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# Environmental cumulative effects of coal underground mining

Meng Lei[a,b], Feng Qi-yan[a,b,*], Zhou Lai[a,b], Lu Ping[a,b], Meng Qing-jun[a,b]

[a]*School of Environmental Science & Spatial Informatics, China University of Mining and Technology, Xuzhou 221008, China*
[b]*Jiangsu Key Laboratory of Resources and Environmental Information Engineering, China University of Mining and Technology, Xuzhou 221008, China*

**Abstract**

More than 70% of primary energy production and consumption in China is occupied by coal. The exploitation quantity has been about 35 billion tons since 1949, over 95% of which is by underground mining. In 2008, the coal production has reached 2.72 billion tons. Long-time and intensive mining has caused spatiotemporal cumulative effects on soil, water, air environment, and ecosystem, which include ground subsidence, hydrodynamics change, land use change, soil pollution, air pollution, and ecosystem evolution etc. In this study, the cumulative sources, paths, and main performances of the environmental cumulative effects on underground coal mining region are analyzed. Moreover, the existence of synergistic effects among all environmental factors is pointed out, with some suggestions proposed for future research.

*Keywords:* coal; underground mining; environment; cumulative effects

## 1. Introduction

Coal accounts for 76% of primary resource production and 69% of total consumption respectively in China, and it will still dominate China's energy structure in the next 50 years [1]. Since 1950s the total production has been about 35 billion tons, and the annual output has reached to 2.72 billion tons in 2008 [2]. However, the distribution of coal resource in China is uneven, 67% of which distributed in north-western China's arid and semi-arid region, and 20% in south-western mountain regions. Ecological environment of these regions are very vulnerable. The ground subsidence, water resource losses, water pollution, air pollution and other environmental problems induced by coal mining became more and more prominent. Because the productive life of a coalmine can last for more than half century, the problems mentioned above will continue to a great extent and form the cumulative effect. Additionally, damage to the habitat of mining area is expected to be inevitable if it exceeds the regional environmental capacity threshold.

Generally speaking, exploitation of coal resource include two ways, underground mining and open mining, among which more than 95% were exploited by underground mining in China. In the past years, plentiful studies had revealed cumulative environmental effect on wetland, bay and basin exploitation, though little investigation on coal mining was found [3-5]. In this study, the cumulative sources, paths and main manifestations of the

* Corresponding author. Tel.: +86-516-83591303; fax: +86-516-83591302.
*E-mail address*: fqycumt@126.com.


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environmental cumulative effects in underground coal mining region were analyzed from topography and geomorphology, water, soil, air and ecosystem. Moreover, the existence of synergistic effects among all environmental factors was presented.

## 2. Principle of environmental cumulative effects

In 1978, American Council on Environmental Quality introduced the concept of cumulative effect: when environmental effect of an activity combines with other previous, present, and future effects, the effect will be enhanced and lead to cumulative effect (American council on environmental Quality regulation 40CFR1508). In 1997, the cumulative effect is further explained as that accumulated through time and space by the effect of other or previous activity on the region which has not totally recovered from previous anthropogenic disturbing activity [6]. According to cumulative process, cumulative effect should include space congestion, time congestion, time delay, space crowed, cross boundary effect, synergy effects, and so on [7].

Based on the principle of the cumulative effect, environmental cumulative impact was defined [8]. In national regulation and technical guide, the cumulative influence on environment and people's health has been taken into accounted with the implementation of Chinese evaluation system of environmental impact [9-10]. It was confirmed that cumulative effect was able to combine more environmental influence and their interaction than cumulative environment influence [11]. Cumulative effect, therefore, was suggested to be used for evaluation of project and regional environmental impact. Presently, the cumulative environmental effect induced by coal mining has not been considered in environmental impact assessment in China but it is extremely important for fully evaluating and predicting environmental evolution of mining area.

## 3. Environmental cumulative effects of coal underground mining

Unlike open mining, underground mining extracting coal resources through the wells, usually leads to land subsidence, water resources destruction, soil erosion, air pollution and biodiversity decrease. Those problems can interact with each other, and develop through time and space, which speed up the environmental deterioration of coal mining area. For example, terrain changing, caused by mining subsidence, affects the surface hydrological processes, which at the same time deteriorates the soil erosion and water quality. According to the concept of cumulative effects, those problems, characterized in spatial and temporal overlay and interaction, generate cumulative effects on landscape, water, soil, air and ecosystem (figure 1). The characteristics of cumulative effects on different elements of environment were discussed as follows.

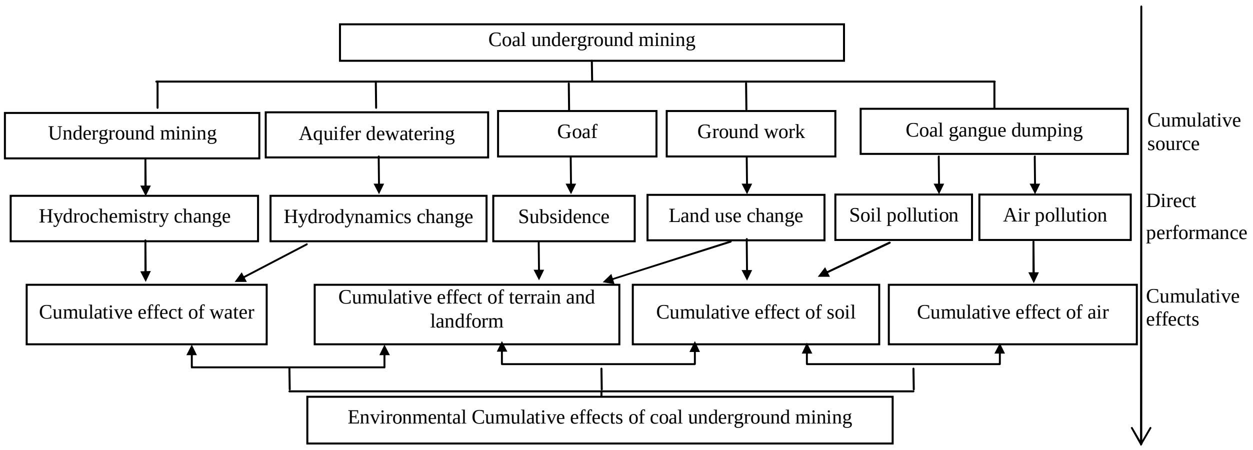
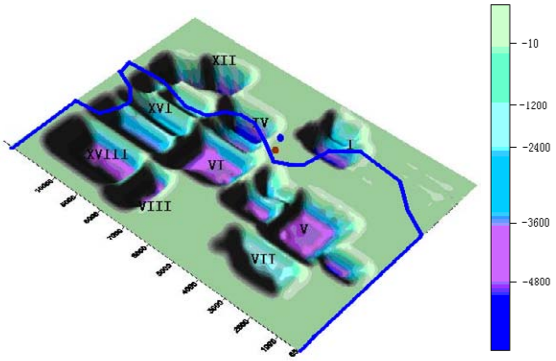



Fig. 1. Route of cumulative environmental effects of coal underground mining

### *3.1. Cumulative effect of terrain and landform*

Because of mining subsidence, the cumulative effect on terrain and landform mainly embody terrain undulation, land use pattern and land cover change. Mining under the high phreatic water level, groundwater can flow into the subsidence area and form many wetlands of different sizes. For example, in Yanzhou mining area, eastern China, the area of abandoned land, seasonal waterlogged region and deep waterlogged region were respectively 9.13, 6.23, 5.99 $km^2$ in 2000, and respectively 9.71, 7.07, 6.36 $km^2$ in 2002. While in arid region mining collapse transforms flat grassland into basin with steep slope. Mining under lakes, reservoirs and rivers can change the riverbed, which affects lake and river hydrological process, aquatic habitat, flooding control and waterway traffic. Taking Jining No.3 Coalmine for example, 70% of mining area was under Nansihu Lake in Yanzhou coal mining area. According to the visual 3D modeling results of subsidence basin in 2015 (figure 2), mining subsidence can significantly change the terrain undulation of the lake bed. Besides mining subsidence, ground industrial constructions occupy much arable land and grass land and change the land use pattern.




Main mining shaft Auxiliary mining shaft Nansihu Lake boundary

Fig. 2. Visual 3D modeling results of mining subsidence in Jining No.3 Coalmine

### *3.2. Cumulative effect of water environment*

Cumulative effect on water environment refers to surface water and groundwater quantity and quality evolution. To make sure the safety of coal mining, a large amount of groundwater was pumped and drained to ground surface. According to the statistics, the pit drainage of water in China was about 4.2 billion cubic meters per year [12]. A large amount of draining water firstly consumes static reserve of aquifers, and then consumes dynamic reserve of aquifers (figure 3). Descending of groundwater level could cause spring dry, vegetation withering, and so on. Especially in the arid region where underground aquatic environment is fairly vulnerable, groundwater table decline can lead to land collapse once it is blow the warned level. In coastal area, groundwater level decline can lead to seawater invasion. For example, Jinci spring in Shanxi province has been dry due to high drainage of karst groundwater in the surrounding coal mines. The formed depression cone of ground water changes the hydrodynamics of groundwater. Moreover, mining activities affect the underground water quality evolution by switching the closed reduction environment to open oxidation environment.

Mining subsidence has changed the previous terrain and landform. Besides, water-log of subsidence area has changed the previous distribution and runoff, which to a large extent alters the water circulation even regional climate. Nitrogen, phosphorus and other nutrient elements in soil can easily move into the water-log and catchments. Mining under water bodies affects the release of chemicals in the mud. In addition, the dumped coal gangue can affect the groundwater and surface water quality by rainfall leaching of the heavy metal, sulfate, alkaline soil and other elements. For example, in Yanzhou coal mining area, the pH, sulfate, total hardness and solid density in the subsidence area filled with coal gangue and in the wells near coal gangue hills were extremely high, which to a large degree exceeded the class Ⅲ quality standard of groundwater(GB/T14848-93) in China and posed a potential risk to public health.

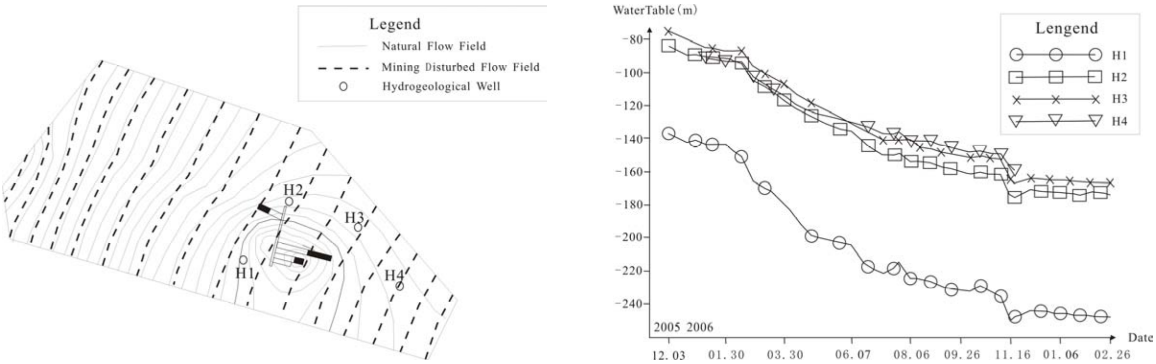



Fig. 3. Hydrogeological response to mining in a coal mine of Henan province (a) Contour of groundwater level (b) Groundwater level change with time in monitoring wells

### *3.3. Cumulative effect of soil environment*

Cumulative effect on soil environment of coal area mainly includes soil erosion and soil pollution. Both of them degraded soil quality and reduced soil productivity. Mining subsidence together with declined regional underground water level and industrial construction of coal area changes the slope of ground surface, and then aggravates soil erosion. The geochemical process in soil will change correspondingly if arable land is transformed into subsidence area or wet land. Due to the long time dumping of coal gangue, hazardous substances are leached into the soil and result in soil pollution. Cui demonstrated that the enrichment factor of heavy metal in the soil around the gangue is proportional to the history of coal mining [13]. Compared to other heavy metal elements, Cu, Pb, Ni, Zn and Sn have stronger transfer abilities.

### *3.4. Cumulative effect of air environment*

Cumulative effect of air environment mainly originates from coal gas, spontaneous combustion or oxidation of coal gangue. Synergistic effect from variation of soil and water can also contribute to cumulative effect of air environment. Methane, the main component of coal gas, usually contributes twenty-one times more than carbon dioxide for green house effect. Annual methane emission in China has reached 7.0~9.0 billion cubic meters presently [14]. Some coal and pyrite (with burning point 250~280℃) in the gangue can arise spontaneous combustion of gangue if it is disposed in the open oxidation environment. It is confirmed that sulfur is crucial to gangue combustion which means if it exceeds 1.5% of gangue weight, spontaneous combustion of coal gangue will happen, and if it exceeds 3.0% of gangue weight, coal gangue will be self-firing. Spontaneous combustion of coal gangue emits a large amount of $SO_2$, $CO_2$, $H_2S$, CO, even sometimes elemental sulfur. Some organic matter in the coal gangue can be oxidized into nitrogen oxide and benzo[α]pyrene etc., which to a great extent degrades the air quality. Furthermore, dust and hazardous substances from the weathering of coal gangue piles aggravates air pollution.

### *3.5. Cumulative effect of ecosystem*

The cumulative effects of ecosystem in coal mining areas mainly show that typological change of ecosystem in mining area induced by water and soil environment change, change of biological species evolution, biomass and biological diversity. In high phreatic water level mining area, eastern part of china, subsidence causes water-logged on surface. Ecosystem there is switched from terrestrial type to aquatic type. Vegetation in water-logged areas disappears. Instead, the alkaline resistant vegetation appears around the saline land in the mining area [15]. In arid mining areas, western part of china, underground water level decreased shapely. What is more, in surface collapse area where surface water connected with the underlying aquifers, the drought was intensified owing to surface water leakage. Hydrophilous plants gradually degenerate into xeromorphic plants accompanied with the reduction of biological species and biomass. As a result, the ecosystem is threatened with complete destruction.

## 4. Conclusions and suggestions

Coal is the vital primary energy in China. Over a hundred years intense underground mining however has arisen numerous environment hazards like mining subsidence, dewatering aquifer and coal gangue dumping, which lead to environmental cumulative effects on coal mining area. Based on principle of cumulative environmental effect, cumulative sources, paths and main performances of the cumulative environmental effects in underground coal mining region were analyzed from topography and geomorphology, water, soil, air and ecosystem. The existence of synergistic effects among all environmental factors was also presented. Due to the deficiency of data and evaluation method, future research was suggested to extend to constructing whole synthetic evaluation model by analyzing and evaluating of single environmental factor, comprehensively making use of environmental monitoring, simulating test, remote sensing and other technologies, ascertaining each environmental factor capacity and threshold, so as to accurately and comprehensively measure the influence of underground mining on environment.

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