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Prospect Analysis of Coal Mines Energy Saving and Emission Reduction Based on Microbial Technology

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Nowadays, carbon dioxide is the main cause of global warming, coal mining and its utilization is a major source of greenhouse gas emission, based on the theory of biogenic coalbed methane, this paper puts forward three models to achieve energy saving and emission reduction by using microbes, respectively they are the biological residual coal mining, the coalbed methane development and the carbon dioxide coalbed sequestration and transformation. And this paper analyses the utilization prospects from the aspects of the research status and technical procedures. Microbial technology has a great potential significance for energy saving and emission reduction and environment protection in coal mine.

Key words: Microbial technology; Energy saving and emission reduction; Greenhouse effect; Coal mine; Residual coal; Coalbed methane.

Coal mining and its utilization plays an extremely important role in relieving the contradiction between the supply and the demand of global energy and ensuring the global economic development, but the resulting emission of greenhouse gas has been arising wide concerns from every coal producing-countries in the world. Chinese government made a pledge to take its share of responsibility of emission reduction at the 2009 United Nations Climate Change Conference, and the use of microbial technology is an important way to meet the commitment.

Biogenic methane in the coal reservoirs refers to the gas produced by the interaction between microbes and coals under the appropriate conditions: temperature, pressure, pH, Eh, mineralization and nutrients, which mainly consists of methane(Schoell, 1988; Penner *et al*, 2010). Biogenic methane comes from the reduction of CO_2 and the acetic acid fermentation, namely: $CO_2+4H_2 \rightarrow CH_4+2H_2O$ and $CH_3COOH \rightarrow CH_4+CO_2$ (Whiticar *et al*, 1986). Shaer Lake in Xinjiang, Liyazhuang in Shanxi, Huainan in Anhui, Enhong in Yunnan have also been found the existence of biogenic methane(Li and Zhang, 1997; Qin *et al*, 2000; Wang *et al*, 2004; Guo *et al*, 2007), thus in almost all the low-rank coal basins, more or less the biogenic methane might exist. This paper presents three aspects of the application of microbial technology respectively in biological residual coal mining, coalbed methane development and carbon dioxide coalbed storage and transformation, which may have important value for the energy saving and emission reduction in coal mines.

Prospect analysis of microbial residual coal mining

Significance of residual coal mining

Residual coal resource mainly includes horizontal coal pillars, interval coal pillars and many other bound coals, fault coals, flung bottom coals and stopped-ming boundary coals that were left in

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the process of coal mining. Due to various factors and the limitations of mining methods, not only were the precious coal resources lost, but also the hidden dangers of production safety were left: (1) due to the effect of the "abutment pressure" of coal pillars, the roof is not fell fully, the maintenance conditions of tunnel are poor and the expenses are high; (2) the underground residual coals are easy to have spontaneous combustion as a result of oxidation, which is a hidden danger of producing harmful gas and causing underground fire; (3) generally the loss rate of residual coal resources in coal mines are up to 40%-50%, which reduces the recoverable reserves in coal mines and wastes the resources.

Table 1. Quantity for CO_2 storage in world reservoir estimated by IPCC(Jiang et al, 2008)

Burial type	Global buried reserves	
	CO_2/Gt	The proportion of emissions in 2050 /%
deep coal bed	40	2
depleted gas reservoir	690	34
depleted oil reservoirs	120	6
deep salt water reservoir	$4\sim10\times10^3$	20~500

The residual coal mining in use of microbes

Artificial exploitation is the common method to do the residual coals mining, but the danger coefficient is high. Underground coal gasification has a bright prospect, but its commercial operations also need much more investments (Heinberg and Fridley, 2010). Injecting the bacteria- enriched liquid into the coal mine goafs, the microbes will take the residual coals as the carbon sources, then flammable gas as methane and hydrogen will be produced. By the conventional CBM extraction the biological residual coal mining can be achieved (Figure 1).

Greenhouse effect of carbon dioxide and its storage way

CO_2 accounts for more than 2/3 of the total amount of greenhouse gas. The study results show the CO_2 underground storage is the most realistic and effective way to cope with the CO_2 emission reduction, and these sites are including the deep coal seams and saline layers(Bruant *et al*, 2002; Reeves, 2003; Hendriks *et al*, 2004; Zhang *et*

Table 2. Basic data of coal samples

Sampling locations	$R_{o.max}$ /%	Proximate analysis /%		
		M_{ad}	A_{ad}	V_{daf}
Yongdingzhuang coal mine	0.74	2.33	3.33	32.15
Shaqu coal mine	1.51	2.09	8.32	22.31

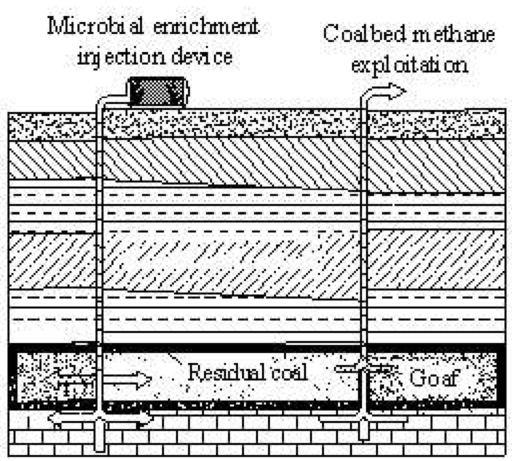


Fig. 1. Diagram of microbial residual coal mining

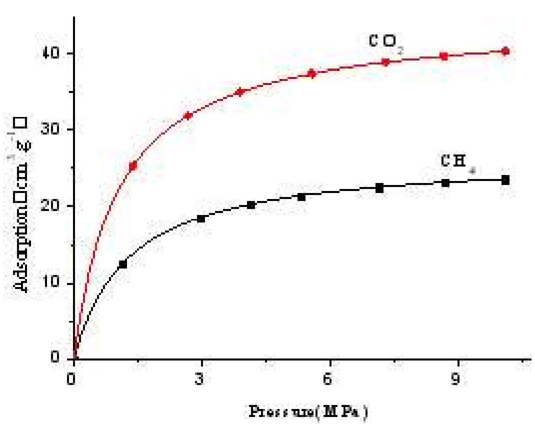


Fig. 2. The isothermal adsorption curve of carbon dioxide and methane

al, 2005; Shen and Liao, 2009; Wang *et al*, 2010), the depleted oil and gas reservoirs and many other types(Table 1).

When the carbon dioxide is buried and stored in the deep coal seams, it can be absorbed onto the surface of the coal seams. It will not only store the absorbed carbon dioxide but also replace the methane from the coal seams, which will bring enormous economic benefits(Klara *et al*, 2003).

Burying and Transformation of carbon dioxide in coalbed

Although the CO_2 sequestration technology in deep coal seams has so many advantages, it is faced with five technical problems: fluid-solid coupling, supercritical adsorption, buried security, geological and engineering problems and carbon leakage(Zhang *et al*, 2000; Wan *et al*, 2012).

Carbon dioxide from power plants into the deep coal seam, and CH_4 is displaced(figure 2), then transform the CO_2 into methane through the ground with the activation bacterial, which reduces the emission of carbon dioxide. Once the methane is injected into the coal seam after burned, which can also realize zero-emissions economy (figure 3).

Microorganisms in the application of CBM development

CBM resources increase

The production of CBM in Powder River basin is far higher than the total resources in the CBM exploration stage, which draws people's attention to the contribution of biological methane resource(Green *et al*, 2008). Because of the existence of indigenous bacteria in the coal seams that can convert coal into biological methane, through the amplification culture of indigenous bacteria and the injection of the colony of microbes and nutrient solution, a large amount of biological methane will be produced by the microbes converting the coal and consequently the quantity of CBM resources will be increased as well.

The permeability increase of coalbed

Apex company in Australia has made systematic studies about the cause of formation of coalbed methane in Sydney basin, and proposed the idea of injecting the methane bacteria into the coal seams to stimulate the formation of biological gas and increase its permeability(Faiz *et al*, 2003). Guo has proved that the permeability of coal seams

Table 3. Test results of specific pore volume and surface area before and after the biological methane metabolism

Sample	specific pore volume/($cm^3.g^{-1}$)					Pore specific surface area/ ($m^2.g^{-1}$)					porosity
No.	>1000 nm	100-1000 nm	10-100 nm	<10 nm	total	>1000 nm	100-1000 nm	10-100 nm	<10 nm	total	(%)
the original sample(Y)	0.026	0.008	0.026	0.014	0.074	0.004	0.15	4.02	7.18	11.35	8.34
the biological treatment(Y)	0.033	0.009	0.026	0.013	0.081	0.005	0.16	3.91	6.97	11.05	9.11
the original sample(S)	0.031	0.001	0.0053	0.0068	0.0434	0.003	0	0.919	3.644	4.566	5.0255
the biological treatment(S)	0.036	0.001	0.0058	0.0055	0.0480	0.003	0.025	0.867	3.269	4.164	5.5292

(Y- Yongdingzhuang coal mine; S-Shaqu coal mine) can a notable increase after the function of biological methane metabolism on the coals through some experiments(Guo *et al*, 2013). In order to further investigate the function law of biological methane metabolism on coal pore structures, we conducted a mercury injection test on the coal samples from Yongdingzhuang and shaqu coal mine, the basic data of coal samples are showed in Table 2 and the results are showed in Table 3 and Figure 4.

As we can see from figure 4, after the biological methane metabolism, the amount of injected mercury in the coal samples has increased to various degrees compared with the original samples, which evidences the fact that biological methane metabolism can increase the porosity of coal samples. The injection-withdrawl mercury curve becomes upturned and then horizontal and its hysteresis loop increases and the volume difference becomes large, which means more open pores in the coal samples are produced after the function of microbes and also the connectivity improve. Microbes not only can convert coals into methane and increase the amount of methane resources, they also can achieve the effect of biological permeability increase, which has a great significance for CBM development.

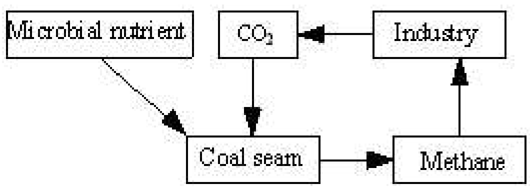
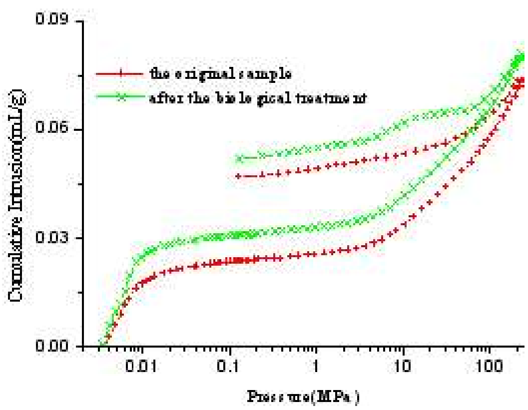
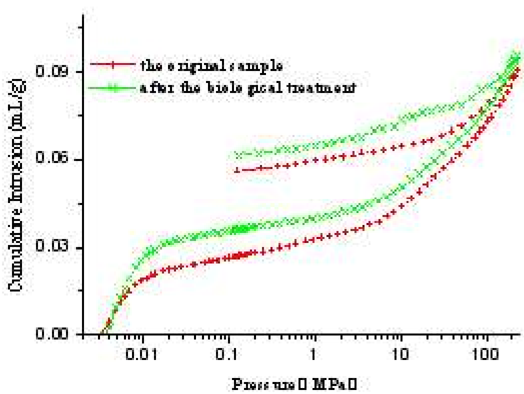


Fig. 3. Diagram of burial and transformation of carbon dioxide



a) Sample of Yongdingzhuang coal mine



(b) Sample of Shaqu coal mine

Fig. 4. Mercury curve of coal samples

The desorption rate improve

Biological methane metabolism has a certain degree of degradation to coals, which leads to the destruction of macromolecular structure and the increase of oxygenic functional groups, so the methane absorption becomes weak and the desorption rate increases in coal seam(Xia *et al*, 2013). The Langmuir volume of coal samples after microbes' function decreases significantly, which is also an evidence that microbes can increase the desorption rate of coalbed methane(Jiang *et al*, 2009).

CONCLUSION

1. Coal mining and its utilization is the main cause of greenhouse gas emission, in order to achieve energy saving and emission reduction, this paper put proposes the idea of using microbial technology to do the residual coals mining, burial and transformation of carbon dioxide and CBM developing. The application of microbial technology will bring about the energy saving, environment protection and technology revolution of coal mining.
2. In terms of the residual coals mining, it can develop and utilize the residual coal resources with a high efficiency under the prerequisites of low investment, small risk and few pollution.Carbon dioxide burial not only can reduce the greenhouse effect, but also can be converted into methane—clean energy. In terms of CBM development, microbial methane metabolism has the

effects of increasing the permeability of coal reservoirs, the desorption rate of CBM and further increasing the amount of CBM resources.

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