# GREEN MINING OF COAL RESOURCES HARMONIZING WITH ENVIRONMENT

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## ABSTRACT

To the serious environment problems of coal mining, a new concept of green mining is advanced. The connotation of green mining is to view and treat coal, coal-bed methane, ground water, rock waste and any other useful resources in abroad sense as "resources". Its basic startingpoint is based on the law of strata movement to prevent or to alleviate the adverse influence of coal mining on other resources and the environment as far as possible. The goal is to maximize the economic and social benefits. The technique frame of green mining includes water-preservation in mining areas, coal mining to retard surface subsidence, simultaneous extraction of coal and coal-bed methane, reducing of rock waste, underground coal gasification, etc.

**Key words:** coal resource, enviroment protection, circular economy, green mining, key stratum.

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## PROPOUNDING THE CONCEPTION OF GREEN MINING

The relationship between the mining area and its surrounding environment is harmonious before mining. But after mining, the impact of human activities change the environment, and many environmental problems in mining areas surface, e.g. the destruction of farmlands and buildings, the migration of villages, the occupation of land by waste rock dumps, fall in the flow rate in rivers and creeks, exhaustion of groundwater, desertification of soil and groundwater pollution. The conceptualization and development of green mining enable us to have a sober judgment of the mining-induced problems. So that countermeasures can be suggested, and ratinal proposals can be put forward to the Government.

The main problems induced by coal mining can be listed as follows:

1) The destruction and occupation of land, which is mainly due to surface subsidence and the land occupied by waste dumps in underground mining; however, in surface mining,

it is mainly the damage due to surface excavation and land occupied by waste dumps.
2) The destruction and pollution of water resources. In the process of mining, the underground water resources are damaged by the man-made drainage for safety and the automatic drainage through flow fractured passages induced by mining.
3) The pollution of the atmosphere, which is mainly caused by coal mine methane emission and the harmful gas emissionsdue to the spontaneous combustion of carbonaceous materials in waste dumps.

We can take ShanXi province as an example, where the raw coal output increased by more than $5.6\times10^9$t between 1949 to 1998. But the land area damaged due to coal mining, the subsided area approaches $670\times10^6m^2$, of which 40% is cultivated land. The waste dumps have occupied about $20\times10^6m^2$. Up to 1998, the underground gob area reached $1300km^2$ (occupying 1% of the area of the province). The damaged underground water resources is about $420\times10^6m^3$/a. The surface runoffs have decreased; this caused 3218 well levels to drop; 433 water projects, 40 reservoirs and 793890m of water pipes were damaged; 1678 villages, 812715 people and 108241 domestic animals faced problems of drinking water. ShanXi's water-scarce environment has been further wrecked. The damaged land is about 0.2 hectares for per 10kt of raw coal on the average and the fresh addition of damaged land is about 20 thousand hectares annually.

Mine methane is a coal-bed gas; it is a of greenhouse gas far worse than $CO_2$, and it is also the ultimate reason of gas explosions in coal mines. On the basis of preliminary estimates, there is $30\times10^{12}$-$35\times10^{12}m^3$ of coal-bed methane above 2000m depth, reserves belong to front rank in the world. Since 1949, more than 1500 accidents of coal and gas outbursts have happened. In 2001 there were 2356 deaths owing to gas explosions in Chinese coal mines, accounting for 40% of the total death toll in coal mines. The amount of methane emitted chinese coal mines is $7\times10^9$-$19\times10^9m^3$ each year. However, methane is a kind of clean energy resource and drainage of methane and utilizing it as an energy resource is fundamental to the solution of these problems.

All these have confirmed that it is very urgent to put forward and implement green mining techniques in Chinese coal mines.

## THE CONNOTATION AND TECHNICAL SYSTEM OF GREEN MINING

The essential of green mining is to view and treat coal, coal-bed methane, water and any other useful resources in abroad sense as "resources". Its basic startingpoint is to prevent or to alleviate the adverse influence of coal mining on other resources and the environment, as far as possible. The goal is to maximize the economic and social benefits. Corresponding to land, underground water, methane, rock waste, etc, the green mining technique comprises the following: 1) the protection of water resources, through water preserving mining technique; 2) the protection of land and buildings, using mining technique with bed separation spaces grouted, backfill and partial extraction; 3) the drainage of methane, constituting the technique of simultaneous extraction of coal and coal-bed methane; 4)

reduction of rock waste output; 5) the technique of underground coal gasification. These ingredients make up the technical system of green mining and are shown in Figure 1.

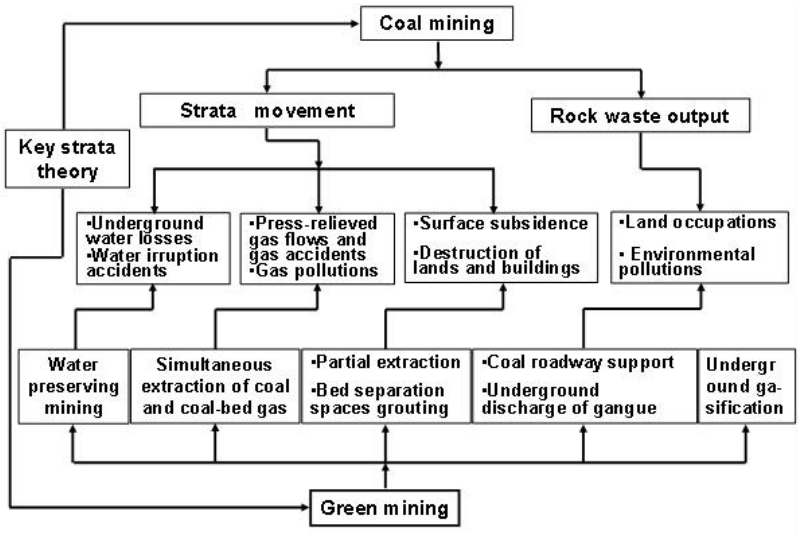


**Figure 1.:** The technical system of green mining

Most of the safety and the environmental problems are related to mining-induced rock strata movements (the above problems would not arise if the rock strata did not break). Therefore, the crucial theory of the foundations of the green mining are: 1) the development and distribution of joints, fractures and bed separations in overburden after mining; 2) the influence of mining on the movement of rock strata and surface subsidence; 3) the seepage and flow of gas and water in the broken rock strata; 4) the distribution of the stress field in the rock mass.

Over the past several years, in order to study how the thick and strong rock strata in overburden control the distribution of joints and fractures, the methane drainage, the prevention and cure of water irruption, and surface subsidence, the key stratum theory in ground control has been put forward [1-3] and it provides the theoretical foundation for "green" mining.

## THE MAIN CONTENTS OF GREEN MINING TECHNIQUE

### Mining for Preservation of Underground Water Resources

After mining, along with the break of the key strata, a cone of depression of underground water will appear. Whether the underground water level can recover rests on the existence of water-impervious strata that are the recompressed soft strata along with the advancement of the work face. If the water- impervious strata exist, due to the supply of surface water, the cone of depression will gradually disappear, its influence on the surface ecological

environment is determined by the interval between the emergence and the disappearance of the cone of depression.

The fourth water-bearing stratum in the alluvium of HuaiBei mining area connects with the coal measure strata; its water level had dropped continuously after mining, and several cone of depression appeared. At present, the drop area of the fourth water-bearing stratum has approached 40km$^2$ in HuaiBei LinHuan coal mine, leading to the permanent destruction of the fourth water-bearing stratum. As an example, the water level of the fourth water-bearing stratum in the 85-02$^{nd}$ bore nearby the west air shaft in HuaiBei LinHuan coalmine was 97.2m in 1985; it dropped to 205.8m in 2001; the water level has dropped 108.6m over 16 years.

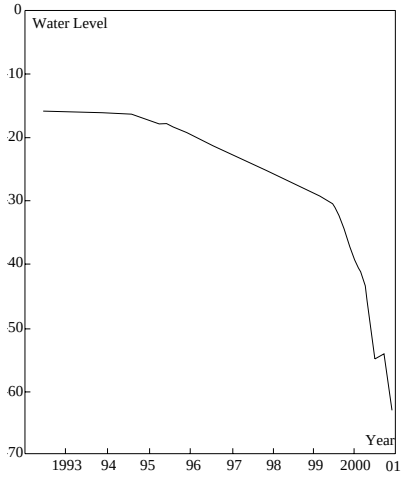


**Figure 2.:** The water level change of the fourth aquifer in the 84-15$^{th}$ observation bore in the ZhuXianZhuang coalmine.

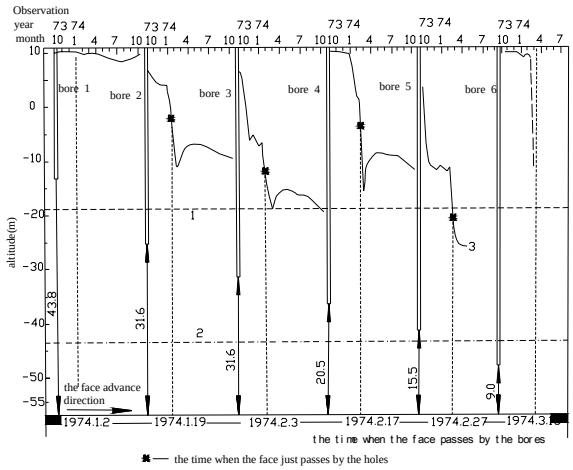


**Figure 3.:** The water level development in the observation bores of the 1201 work face in the HuangXian coalmine.

According to practical observations, the lowering of the water level in the fourth water-bearing stratum is closely connected with the water flowing in fractured passages. Figure 2. shows the water level change curve of the fourth aquifer in the 84-15$^{th}$ observation bore in HuaiBei ZhuXianZhuang coalmine. The velocity of lowering the water level is slow before 2000 March. The working section nearby the 84-15$^{th}$ observation bore began to mine in 2000 March. From then on, the water level in this bore dropped rapidly. In the test mining below the water and sand-bearing stratum in HuanXian coal mine, a set of observation bores along the strike of the 1201$^{st}$ work face had been laid out. The observations began before mining, and had been undertaken for a year till the completion of the mining in this work face. The results are showed in Figure 3 and Table 1[4]. According to Table 1, we know that the water level descent has a relation with the height from the bore bottom to the mined coal seam. From Figure 3, we can see the following phenomenon: the water level in bore 1 had recovered to its original state after a little change; while the water level in bore 2, 3, 4 and 5 did not recover to their original state, though some recoveries have occurred; and the water in bore 6 leaked entirely. Therefore, to protect the underground water

resources, the water preserving mining technique must ensure that the underground water level only changes as in bore 1.

**Table 1.:** Water level observations in bores over 1201 work face of the HuangXian coalmine[4]

| Bore hole number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Height from the bore hole bottom to seam /m | 43.8 | 31.6 | 25.4 | 20.5 | 15.5 | 9 |
| Water level change | transient change | changed | changed | changed | changed | leaked entirely |
| Lowing of the water level /m | 0 | 13.79 | 20.97 | 16.11 | 25 | — |

In General, the underground water should be treated as a resource. Mining techniques for water preservation must be developed in the northwest of China. That is, the mining-induced cone of depression of underground water must recover to its original state.

## Coal mining under buildings

There are about 900 million tons coal under buildings in eastern China. It is always a puzzle for China's coal mines for mining under buildings. At present, partial extraction is the main method to conduct mining under buildings. The low mining efficiency and the low recovery rate are its shortcomings.

The experimental and in-situ survey research results prove that the primary key stratum control the dynamic process of surface movement, and the breakage of the primary key stratum will obviously augment the subsidence velocity and the boundary of subsidence[5-6]. Based on the key stratum theory in ground control, the basic principles for the design of mining under buildings should ensure that the primary key stratum does not break. In order to obtain the highest economic benefit and at the same time the buildings should not be damaged, it is important to select a rational technique and parameters to alleviate surface subsidence according to the actual overburden structure and key stratum characteristics.

Grouting of bed separation spaces is a new technique to reduce surface subsidence. Its function is to support the overburden by grouting the bed separation spaces induced by the rock strata movements, preventing the overburden movements from being transmitted to the surface. The study of the key stratum theory shows that the bed separations mainly occur under the key strata[7]. Since for the current bed separation spaces grouting technique can not prevent the initial break of the key strata, based on bed separation developing dynamicaly below the key strata, the authors have advanced the concept of "section-grouting for the overburden bed separation spaces" [7].

## Mining with backfilling of gob areas

The gob area backfill technique is an important component of green mining technique. Especially, in developed areas, attention is called for in solving the issue of mining under buildings. Theoretically speaking, backfill mining is the perfect way to solve the environmental problems induced by mining, but its high cost restricts the experiments and applications of this method in China.

In order to cut down the cost of backfill, based on the key stratum theory in ground control, an idea of partial backfilling to control coal mining subsidence has been put forward [8]: just to fill parts of the goaf instead of the whole goaf, ensuring that the width of the unfilled goaf is less than the initial break span of the primary key stratum and the backfilling strips can maintain stability for a long time. Thus surface subsidence can be controlled effectively, and the quantity and the cost of filling can be cut down.

## Simultaneous extraction of coal and coal-bed methane

Methane drainage method includes methane drainage without distressing from the solid before coal extraction and stress-relieved methane drainage during or after coal extraction. Acording to the national statistics, permeability of coal seams in China is low, about 70% coal seam permeability coefficient is less than 0.001md. Due to the low permeability of coal seams, the results of field tests of the un-pressure-relieved methane drainage in China recently are not ideal. There are only 30 gas wells producting upto 3000$m^3$/d among the 200 test gas wells [9]. So, the stress-relieved methane drainage method should deserve more attention in China.

The changes in stress field and mining-induced fractures resulting from the overburden movement cause the gas pressure to release and the coal permeability to increase. The flow pattern of the stress-relieved methane is closely related to the movement and deformation of rock mass and its fractures distribution. In order to improve the pressure-relived methane drainage rate and reduce the drilling works, the study of pressure-relieved methane drainage should be combined with rock strata movement. Based on the key stratum theory in ground control, the conception of "simultaneous extraction of coal and coal-bed methane system" has been put forward [10].

## Reduction of rock waste output

Mine rock waste is harmful to the environment and the main measure to reduce rock waste output is to use coal roadways instead of rock roadways. The coal roadway supporting techniques need there for to be developed, such as bolting technology. Along with the increasing mining depth, it is inevitable to excavate roadways in rock. In order to reduce rock waste output, a system of underground disposal of rock waste must be established. This brings a question: how much is its cost? In fact, the underground discharge of rock waste under the economical principle belongs to the green mining issues. The disposal of

rock wastes on surface is not a green mining issue and belongs to environmental protection, such as reclamation.

### Underground coal gasification

Underground coal gasification is an overall green mining technique. As a result of Professor YuLi's 10-year practice in China[11-12], this technique has accumulated considerable experience; all these are the good foundation for subsequent works. In future, the following problems in underground coal gasification must be solved: 1) how to produce domestic gas with high calorific value; 2) how to establish an effective monitoring and controlling system, especially in the method that control burning location and burning velocity; 3) the structure of the gasified furnace and the surface subsidence characteristics after burnout; 4) how to prevent the burning-induced carcinogens (benzene and phenol) from polluting the underground waters; 5) how to deal with the ever-emitting contaminant, $CO_2$, which can pollute the aerosphere. If these problems are not solved successfully, underground coal gasification will lose its significance as a part of green mining techniques.

## CONCLUSIONS

To prevent or alleviate the environmental problems induced by coal mining, the green mining technique deserves to be studied in depth. The study of the distribution of fractures in the process of strata movement and the seepage and flow behavior of methane and water in the broken rock are the bases of green mining. The following are the significant trends for green mining:

1) To treat methane as an useful resource, to change wastes into valuables, and to form surface or underground methane drainage system along with mining;
2) According to the structures of rock strata, to select appropriate water preserving mining methods;
3) According to the actual condition, to develop the technique of backfill, partial extraction, bed separation space grouting and so on in order to protect buildings and land. For mining in China's eastern developed area, it is the inevitable selection, and thus the research direction is to cut down the cost of backfill and to promote the backfill technique;
4) To maintain roadways within coal seams, and reduce the output of rock waste;
5) To develop underground coal gasification technique, and to study its influence on underground water.

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