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Comparative Analysis of Ecological Rucksack Between Open-pit and Underground Coal Mine

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Abstract

Coal is the major energy in China, which always account for more than 70% in the structure of consumer demand for primary energy. on the one hand, coal mining provides us with the main energy , on the other hand, it gives a tremendous pressure on ecology in the mining process. Comparative analysis of ecological pressure between open-pit and underground coal mine with using the method of ecological burden. The result shows, the total ecological burden and the coefficient of ecological burden of open-pit are 4.31 to 11.36 times and 2.77 to 7.74 times of underground coal mine's respectively. Meanwhile, It is the main method by adopt measures such as pay attention to the mining section and improving technology to reduce the amount of stripping and tunneling, and lower the electricity consumption and improve the water cycling utilization ratio, as well as adopt the clean energy and biological energy to reduce the ecological pressure of coal mine. Underground coal mining is recommended if the two mining methods are allowed.

Keywords: Open-pit coal mine; Underground coal mine; Ecological pressure; Ecological rucksack

1. Introduction

As China's joined WTO in 21st century, the world economic globalization and the further opening up, China's coal industry will face more severe challenges, facing fierce market competition and stringent environmental constraints, it needs to a comprehensive study on coal industry measures from a strategic perspective to ensure our energy security and sustainable development of coal industry[1]. This requires new understanding of the relationship between coal mining and ecological resources and finds out all aspects of coal brought by ecological stress. Re-shaping a cycle of development system of "resource

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conservation, less pollution, low energy consumption." Ecological burden indicators are widely used to study the metabolic characteristics of social - economic system, the ecological burden of human consumption and the impact on the ecology, quantitative ecological pressure.

The article comparative analysis of ecological pressure between open-pit and underground coal mine with using the method of ecological burden, and reaches its best way to restore the ecological carrying is afforestation. Underground coal mining is recommended if the two mining methods are allowed.

2. The ecological rucksack of coal mining

2.1 About ecological rucksack

The concept of ecological rucksack was first proposed by Weizsaecker, ecological rucksack is the economic system of an important part of metabolism, about 50% of total material requirement in EU is the ecological rucksack [2]. The ecological rucksack vividly express humanity in order to obtain a useful material that caused additional ecological pressure. Ecological rucksack is human access to useful materials and production of products that are not directly entered the trade and production processes of the material, the material flow account also known as the hidden flow [3]. For example, it's necessary to dug many large rock tunnel and peel in order to mine the exploitation of coal, these do not directly enter the production process and the product itself, it is known as the hidden stream, that is, ecological rucksack. Ecological rucksack can fully reveal from the product input consumption of natural resources and environment impact[4]. The ecological rucksack of a product equivalent to the total weight of the material input weight difference with the product itself, its ecological rucksack factor is the total weight of the material ratio of its own weight[5].

Generally speaking, direct use of material of products is not a single, Its ecological rucksack calculations need to consider of all the substances involved, including direct and indirect use of the material. All material quantity by weight. Production of a product containing the various substances consumed, the weight(W_i) of the substances multiplied by their ecological rucksack factor(γ_i), the total weight of material input of the product is the sum, then minus the weight of the product itself is the product of the ecological rucksack(R)[6]. That is:

$$R = \sum_{i=1}^{n} \gamma_i W_i - W \qquad (1)$$

Ecological rucksack factor is :

$$\gamma = \frac{1}{W} \sum_{i=1}^{n} \gamma_i W_i \qquad (2)$$

The key of calculation ecological rucksack is to find all the inputs, and stress two points:(1) Take energy consumption (e.g. electricity) as a "material" inputs;(2) Need to track the "input into" and their ecological rucksack , such as power input due to coal into and the ecological rucksack of the coal, and steel input caused by the ecological rucksack of iron ore.

It requires to keep track of their processes into the previous process in order to find all the inputs, the benefits of ecological rucksack factor is not necessary to repeat the calculation for each process. However, the application of ecological rucksack factor is limited, not all data are obtained. Therefore, the ecological rucksack factor need be calculated separately. The natural material input is divided into five parts by German Wuppertal Institute: non-biological material, biological material, soil movement, water and air.

Non-biological material including minerals, carry energy , non-use of excavation, soil excavation; Biological materials including cultivated plants, non-cultivated plants, non-farmed animals; Soil movement including the use of agricultural and forest land, soil erosion; Water including process water (extraction of surface water, groundwater extraction, extraction of deep groundwater), cooling water (extraction of surface water, groundwater extraction, extraction of deep groundwater); Air including combustion gas, chemical conversion gas, the physical transformation of gas (condensed state), the other taking the air.

This material input coefficient using the ecological rucksack of computation by German Wuppertal Institute , as shown in table 1

Table 1 Some material input coefficients

Name	Non-biological material	Biological material	Water	Air
Electricity	4.22kg/Kwh	None	72.5kg/Kwh	0.607kg/Kwh
Diesel fuel	1.36t/t	None	9.7t/t	3.238t/t
Coke	4.22t/t	None	22t/t	3.1t/t
Carbon piece	20.06t/t	None	306.25t/t	5.7t/t
Coal	2.36t/t	None	9.1t/t	0.05t/t
Cement	2.42t/t	None	None	None
Steel	6.90t/t	None	None	None
Timber	0.13t/t	4.37t/t	0.27t/t	0.1t/t

2.2 Ecological rucksack and its analysis of open-pit coal mine

According to the production data of the open-pit coal mine, calculate its ecological rucksack, as table 2. Calculated ecological rucksack factors according to coal production in table 3, the changes in figure 1.

Table 2 Various kinds of total ecological rucksacks of open-pit coal mine

Grass weight：t	Year 2004	Year 2005	Year 2006	Year 2007	Year 2008
Solid non-biological	329875.143	311841.273	302591.797	226334.285	121070.852
Stripping capacity	5500720.000	5454239.000	5201146.000	4203214.000	2876057.000
Biological	13983.472	11292.181	15651.340	5791.795	754.045
Water	9373951.930	9080497.223	8978482.339	7297737.562	4496492.519
Air	42419.027	40658.277	40142.924	30846.721	17609.608
Others	1386.077	1404.255	1454.540	1300.085	1115.646
Total：t	15262335.649	14899932.209	14539468.94	11765224.449	7513099.670

Table 3 Ecological rucksack coefficients of open-pit coal mine

Ecological rucksack factor：t/t	Year 2004	Year 2005	Year 2006	Year 2007	Year 2008
Solid non-biological	0.194	0.175	0.172	0.099	0.052
Stripping capacity	3.229	3.058	2.960	1.834	1.227
Biological	0.008	0.006	0.009	0.003	0.000
Water	5.503	5.091	5.110	3.185	1.918
Air	0.025	0.023	0.023	0.013	0.008
Others	0.001	0.001	0.001	0.001	0.000
Total：t	8.959	8.354	8.275	5.134	3.205

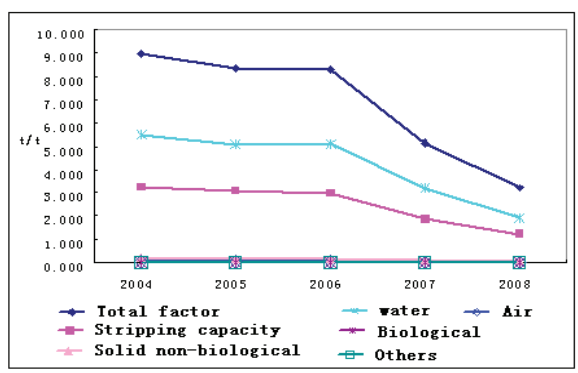

Fig1 Ecological rucksacks coefficeients' variation of open-pit coal mine

The ecological rucksack of stripped, other solid non-biological substances, water and air account for 35.73%-38.28%, 1.62%-2.17%,59.85%-62.03% and 0.23%-0.28% of total ecological rucksack respectively of open-pit coal mine. Solid non-biological and water's ecological rucksack composing the main part of the total ecological rucksack. Ecological rucksack factor of the solid material is the biggest and its value between 1.279 and 3.424 among all the ecological rucksack factors of open-pit mine. As mining progresses, the ecological rucksack coefficient showed a downward trend, indicating that the resources consumed of mining per ton of coal decreased.

2.3 Ecological rucksack and its analysis of underground coal mine

According to the production data of underground coal mine, calculate its ecological rucksack , as table 4. Calculated ecological rucksack factors according to coal production in table 5, the changes in figure 2.

Table 4 Various kinds of total ecological rucksacks of underground coal mine

Grass weight：t	Year 2004	Year 2005	Year 2006	Year 2007	Year 2008
Solid non-biological	75049.090	76407.253	82650.459	88002.909	97402.611
Stripping capacity	55179	63258	111621	253396	295625
Biological	17165.360	13242.848	9201.472	8163.160	5810.352
Water	985984.157	1059582.038	1161397.226	1226638.700	1303135.084
Air	8803.722	9416.747	10257.076	10796.679	11433.563
Others	121.701	61.784	56.927	61.411	25.941
Total：t	1142303.031	1221968.671	1375184.161	1587058.859	1713432.552

Table 5 Ecological rucksack coefficients of underground coal mine

Ecological rucksack factor：t/t	Year 2004	Year 2005	Year 2006	Year 2007	Year 2008
Solid non-biological	0.076	0.072	0.065	0.065	0.066
Stripping capacity	0.056	0.060	0.088	0.187	0.199
Biological	0.017	0.012	0.007	0.006	0.004
Water	0.999	0.998	0.914	0.904	0.879
Air	0.009	0.009	0.008	0.008	0.008
Others	0.000	0.000	0.000	0.000	0.000
Total：t	1.157	1.151	1.082	1.170	1.155

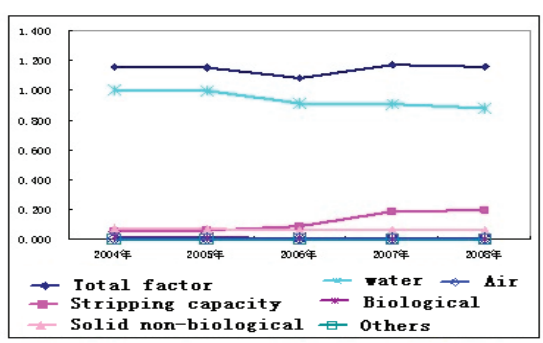

Fig2 Ecological rucksacks coefficeients' variation of underground coal mine

Discharge cash, other solid non-biological substances, water's ecological rucksack account for 4.83%-17.25%,5.68%-6.58%,76.05%-86.32% of total ecological rucksack respectively of underground coal mine. These three items composing the main part of the total ecological rucksack. Ecological rucksack factor of the water is the biggest and its value between 0.879 and 0.999 among all the ecological rucksack factors of underground mine. The second place of the ecological rucksack factors is other solid non-biological substances and its value between 0.153 and 0.265. As mining progresses, the ecological rucksack coefficient did not change much, it indicating that the resources consumed of mining per ton of coal also did not change much.

3. Conclusions

Based on the method of ecological rucksack, the ecological stress of open-pit and underground coal mine are calculated respectively and analyzed, and then obtain the following conclusions.

(1) The total ecological burden of open-pit is 4.31-11.36 times of underground coal mine's. Of which the ecological burden of solid non-biological substances, stripped ,others of open-pit is 1.24-4.40 times, 9.73-99.69 times , 11.39-43.01 times of underground coal mine's respectively.

(2) The ecological burden factor of open-pit is 2.77-7.74 times of underground coal mine's. it shows that the resources consumed of mining per ton coal of open-pit is 2.77-7.74 times than that of underground coal mine. In other words, the ecological pressure caused by open-pit is much higher than by underground mine.

(3) As mining progresses, the ecological rucksack coefficient of open-pit showed a downward trend, it indicating that the resources consumed for mining per ton of coal decreased. However, for underground coal mine, the resources consumed of mining per ton of coal did not change much.

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