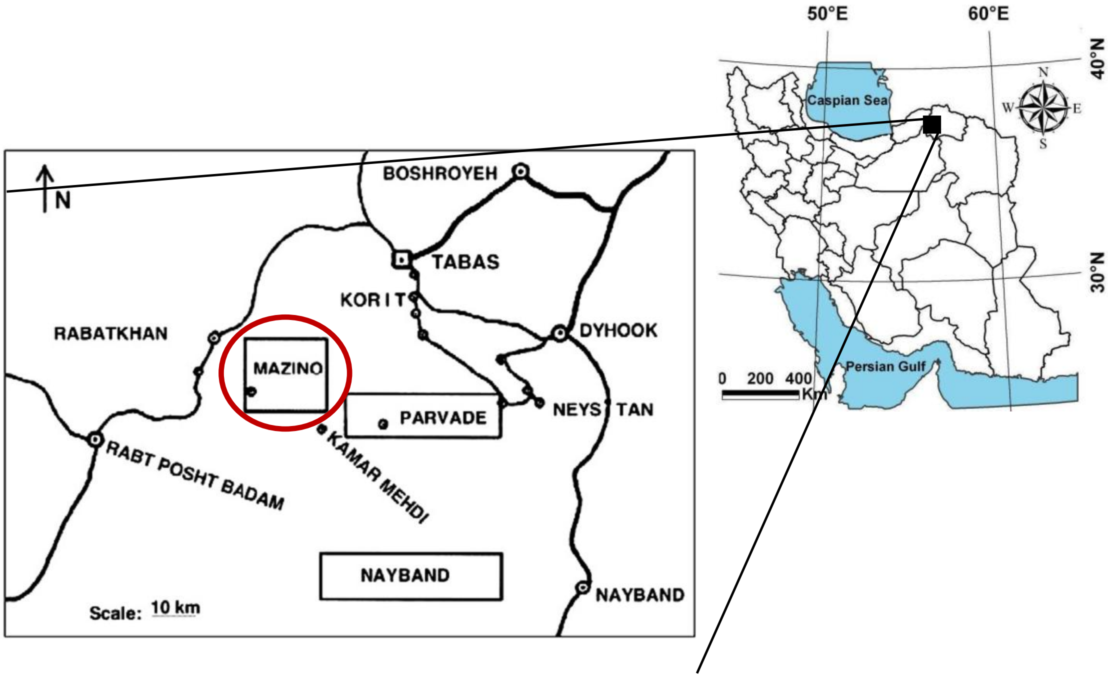

Figure 2. Location map showing the Mazino coal deposit (Yazdani et al., 2013).

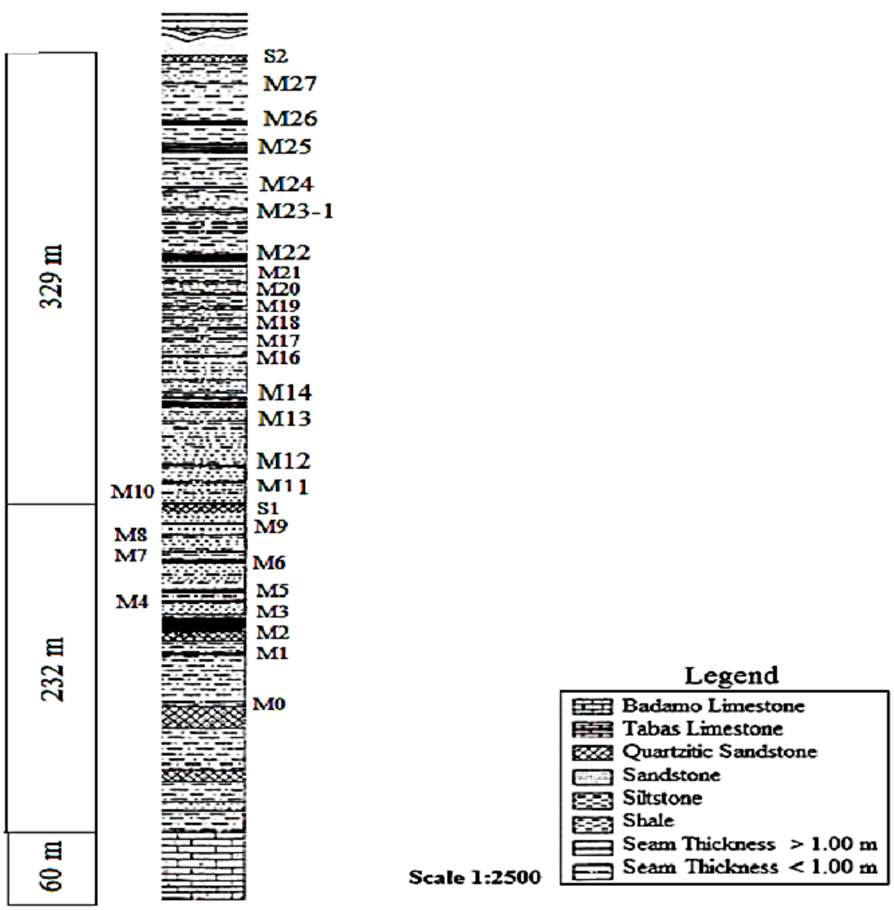

Figure 3. A generalized stratigraphic column at Mazino coal deposit.

Table 1. Coal seams properties in Mazino coal deposit (Anon, 2002).

Seam	Thickness (m)	Dipangle (Degree)	Ash (%)	Volatile matter (%)	Moisture (%)	fixed carbon (%)	Depth (m)	Calorific value (Kcal/kg)	Reservoir (Million ton)
M27	0.52	−	−	−	−	-	80	4802	−
M26	1.21	18	39.1	12.9	0.9	47.1	95	4802	15.8
M25	1.1	20	38.3	13.15	0.7	47.85	160	4822	25.8
M23-1	0.68	−	35.7	−	0.6	-	172	5164	8.5
M23	0.64	−	28.7	−	0.7	-	192	5787	38.8
M22-1	0.58	26	21.4	−	0.7	-	280	6435	7.5
M17	0.58	26	38.1	12.27	0.6	49.03	310	4900	12.8
M14-1	0.87	−	35.4	−	0.9	-	345	5171	22.4
M10-2	0.76	−	32.9	−	−	-	350	5404	14.5
M10-1	0.58	−	37.9	−	−	-	362	4951	10.6
M10	0.52	25	25.2	8.68	0.9	65.22	383	6124	11.5
M9	0.85	−	34.7	9.45	0.6	55.25	405	5240	26.4
M8	0.68	−	34.8	9.9	0.6	54.7	450	5214	15.3
M6	1	23	38.1	10.08	0.7	51.12	485	4900	26.9
M5	1.88	20	36	9.29	0.6	54.11	505	5114	80.3
M4	1.68	15	33	8.63	0.8	57.57	541	5407	60.8
M2-1	1.51	−	36.2	−	0.8	-	570	5087	44.4
M2	3.57	15	36.4	8.33	−	-	600	5066	139.6
M1	2.5	25	35	9.23	-	-	650	5209	100.5

water wells, underground aquifers and oil and gas fields. Based upon the factual data, it seems that Mazion deposit is a candidate for UCG method.

Two steps are considered for ranking of coal seams in Mazino coal deposit. In the first one, suitable coal seams were selected only by considering UCG operation in traditional scale. In the second one, by considering final result of Step 1, coal seams ranking was performed for UCG based on CRIP configuration.

RESULTS

Step 1: Suitable coal seam based on UCG in traditional scale

In the first step, by considering criteria for UCG site selection, suitable coal seams were selected. The results of Step 1 are shown in Table 2. It should be noted that in the step one each stage performed sequence. This means, when a coal seam is unsuitable in each stage, it removed and not considered in other stages. According to Table 2, the most important points areas follow:

(i) Based on coal seam thickness criteria for UCG site selection (Couch, 2009; Burton et al., 2006), in stage 2, the M2, M23-1, M23, M22-1, M17, M14-1, M10-1, M10-2, M10, M9 and M8 coal seams are unsuitable for UCG because their thickness is less than 1 m.
(ii) The M26 coal seam depth is lower than 100, therefore considering the gas leakage to the surface andsubsidence problem, the M26 coal seam is unsuitable for UCG in stage 4.

According to the result of Table 2, it is clear that M25, M6, M5, M4, M2-1, M2, M1 coal seams are suitable for UCG in Step 1.

Step 2: Coal seam ranking based on CRIP configuration

There are several configuration including vertical well, εUCG, long-tunnel large-section two-stage, steeply dipping and CRIP for UCG method (Couch, 2009; Burton et al., 2006). Nowadays, in UCG methods, the CRIP configuration is considered and has remarkable advantage compared with the others. In CRIP configuration, the UCG panel has a large dimension and intends to the huge cost drilling. Moreover, two in-seam holes are drilled in parallel in the lower part of the seam, and then turned near the end to meet at a point, maybe as much as 500 to 700 m from where they have started. Where they intercept, a vertical ignition well is drilled. Then the seam is ignited at the base of the vertical well and the air flow established from the injection well to the vertical well, drawing the fire to the end of the liner (Couch, 2009).

The CRIP configuration was used at Rocky Mountain 1, in the USA, and is developed in larger scale trial at Bloodwood Creek in Australia by CSIRO and Carbon Energy Pty Ltd (CEPL) from 2008 to 2010 (Figure 4)

Table 2. Coal seam qualification for UCG in step 1.

Stage	Parameter	Characteristics for UCG	Mazino coal deposit		
			Characteristics	**Coal seams unsuitable**	**Coal seams suitable**
1	Rank	All coal Rank	Coal seams rank in Mazino is semi-anthracite	---	All coal seams in Table 1 are suitable
2	Coal thickness	1 to 25 m	According to the Table 1, coal seam thickness varies from 0.5 to 4 meters.	M27,M23-1, M23, M22-1, M17, M14-1, M10-1, M10-2, M10, M9 and M8	M26, M25, M6, M5, M4, M2-1, M2, M1
3	Dipangle	0^{o}-70^{o}	Coal seams dip is lower than 26°	-----	M26, M25, M6, M5, M4,M2-1, M2, M1
4	Depth	Considering the ground subsidence the optimum depth must be greater than 100m	The coal seams depth in study area varies from 80 to 600m	M26	M25, M6,M5, M4,M2-1,M2, M1
5	Fault density	Less than one in 30 meters	Maps and site investigation showed that the fault density in less than 1in 500 m.	----	M25, M6, M5, M4,M2-1, M2, M1
6	Ash content	Less than 60%	According to Table1, coal seams ash content is lower than 40 percent.	-----	M25, M6,M5,M4,M2-1, M2,M1

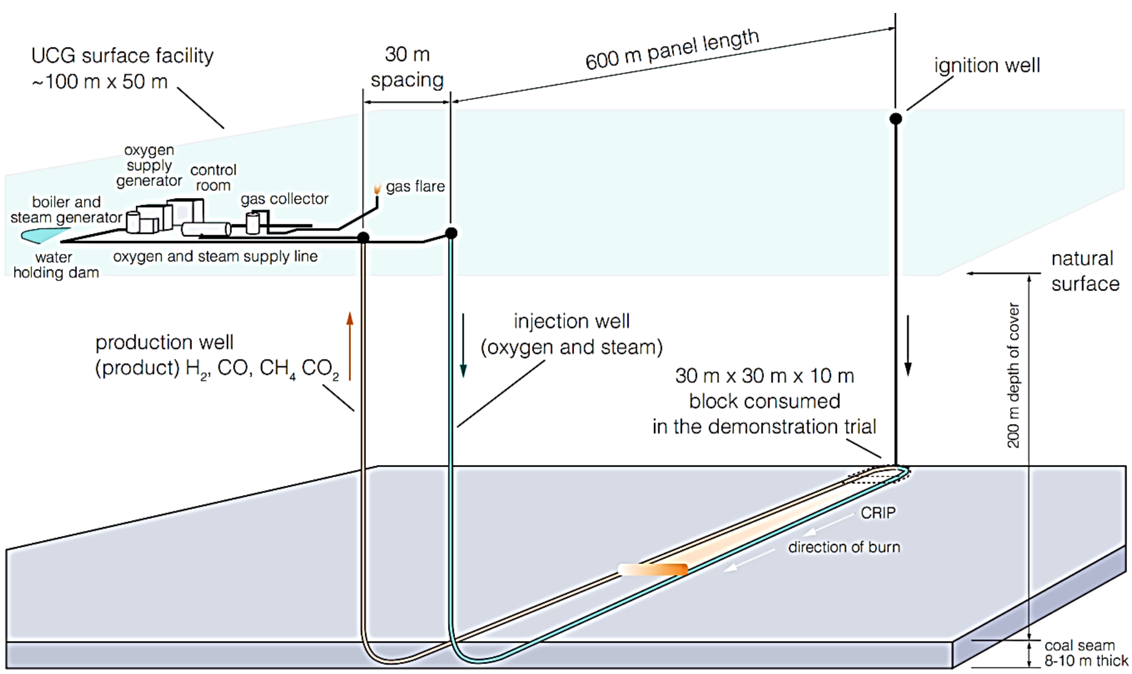

Figure 4. The Bloodwood Creek layout with parallel-holes CRIP for the 100-day trial (Couch, 2009).

Table 3. Coal seams ranking for CRIP configuration in Step 2.

Stage	Parameter	Characteristics for UCG	Mazino Coal Deposit		
			Characteristics	Coal seams unsuitable	Coal seams suitable
1	Coal reserve	Depending on the amount of electricity and the life cycle of the power plant, varying amounts of coal are needed to meet the energy requirement. In UK 5Mt of coal in resource to provide 20 years of operation and in USA is 3.5 Mt for 15 years (Irwin et al., 2009)	All suitable seams in the step 1 have a suitable resource.	-----	M25, M6, M5, M4,M2-1,M2, M1
2	Coal seam thickness	The thickness of coal is an important factor in CRIP configuration. Considering the economic issue, it is better that the thickness of coal seam should be more than 2m.	All suitable seam thickness in the stage 1is more than 1m.	M6 andM25	M5, M4,M2-1, M2, M1

(Couch, 2009). As clearly seen in Figure 4, the UCG by the parallel CRIP is similar to the longwall mining method, while with more of the coal removed, and the ash staying behind underground. According to the aforementioned text, at the second step, by considering final result of Step 1, coal seams ranking was performed for UCG based on CRIP configuration. The results of Step 2 are shown in Table 3. According to Table 3, the most important points are as follow:

(i) The reserve of coal seam is an important factor in the CRIP configuration method. Shafirovich and Varma (2009) concluded for 20 years continuous operation of a 300 MW UCG-based combined-cycle power plant (efficiency, 50%), it is necessary to produce 75.6 × 10^9 Nm^3 of syngas with a heating value of 5 MJ/m^3. It means 33 million metric tons coal needs to be gasified for this purpose.We can conclude that a 200 MW UCG-based combined-cycle power plantrequire to 1.2 million tons of coal per year. Therefore all coal seams in stage 1 are suitable for gasification. The thickness of coal seam is an important factor in CRIP configuration. Considering the economic issue, it is better that the thickness of coal seam should be more than 2 m (Couch, 2009). Forasmuch as the thickness of coal seam has important role in the CRIP configuration method, Therefore, the M6 and M25 seams with thickness less than 2 m, are unsuitable in the CRIP method. Because the M2 seam has suitable thickness and reserve, it has great advantage related to the other seams for the gasification by CRIP method.

Conclusion

Underground coal gasification has the potential to harness energy from coal seams in an economic, environmental and sustainable manner. This technology can be applied to abandoned coal mines and deposit considered uneconomic or technically difficult for conventional mining methods. The selection of suitable coal seams for UCG project is the most important step and has a significant effect on the successful of whole process. This procedure involves taking into account geological and environmental parameters. The present work gives rise to be ranked coal seams in Mazino coal deposit. The most important results as are follow:

(i) The M2 coal seam has a highest ranking for UCG by CRIP configuration in Mazino coal deposit and M1, M5, M4 and M2-1 coal seams are in the other ranking, respectively.
(ii) The M2 coal seam reserve is 139Mt. Thus considering 1.2 million tons of coal per year for a 200 MW UCG-based combined-cycle power, it can be predicted that this seams supply the coal for power plant more than 100 years.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Ag Mohamed A, Batto SF, Changmoon Y, Chien SC, Choe JI, Cole KR (2012). Viability of underground coal gasification with carbon capture and storage in Indiana. School of Public and Environmental Affairs, Indiana.
Anon (2002). Review of the data of preliminary exploration of Mazino-1, TPE report, Iran Power Development Company (IPDC). P. 242.
Anon (2003). Provisional results of chemical and coal-petrographic analyses of coal from Mazino deposit, Iran TPE Report, Power Development Company (IPDC). P. 24.
Białecka B (2009). Analysis of criteria for UCG siting and operation. Central Mining Institute, 40-166 KATOWICE, Plac Gwarków 1, Poland. pp. 298-305.
BP (2010). BP statistical review of world energy. Technical report. London, UK: BP Global.
Burton E, Friedmann J, Upadhye R (2006). Best practices in underground coal gasification. Draft. US DOE contract no W-7405-Eng-48. Livermore, CA, USA, Lawrence Livermore National

Laboratory. P. 119.
Couch GR (2009). Underground Coal Gasification.IEA Clean Coal Centre, International Energy Agency, London.
Daggupati S, Mandapati R, Mahajani S, Ganesh S (2011). Laboratory studies on cavity growth and product gas composition in the context of underground coal gasification. Energy 36:1776-1784. http://dx.doi.org/10.1016/j.energy.2010.12.051
Gregg DW, Edgar TF (1978). Underground coal gasification. All Chem. Eng. J. 24(5):753-781.
Irwin WM, Brian H, Barbara J (2009). Indiana Coal Report 2009", Indiana center for coal technology research, Purdue University. P. 189.
Khadse A, Qayyumi M, Mahajani SM, Aghalay AMP (2007). Underground coal gasification: a new clean coal utilization technique for India. Energy 32(11):2061-2071. http://dx.doi.org/10.1016/j.energy.2007.04.012
Oliver R, Covell J (1989). Handbook for selection and characterization of potential UCG sites.U.S. Department of Energy, Morgentown Energy Technology Center, Laramie Project Office, Laramine, Wyoming.
Sarraf SA (2012). CFD simulation of underground coal gasification.MSc Thesis, Department of Chemical and Materials Engineering, University of Alberta.
Shafirovich E, Mastalerz M, Rupp J, Varma A (2008). The potential for underground coal gasification in Indiana. Phase I Report to CCTR.
Shafirovich E, Varma A (2009). Underground coal gasification: a brief review of current status. Ind. Eng. Chem. Res. 48(17):7865-7875. http://dx.doi.org/10.1021/ie801569r
Yazdani A, Razani M, Yakhchali SH, Zavadskas EK, Turskis Z (2013). Developing a fuzzy model based on subtractive clustering for road header performance prediction. Autom. Constr. 35:111-120. http://dx.doi.org/10.1016/j.autcon.2013.04.001
Yazdi M, Golzar H (2012). Geochemical properties and its environmental impacts of the Mazino coal deposit, Central Iran. Euro. Chem. Bull. 1(5):125-129.


Journal of Geology and Mining Research
Related Journals Published by Academic Journals
■ Journal of Geochemistry Research
■ International Journal of Geophysics and Seismology
■ International Journal of Physics Research
■ International Journal of the Physical Sciences
■ African Journal of Pure and Applied Chemistry
academicJournals