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ENVIRONMENTAL ISSUES IN UNDERGROUND COAL GASIFICATION: THE FUTURE CLEAN AND GREEN ENERGY RESOURCE

Ritesh Kumar*[1], Sadanand Sharma[2], Muniyan Sundararajan[3] and Braj Kishore Pandey[4]
*[1]Scientist, CSIR-Central Institute of Mining & Fuel Research, Dhanbad-826015, Jharkhand, India
[2]Senior Scientific Officer, CSIR-Central Institute of Mining & Fuel Research, Dhanbad-826015, Jharkhand, India
[3]Scientist, CSIR-Central Institute of Mining & Fuel Research, Dhanbad-826015, Jharkhand, India
[4]Principal, Government Polytecnic, Adityapur, Jamshedpur-832109, Jharkhand, India

ABSTRACT

India and World at large is in the need of some alternative energy source, an energy source that will do less harm to the environment and will be free of the disadvantages of opencast and underground mining. Underground coal gasification (UCG) could serve as an alternative clean source of energy. The UCG process holds multiple benefits. It can extend coal reserves by exploiting deposits thought to be uneconomic through conventional methods of extraction or where reserves have limited access due to excessive depth or geological arrangement. Increasing concern about the environment and significant domestic and international pressure has led to the development and growth of UCG worldwide. The present paper provides an overview of this much talked about alternative clean source of energy which one can also say is a green energy resource

KEYWORDS: Environment, Underground Coal Gasification, Challenges, Benefits, Remedies, Clean & Green Energy

INTRODUCTION

Coal Reserves in World and India

Coal has been and shall remain the main fuel for power generation. India has vast reserves of coal. Indian proven coal reserves stands at 60600 MT which is 6.8% of the world's total reserves of 891531 MT (BP Statistical Review, June-2016). So far, we have been trying our hands for those coal reserves that could be easily recovered by the conventional mining method. However, with the increasing awareness for the environment and with the advent of the technology it has become possible to recover even those coal reserves which is either located at the greater depth or is not economically feasible to recover. Underground coal gasification (UCG) technology is one that though owes its existence long back in other parts of the world but has gained its importance in India during the last two decades or so. India has fourth-largest coal reserves in the world. UCG will be used to tap those Indian coal reserves that are difficult to extract by conventional technologies.

UCG: Definition

UCG in general is a process in which unminable underground coal/lignite reserves is converted into combustible gases by gasifying the coal in-situ. It is a very unconventional gas having multi gas composition, has low btu and contains moderate CO_2 content. Interest in UCG spread around the world following increase in oil and gas prices and also need for clean energy.

The Process and the Reactions

The process of gasification here is similar to the one that is found in the case of surface gasifiers. In this process the coal reacts with injected air or oxygen and steam, to form gases, liquids and ash. Produced gases are a

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mixture of combustible (carbon monoxide, hydrogen & methane) and non-combustibles (carbon dioxide, nitrogen & un-reacted water vapour) gases. UCG, at present, is the only feasible technology to harness energy from deep unminable coal seams, in an economical and environmentally clean way.

The chemical reactions that usually take place during the process and involve oxidation, reduction and distillation are given in Table 1 below:

Table 1: Reactions Occurring during the Gasification Process

Reaction Zone	Reactions	Remarks
Devolatization Zone **(Methane evolved from coal is consumed)**	**$CH_4 + O_2 \gamma CO_2 + 2H_2O$ -891 kJ/mol**	Carbon dioxide formation occurs. Reaction provides heat in advance of main burn front.
Combustion Zone **(Burning at coal face provides heat.)**	**Oxidation:** **$C + O_2 \gamma CO_2$ -406 KJ/mole** **Partial Oxidation:** **$C + 1/2\ O_2 \gamma CO$ -123 KJ/mole**	Main volume of heat generation zone is surprisingly thin. CO_2 produced to provide energy to make combustible gases.
Gasification Zone **(As Oxygen is used reduction of CO_2 occurs)**	**$C + CO_2 \gamma 2\ CO$ +159.9 KJ/mole** also reversal **$2\ CO + O_2 \gamma 2\ CO_2$**	Heat is used up to generate a gas rich in CO.
Reduction Zone **(Water shift reaction steam enters burn zone)**	**$H_2O + C \gamma CO + H_2$ +118.5 KJ/mole** **Shift conversion reaction:** **$CO + H_2O \gamma H_2 + CO_2$** - 42.3 KJ/mole **Hydrogenating gasification:** **$C + 2H_2 \gamma CH_4$ –87.5 KJ/mole** **Methanation:** **$CO + 3H_2 \gamma CH_4 + H_2O$ -206 KJ/mole**	Reactions use heat Temperature falling. Reactions use water entering cavity to convert CO to H resulting in a lower heat value gas.

The Set-up: Requirements

The UCG process utilizes two wells drilled into a coal seam. One well injects an oxidant such as air to start a combustion reaction underground. Heat and pressure gasify the coal, and the second well produces to the surface. Ash and other byproducts remain underground.

Coal is gasified underground by drilling boreholes from the surface into the coal seam, creating a linkage through the coal seam between the injection and production wells and injecting air (or oxygen) and water (or steam) into the underground reaction zone. In the process, the coal is partially oxidized, producing low and medium Btu gas (Figure 1). If only air is injected, the produced gases contain a high percentage of Nitrogen and have a heating value roughly one-tenth of natural gas, named as low-Btu gas. Injecting oxygen rather than air reduces the nitrogen content and raises the heating value of the produced gas to the 'medium-Btu' gas range – of heating value roughly one-fourth of natural gas. If the goal is high-Btu gas (also called as substitute natural gas or SNG), the percentage of methane in the produced gases needs to be boosted. For methane formation in UCG, two additional steps are required. First, some of the carbon monoxide made in the gasification process is reacted with steam to form additional hydrogen. This step, called shift conversion, sets up the proper ratio of gases for the next step called methanation. The hot gas thus produced is allowed to pass through the coal seam to the exit boreholes and is carried to the surface where it is cleaned and upgraded for use.

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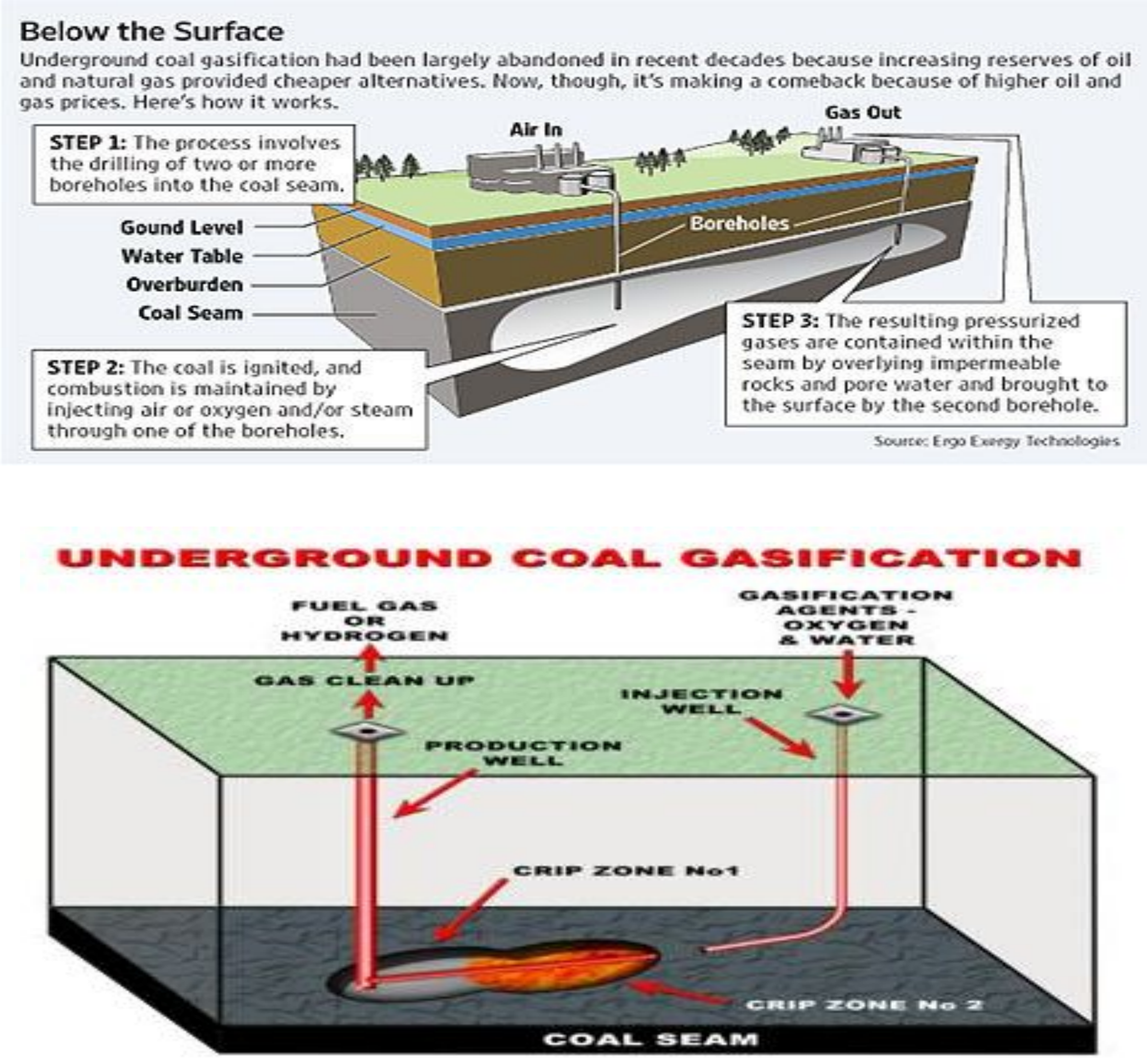

Figure 1: UCG Set-up

BENEFITS OF UCG

UCG presents several advantages over conventional coal mining and utilization techniques. The lack of need of mining and transportation results in much savings, especially for coals that contain a large fraction of ash. Besides this, the effects on the landscape, local wildlife and the hazardous nature of coal mining are virtually eliminated. Furthermore, some of the environmental impacts, such as the production of NOx and SOx due to surface coal processes, are significantly reduced in case of UCG, through the maintenance of a reducing atmosphere underground. Finally, UCG enables the utilization of deep and thin coal seams, which are not accessible for mining, and could provide an efficient carbon capture and sequestration (CCS) possibility. UCG allows for the economical exploitation of underwater coal reserves with minimal disruption to the surrounding environment.

UCG eliminates the need for energy intensive mining and transportation of coal, therefore the energy conservation is greatly improved from the typical 30% (24% with CCS) overall efficiencies achieved by coal fired power plants.

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UCG IN WORLD

International development of UCG owes its origin more than a century ago in the former Soviet Union in the 1920s. Commercially, the most UCG activity is occurring in Australia, China, and South Africa—with China having the largest UCG program worldwide. There are a limited number of projects in Canada and the U.S. In addition, India and New Zealand have begun the initial efforts to explore UCG. Several of these projects involve carbon capture and sequestration.

UCG does face a number of issues, including:

- A number of coal seams may not be suitable for UCG because of geologic or hydrologic conditions
- Project economics may be uncertain until a number of commercial UCG projects are in commercial operation
- Site selection needs to be done properly to avoid potential groundwater contamination and surface subsidence.

The issues associated with UCG as pointed above can be mitigated through careful project design, site selection, and monitoring. UCG has enormous potential to allow the world to take advantage of coal resources that would otherwise be too expensive or difficult to reach and mine.

Several demonstration projects and studies are also currently under way in a number of countries, including the USA, Western and Eastern Europe, Japan, Indonesia, Vietnam, Australia and China, with work being carried out by both industry and research establishments (www.gasification.org).

China has the largest UCG program at the global level. China has about 30 projects in different phases of preparation that use underground coal gasification. South African companies Sasol and Eskom both have UCG pilot facilities that have been operating for some time, giving valuable information and data. In Australia, Linc Energy has the Chinchilla site, which first started operating in 2000. Carbon Energy has completed a successful 100 day commercial scale study in Bloodwood Creek in 2008.

Linc Energy has spent over a decade perfecting these world-class technologies and we are now taking them to the world. Our goal is to empower nations to be energy self-sufficient. Linc Energy has successfully combined and demonstrated UCG and GTL technologies at our Chinchilla Demonstration Facility in Australia. Since the Demonstration Facility was established in 1999, we have developed and operated five successive UCG gasifiers and a GTL pilot plant. We have refined the process to a point where we can produce syngas in around 60 minutes, from coal seam to output (linc Energy: underground coal gasification).

POTENTIAL FOR UCG IN INDIA

India is a traditional coal country, possessing >300 billion tonnes of coal (Table 1), with >50% of energy needs being met through coal-based technologies (TEDDY, 2015). The concerns around the potential depletion of coal reserves in the foreseeable future have been abundant in recent times, alongside the focus on the environmental impacts of coal utilization. At least 30% of Indian coal reserves are situated at a depth >300m below the earth's surface (see Table 3). The country has very large deposits of deep seated coal and lignite which are not amenable to extraction by conventional mining methods.

As a result of Regional, Promotional and Detailed Exploration by GSI, CMPDI and SCCL etc, the estimation of coal resources of India has reached to 3,01,564 Million Tonnes as on 01.04.2014. The estimates of coal resources in the country during last 5 years are given below:

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Table 1: Status of Coal Resources in India during Last Five Years *(in MT)*
(Source: http://coal.nic.in/content/coal-reserves)

As on	Geological Resources of Coal			
	Proved	**Indicated**	**Inferred**	**Total**
1.4.2009	105820	123470	37920	267210
1.4.2010	109798	130654	36358	276810
1.4.2011	114992	137471	34390	285862
1.4.2012	**118145**	**142169**	**33183**	**293497**
1.4.2013	123182	142632	33101	298914
1.4.2014	125909	142506	33149	301564

Furthermore, the 'rank' or quality of Indian coals is usually low, with high ash content. Thus, the economical mining and utilization of this valuable, deep, coal resource is not feasible through conventional techniques.

Table 1 Coal reserves in India on 01.04.14 (in MT)
(Source: http://coal.nic.in/content/coal-reserves)

Type of Coal	Proved	Indicated	Inferred	Total
Coking	18400	13569	2101	34070
Non-coking	106916	128838	30249	266002
Tertiary	594	99	799	1493
Total	125909	142506	33149	301564

Table 3: Depth-wise Coal Resources as on 1.1.2007
(Source: Khadse et. al, 2007; Chand 2009)

Depth (m)	Proved (Bt)	Indicated (Bt)	Inferred (Bt)	Total (Bt)	Total (%)
0-300	75.76	66.56	14.42	155.74	61
300-600	6.78	41.65	18.04	66.47	26
0-600 (Jharia)	14.00	0.50	-	14.50	6
600-1200	1.67	11.28	5.8	18.75	7
Total 0-1200	97.92	118.99	38.26	255.17	100
%	38	47	15		

In 1981 a protocol for UCG development was signed between the Government of India and the Government of erstwhile Soviet Union. In 1984 the Government of India constituted a National Committee on UCG. ONGC drilled two pilot wells near Mehsana city, in North Gujarat. It is believed that UCG will play a unique role in enabling us to utilize these reserves. At this time, ONGC, GAIL, and RIL are some of the companies that have expressed interest in UCG in India. ONGC has recently proposed a pilot UCG station, producing 5.5 lakh m^3/day of syngas, by the end of 2010 at Vastan near Surat in Gujarat (Business Standard, 2009). The norms & guidelines for the practice of UCG have been recently notified by the coal ministry (on July 13, 2009) (Aghalayam, 2009). It seems logical and evident that in the near future, UCG will emerge as a major clean coal utilization technology capable of providing significant impact in our country.

CHALLENGES FOR UCG IMPLEMENTAIION IN INDIA

- Regulatory framework governing UCG Operations in the formulation stage.
- Lack of understanding of the environmental impact of UCG

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- UCG being is a new technology in India
- Unavailability of a proven track record and implementation guidelines
- Lack of Understanding of the technology
- Concern over safety issues on UCG Implementation

MAJOR ENVIRONMENTAL ISSUES OF UCG: ADDRESSING W.R.T ENVIRONMENTAL PERSPECTIVES

UCG offers several benefits to the society as compared to the conventional opencast and underground mining. However, UCG possesses some distinct disadvantages as well. UCG is fairly capital intensive, and has been successfully practiced at only a few world-wide locations. The environmental impacts on aquifers situated close to UCG operation, and the potential of surface subsidence are some of the other problems associated with UCG. These problems may only be overcome through proper site monitoring and management. Some other environmental issues that are equally important and that needs our attention includes, 1) Migration of VOCs in vapor phase into potable groundwater, 2) Organic compounds derived from coal and solubilized metals from minerals contaminating coal seam groundwater and 3) Upward migration of contaminated groundwater to potable aquifers due to: Thermally-driven flow away from burn chamber, buoyancy effects from fluid density gradients resulting from changes in dissolved solids and temperature and changes in permeability of reservoir rock due to UCG.

MITIGATION MEASURES

Underground Fire

Studies from the past have demonstrated that the UCG operations are not only safe but even, controllable and containable. Considering Indian conditions, where apprehension is there regarding chances of underground fires due to UCG operations, pilot scale study can be taken up and such fears should be addressed and dispelled. Precautions should be taken and properly managed in order to make it safe and environmentally friendly.

Land Subsidence

Subsidence refers to the lowering of the ground surface caused by a collapse or compression of underlying rock strata. It is the most common occurrence as a result of underground mining or extensive groundwater extraction.

As the fire burns along the coal seams the space is created. This can cause collapse of the overlying geology and could lead to subsidence and damage to buildings and infrastructure including the UCG boreholes themselves. Such situation results in chances of land subsidence similar to conventional underground mining operations but that is not so alarming in the current situation as the ash residue remains underground. Land subsidence study is very easy to carry out. UCG operations in Uzbekistan have demonstrated negligible land subsidence. However, if such subsidence is the likely chance then it can be solved through careful site selection and subsidence modeling. Surface subsidence monitoring is carried out by surveying monuments installed prior to operations and detecting any changes in the elevation after operations.

Ground Water Pollution

Ground water pollution can be monitored and checked by maintaining sufficient separation between aquifers and UCG target coal seam. Such monitoring is very easy to carry out.

CONCLUSION

Coal has been and shall remain the main fuel for power generation. However, too much dependency on coal can prove suicidal as the reserves are limited and we need to make judicious use of the energy that we possess for future generation to also avail such facilities. Coal reserves at a greater depth can only be utilized well in an eco-friendly manner through the use of technology of underground coal gasification which has a lot to offer to the mining industry compared to the conventional mining. Underground coal gasification can truly make mining green mining.

REFERENCES

[1] Khadse, A, Qayyumi, M., Mahajani, S.M., Aghalayam, P., "Underground Coal Gasification: A New Clean Coal Utilization Technique for India," Energy, 2007, 32, 2061-2071.

[2] Aghalayam, P., 2009, Underground Coal Gasification: A Future Clean Coal Utilization Technology for India, The Bulletin of the Energy Forum, The Newsletter of the Energy Forum of IIT Madras, 1(12).

[3] Pathak, M. (August 21, 2009). ONGC Gears for Coal Gasification Project. Retrieved from http://www.business-standard.com/article/economy-policy/ongc-gears-for-coal-gasification-project-109082100094_1.html.

[4] BP Statistical Review of World Energy, 2016, June, Coal, p. 30. (www.bp.com)

[5] TEDDY-2016. Annual Report. The Energy Research Institute, TERI: New Delhi.

[6] Coal Reserves. Retrieved from http://coal.nic.in/content/coal-reserves

[7] Overview of underground coal gasification. Retrieved from http://www.lincenergy.com/data/info_sheets/Underground_Coal_Gasification.pdf

[8] "Gasification vs. Incineration." Gasification Facts. Gasification Technology Council. Retrieved from http://www.gasification-syngas.org/

[9] Chand, S. K., 2009, Role of Coal in Indian Energy Basket, PDPU-CFSR Conference on Clean Coal Technology. www.pdpu.ac.i n