Analysis of ecological environment impact of coal exploitation and utilization

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Abstract. Based on the theory of life cycle assessment, the ecological and environmental impacts of coal mining, processing, utilization and transportation will be analyzed, with analysing the status of china’s coal exploitation and utilization as the basis, it will find out the ecological and environmental impact in the development and utilization of coal, mainly consist of ecological impact including land damage, water resource destruction and biodiversity loss, etc., while the environmental impact include air, water, solid waste pollutions. Finally with a summary of the ecological and environmental problems, to propose solutions and countermeasures to promote the rational development and consumption of coal, as well as to reduce the impact of coal production and consumption on the ecological environment, finally to achieve the coordinated development of energy and the environment.

1. Introduction
China is a country with the coal as the main energy, which is also the world's largest coal producer and consumer. However, the ecological environment problems produced by the development and utilization of coal are very serious. China has introduced a lot of coal-related policies, from the perspective of total control, consumption structure, and consumption intensity, giving provisions of the coal development and utilization. In order to control air pollution and promote energy development and reform in recent years, China regards a more mandatory management for coal as the main entry point. Therefore, it is the fundamental requirement to solve the energy and environment problems in such a situation, which can provide the most direct basis for the rational exploitation and utilization of coal, with strengthening the prevention of ecological damage and the environment pollution prevention and control, to further promote the sustainable development of energy and environment.

As for research on the ecological and environmental impact of coal development and utilization, compared with China, coal accounts relatively small proportion in the energy structure in foreign countries, especially developed countries, and its pollution is effectively controlled. So the related research is not too much, mainly including case studies or LCA application study [1-3]; While in China, related studies are mainly about qualitative description or assessment methods in process of coal mining, or coal combustion and coking [4-6], which lack some certain predictions or quantized analysis, this paper will try to systematically and comprehensively display the impacts level through the main phases of coal exploitation and utilization, so as to reflect issues and find the cutting point to solve them.
2. Development and utilization status of coal

2.1. Reserves of coal resources
China's coal reserves are abundant. Till the end of 2015, Chinese identified coal reached 1.57 trillion tons, an increase of 16.8% compared to 2014, and the new increased identified reserves was 39 billion tons. The basic reserves of coal resources are part of the identified reserves, which ought to meet the requirements of existing mining and production. According to the statistics made by National Bureau of Statistics on coal reserves in the provinces over the years, from 2003 to 2014, before 2011, China's coal reserves of basic resources showed a downward trend, from 300~350 billion tons in 2003 to 210 billion tons, after 2011, the data gradually Rise, as of 2015, China's coal reserves of the province's total reserves of 244 billion tons (Figure1).

![Coal Reserves(10^8 tons)](chart1.png)

*Figure 1.* China's basic reserves of coal resources from 2003 to 2015.

2.2. Coal production and consumption
Before 2013, China’s coal production and consumption has basically presented an upward trend, respectively, reached nearly 4 billion tons and 4.2 billion tons. Then the coal production declined, as well as the coal consumption, which indicated that the state had played an important role in the control of coal production( as seen in Figure2), while the total consumption of coal control policy had also played a certain effect.

![Coal Production (10^8 tons) & Coal Consumption (10^8 tons)](chart2.png)

*Figure 2.* China's coal production & consumption from 2000 to 2015.

*Data resource: China Statistical Yearbook 2001-2016*

2.3. Research methods
Life cycle assessment (LCA) is an analytical tool for quantifying the various emissions, resource consumption and energy use and related environmental factors in the conversion of raw materials into
the final product. The life cycle encompasses the products, processes, engineering or activities, the environmental load process associated with the entire life cycle system, which includes the process from raw material acquisition and processing to production, transportation, sale, use, maintenance and final disposal. The LCA will be used to analyze the development and utilization of coal for the whole life cycle, so as to carry out the qualitative or quantitative analysis of the ecological environment influence caused by coal mining, processing, transformation, utilization and transportation.

3. Analysis of the impact of the whole life cycle on the ecological environment

3.1. The whole life cycle division of coal

The development and utilization of coal resources has obvious life cycle. The whole life cycle of coal refers to the various stages and the whole process of coal from coal mining to utilization. Therefore, the coal life cycle will be divided into coal mining, coal consumption and coal transporting process.

3.2. The whole life cycle of coal ecological environment

3.2.1. Coal mining process

(1) Ecological impact The impact of the coal mining process on the ecological environment mainly included the occupation and destruction of land resources, the occurrence of geological disasters, the destruction of water resources, damage to the stability of the ecosystem,[7-9], etc., which reflected in the land collapse, water consumption and biodiversity loss and some other indexes (seen in Table 1). China's annual emission of waste rock was about 300 million tons, accounting for 10% to 15% of the coal production. International Energy Agency (IEA) pointed out that in 2035, China's water consumption caused by energy production will increase 83% over 2010, of which coal production and consumption is the main factor in water consumption.

Table 1. The impact of the coal mining process on ecological environment.

| Impact index                  | Extent of impact                                      |
|-------------------------------|-------------------------------------------------------|
| Land occupation               | more than 300 to 400 hectares                         |
| Land collapse                 | 0.267 hectares collapse with \(10^4\) tons coal mining, accounted 97.43% of all mine collapse |
| Water resource destruction    | 2 billion cubic meters                                 |
| Biodiversity loss             | 1 million \(hm^2\) of forest damage, 250,000 \(hm^2\) of grassland area destruction |

(2) Environmental pollution problems The impact of environmental pollution caused by coal mining is enormous, including atmospheric, water, solid waste pollution[10]. According to incomplete statistics, the gangue can generally reach 0.12t ~ 0.4t caused by 1 tons of coal production, emissions accounted for about 15% to 20% due to coal production. Take coal mining and washing industry as an example, its water and atmospheric environment was caused by damage and pollution. In 2014, the contribution of coal mining and washing industry to total industrial wastewater discharge was 7.7% in all industrial sectors; smoke dust emissions contributed the most to the total industrial air pollutants emissions, while solid waste emissions and proportion declined year by year (Table 2, Table 3 and Table 4).

Table 2. Wastewater discharge from coal mining and washing industry.

| Year | Industrial wastewater discharge(10^4 tons) | Wastewater discharge of coal mining and washing industry(10^4 tons) | Proportion |
|------|--------------------------------------------|---------------------------------------------------------------------|------------|
| 2011 | 212.90                                     | 14.35                                                               | 6.7%       |
| 2012 | 203.36                                     | 14.22                                                               | 7.0%       |
| 2013 | 492.48                                     | 17.74                                                               | 3.6%       |
| 2014 | 186.96                                     | 14.48                                                               | 7.7%       |
Table 3. Emission and proportion of air pollutants in coal mining and washing industry.

| Year | Industrial fluegas E(10^8 cubic meters) | SO\(_2\) E(10^4 tons) | NO\(_x\) E(10^4 tons) | Smoke and dust E(10^4 tons) |
|------|----------------------------------------|------------------------|------------------------|-----------------------------|
| 2011 | 2039                                   | 0.30                   | 12.93                  | 0.68                        |
| 2012 | 3249                                   | 0.51                   | 12.49                  | 0.70                        |
| 2013 | 2363                                   | 0.35                   | 12.62                  | 0.75                        |
| 2014 | 2088                                   | 0.30                   | 11.43                  | 0.72                        |

*E-Emissions, P-Proportion

Table 4. Emission and proportion of solid waste in coal mining and washing industry.

| Year | General industrial solid waste E(10^4 tons) | Proportion (%) |
|------|---------------------------------------------|----------------|
| 2011 | 129.84                                      | 33.35          |
| 2012 | 17.90                                       | 13.66          |
| 2013 | 12.09                                       | 10.64          |
| 2014 | 4.55                                        | 8.35           |

3.2.2. Coal consumption process

(1) Air pollution Thermal power generation is one of the key points of environmental pollution control\[11,12\]. Coal-fired power generation is an important part of thermal power generation, which occupied about 95% in the thermal power installed capacity\[13\]. In 2014, thermal power development was required to realize "near zero emissions", and strived to clean efficient power generation. According to statistics, the contribution of thermal power to air pollutants in China had been declining year by year, while non-power coal consumption has gradually become the main source of pollution (Figure 3).

![Figure 3](image-url)

**Figure 3.** Air pollutants emissions of Coal-fired power generation and non-power industry.
Air pollutants produced by coal chemical Industry had the characteristics of various emission links, great intensity, variety, large toxicity. While used to construction industry, the production of CO₂ and dust emissions of cement industry is very prominent\[14\]. Meanwhile, currently the use of bulk coal is an important source of air pollution, and the specific pollution extent of above aspects is seen in Table 5.

Table 5. Air pollution resulting from coal utilization.

| Type of coal utilization          | Air pollution extent                                                                 |
|----------------------------------|---------------------------------------------------------------------------------------|
| Coal chemistry                   | About 400 cubic meters of gas produced by 1 ton of coke production                    |
| Construction industry            | The volume of cement smoke per unit area is 8.45 times the world average, about several million tons, accounting for 39% of the total industrial dust emissions, ranking first in the industrial sector. |
| Bulk coal combustion             | The emission of pollutants of 1 ton coal combustion is 5 to 10 times the emissions of the thermal power coal. Emissions of sulphur dioxide is close to 10 million tons, more than 320 million tons of nitrogen oxides each year. |

(2) Water resources impact  According to the different transformation and utilization of coal processing, the impact of coal consumption on water resources reflected in a large number of water consumption on the one hand, and on the other hand reflected in water environment pollution problems caused by sewage discharge. The expansion of coal industry is exacerbating China's water crisis. Till the end of 2013, the annual water consumption of coal-fired power generation reached about 7.4 billion cubic meters. Of which 3.4 billion cubic meters located in water-lacking areas, equivalent to a year of basic water demand of 186 million people.

In the coal chemical industry, usually, the water consumption of 1 ton of coke should be more than 2.5 tons, waste water treatment is difficult to control, COD concentration is about 3000~5000mg/L, ammonia nitrogen concentration is between 200~500mg/L. Coking wastewater discharge, not only caused serious pollution to the environment, but also set a direct threat to human health.

(3) Solid waste impact  Coal-fired power plants produce a variety of solid waste and by-products. The coal ash and other solid waste of China’s thermal power plants emissions was more than 40 million tons, desulfurization gypsum emissions were 0.5 million tons, which took up a lot of land, aggravated land use contradictions, greatly damaged land resources, and also produced a variety of environmental issues. The waste residue of coking plant, included coal dust, tar residue, excess sludge and so on. For an annual output of 1.45 million tons of coking plant, 3,000 tons of tar residues, 500 tons of acid tar and 1,300 tons of coal dust can be produced each year.

3.3. Coal transportation process  The impact of coal transportation on the ecological environment mainly reflected in the impact on the atmospheric environment. As the main way of coal transport, in the railway transport due to train bumps and wind, coal surface dust and other fine particles will be scattered on the road or raised, causing various degrees of dust pollution on the railway line environment\[15\]. Updated data showed that in recent years, the amount of dust produced during China's coal storage and coal production process was about 20 million tons per year, imposing a great impact on environment. According to the statistics of transport sector of Ministry of Railways, in 2012 China’s dust caused by scattered coal powder reached 18.5 million tons due to coal transport, or about 8.5 billion Yuan. In the north area including Shaanxi, Shanxi, Inner Mongolia and some places, the mass concentration of dust in the air reached 34 ~ 85mg/m³, far more than 0.5mg/m³ of the national standard, throwing a great threat to the health of people along the line.
3.4. Analysis of the main ecological and environmental problems

3.4.1. Disorderly coal mining phenomenon is serious, affecting the sustainable development of resources

In the maximization of efficiency and a large number of coal demands, many local coal mines increased production and efficiency by means of super-capacity production, super-intensive mining methods. For a long time enterprises rely on the state for free allocation of coal resources, lacking of awareness of resources conservation and utilization and operational mechanism, driven by economic interests, part of the coal enterprises pursued quick success, with a large number of resources consumption, shorten the service life of the mine at the cost of over-production, finally led to phenomenon of thin coal seam abandoned mining, recoverable thickness loss of thick coal seam, and unreasonable loss of coal reserves and other serious waste of coal resources. The western region, with rich coal resources and fragile ecological was influenced a lot by the impact of coal mining.

3.4.2. The coal development and utilization layout is uneven, aggravating the shortage of water resources

China's coal resources and water resources displays reverse distribution characteristics. The coal reserves of south and east are much lower than those in the north and west regions. Most of the key coal bases are located in the areas where the contradiction between water supply and demand is more prominent, while the production and construction of the coal bases will further aggravate the water resources shortage. In addition, the development of coal chemical industry also needs to spend a lot of water resources, large water consumption due to immature modern coal chemical engineering is one of the main reasons, and thus to a large extent make water resources more and more scarce.

3.4.3. The utilization of coal is extensive, resulting in great pollution and energy loss

At present, the use of coal is extensive, especially the direct combustion, and low clean utilization of coal. Direct combustion of coal without washing or other clean treatments, the pollutant control facilities are not standardized or even emit directly, bulk coal combustion without any pollution control measures, etc., have caused serious pollution to the air environment. Direct coal combustion will produce a lot of SO2, NOx, smoke and dust, contributing 30% to the national PM2.5 annual average concentration. On the other hand, the use of heat arising from coal combustion is not sufficient, energy-saving measures are not in place, all these can cause energy loss and waste.

3.4.4. The proportion of coal consumed by power generation is low, against the ecological and environmental management

In China, some areas have achieved "near zero emissions" in coal-fired power generation with drawing lessons from the experience of developed countries to control air pollution and its higher proportion of coal consumed by power generation, combined with the characteristics of China's coal consumption structure, it can be analyzed that, China's coal consumption on power generation accounted for a lower proportion compared to the corresponding non-power coal consumption, especially the dispersed combustion of bulk coal contributes a lot to air pollution, which is unfavourable to the effective management of the ecological environment in China.

4. Policy suggestions

4.1. Regulate the planning and management of coal resources

Standardize coal resource planning and coal industry development management. The approach should be changed from the extensive development to protective, conservative, scientific and rational development. Comprehensively using industrial policy, development planning, laws and regulations and other means of coal resources, to conduct a strict mining sequence, mining methods and intensity management, prohibit the cross-border and private digging. Adhere to the development and layout strategy of "Compress the east, limit the middle and northeast, and optimize the west"[16], to improve the legislation of coal resource planning legislation as soon as possible, so as to strengthen the overall
planning and rational allocation of coal resources, increase environmental impact assessment efforts on coal mine project planning and protection, finally promote the standardization, intensification, rational and orderly development and utilization of coal resources.

4.2. Implement coal consumption control measures
Coal consumption control is the focus of energy reform, one of the important means conducive to promote the realization of ecological and environmental protection, resource conservation and climate change. The whole country and provinces should develop a coal consumption plan, speed up the improvement of coal consumption control target management system, formulate the coal reduction work program, and put forward specific measures and corresponding targets of coal reduction, then strict implementing the mandatory constraints given by scientific planning. At the same time, it should also try to establish a unified mechanism of coal decomposition, attach importance to the regional coordinated coal control, take differentiated coal consumption control measures according to the regional natural resources, ecological environment and economic development needs and other conditions.

4.3. Comply with the principle of water red line constraints
Attach great importance to the water crisis facing with coal-fired power plants and coal chemical industry and other coal industry, focus on solving water shortages and water pollution problems, to ensure water security. In particular, make analysis of water resources in the fragile ecological areas of coal and electricity bases. Implement the red line restraint policy to strictly control the groundwater overdraft, eliminate old coal-fired power plants with low efficiency, improve the water-saving technology of coal-fired power plant, saving water intake of coal-fired power plant. Be clear about the coordination between water resources management and energy planning. Take water as the decisive factor to coal consumption, optimize water resources allocation. If necessary, promote water rights transactions, so as to improve the efficiency of water use in coal bases.

4.4. Use a variety of joint control means to prevent air pollution

4.4.1. To increase the proportion of coal consumption on power generation. Learn from the effective practices of foreign developed countries to control pollutants, combined with China's national conditions, to promote the introduction of a large number of coal consumption to the electricity production sector, with relying on ultra-low emission technology of coal-fired power generation to achieve the use of clean coal, so as to promote the effective improvement of atmospheric environmental quality.

4.4.2. Control the burning of bulk coal. Strengthen the management of bulk coal control, and constantly strengthen the standardization of bulk coal combustion supervision and management; to improve the supply of high quality coal, promote the use of clean coal, electricity and gas and other alternative clean energy, popularize clean stoves, central heating and other measures to fundamentally reduce the haze and other air pollution phenomenon caused by coal burning.

4.4.3. Promote the transformation of coal to the transmission of electricity. At the time of establishment of green and efficient coal transport system, the innovative energy transmission mechanisms should be researched, to increase the transmission channel construction, and strive to improve the local coal conversion rate. To replace the way of coal transportation is to promote coal to achieve green, clean conversion, also a way from the source point to solve the energy waste and dust pollution and other air pollution problems brought by coal itself.
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