Influence of Coal Mining on Water Environment and Ecology in the Yellow River Basin

Fawang Zhang[1], Zhiqiang Zhang[1,2,3]

[1]*Chinese Academy of Geological Sciences, Beijing 100037, China, zzqiang187@163.com*

[2]*Hefei University of Technology, Hefei 230009, China*

[3]*Hebei GEO University, Shijiazhuang 050031, China*

Abstract

The upper and middle reaches of the Yellow River are important coal production bases in China, and the current situation of "more coal and less water" has been the main factor restricting its economic development. In addition, the destruction of water resources caused by coal mining makes the "coal and water contradiction" more prominent and becomes the bottleneck restricting the high-quality development of the Yellow River Basin. Based on the coal resources in the upper and middle reaches of the Yellow River and the history of the Yellow River's dry-up, this article puts forward the main environmental problems faced by the Yellow River; Such as prominent coal-water contradiction and sharp contradiction between water supply and demand; declining natural river runoff and river dry-off; fragile ecological environment and increased soil erosion; serious water pollution and so on. The impact of coal mining on the natural water cycle, water environment, soil erosion, and water-sediment relationship are systematically analyzed, and the following conclusions are drawn: coal mining damages the underlying hydrological surface and changes the transformation relationship between precipitation, surface water and groundwater. Therefore, the natural water cycle process is destroyed; A large amount of mine water, slime water and coal gangue leaching water produced in the process of coal mining are the main pollution sources that cause ammonia nitrogen, permanganate index, BOD5 and other factors in the Yellow River Basin to exceed the standard; The sediment of the Yellow River mainly comes from the gully area of the Loess Plateau between Hekou Town and Longmen. The large-scale mining of coal resources in the basin has aggravated the process of soil erosion of the original landform, changed the natural relationship between water and sand in the basin, and led to the siltation of downstream rivers. In order to effectively and rationally use water resources and realize the coordinated development of ecological protection and social economy in the Yellow River Basin, the coordinated development proposal of "Ecological Environment-Water Resources Protection-Mineral Development" was finally put forward, which provided ideas for solving the problem of "coal-water contradiction" in the Yellow River Basin.

Keywords: Coal and Water Contradiction, Water Resources, Yellow River Basin, Coal Mining

Introduction

The Yellow River basin is an important link connecting the western, central and eastern regions of China. It is also known as China's "energy basin" because it is rich in coal, oil and non-ferrous metals. In recent years, the large-scale mining of mineral resources in the Yellow River basin has not only promoted the economic development of the basin, but also brought about new environmental problems (Zhang *et al*. 2000, 2007). In particular, the mining of coal resources in the upper and middle reaches of the Yellow River has caused a series of ecological and environmental problems, such as soil erosion, land subsidence, water shortage and water pollution and so on.

The key to solve the ecological environment problems in the upper and middle reaches of the Yellow River lies in the coordination of the "coal-water contradiction" and the maximum reduction of the damage of coal mining to water resources (Zhang *et al.* 2001).

It is an important content to protect the ecological environment of the Yellow River Basin, and the key to promote the high-quality development of the Yellow River Basin.

Overview of coal resources in upper and middle reaches of the Yellow River

The upper and middle reaches of the Yellow River are the main coal production bases in China. Seven of the 13 large coal bases in China are located in the upper and middle reaches of the Yellow River, and the total coal resources account for 60.4% of the 13 large coal bases. The basic information of large coal bases in the upper and middle reaches of the Yellow River is shown in Table 1.

The break-off discharge in the Yellow River

The break-off discharge in the Yellow River began in the 1970s (Zhang *et al.* 1998). The break-off discharge in the Yellow River means that the measured runoff at Lijin Hydrological Station, the lowest reaches of the Yellow River, is less than $1m^3/s$. According to statistics, the lower reaches of the Yellow River were break-off discharge for 22 years, from 1972–1999 (Wang 2002; Cao *et al.* 2007). A total of 902 days, 1991 ≈1999. Especially in 1997, the precipitation and runoff in the Yellow River basin were less, and the lower reaches of the Yellow River have been severely break-off discharge in history.

Main environmental problems in the upper and middle reaches of the Yellow River

(1) The contradiction between coal and water is prominent, and the contradiction between supply and demand of water resources is sharp

The middle reaches of the Yellow River are dominated by the coal industry. As a high-water consuming industry, the coal industry consumes a large amount of water resources on the one hand, and on the other hand, it destroys the natural water circulation system and pollutes water resources, which leads to the decrease of available water resources and intensifies the contradiction between supply and demand of water in the basin.

Table 1 *Basic information of large coal bases in the upper and middle reaches of the Yellow River.*

Coal bases	Area km^2	Location	Coal resources	
			Coal resources (10^8t)	Proportion(%)
Shendong	9000	North Shanxi Province and west Inner Mongolia Autonomous Region	1723.59	36.46
Jinbei	6700	North Shanxi	262.89	5.56
Henan	10849	West and East (Middle) of Henan Province	265.89	5.62
Jinzhong	27475	Central Shanxi Province	1098.08	23.23
Huanglong	11084	Central Shaanxi Province and eastern Gansu Province	247.97	5.25
Ningdong	2105	East of Ningxia Hui Autonomous Region	377.70	7.99
Shanbei	18366	Northern Shaanxi Province	751.17	15.89
Total	85579	—	4727.29	100

Table 2 The break-off discharge in the Yellow River over the years.

Years	The average number of days without flow d	The longest number of days without flow in a year d	Maximum channel length without flow in a year km
1972-1979	86	21	316
1980-1989	105	36	662
1990-1999	901	226	704
1972-1999	1092	226	704

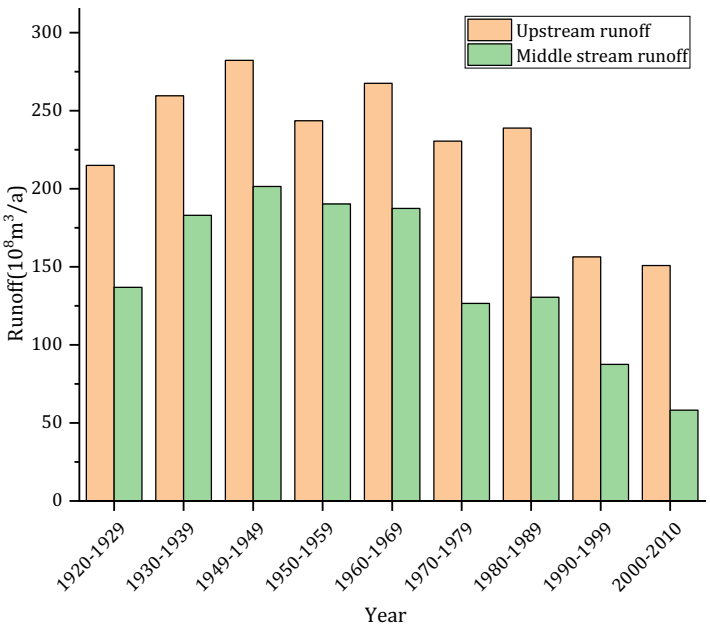

Figure 1 Variation of annual average runoff in the upper and middle reaches of the Yellow River.

The "Impact and Evaluation of Coal Mining on Water Resources in Shanxi Province" shows that every ton of coal mined in Shanxi consumes 2.48 tons of water resources. From 1949–2004, Shanxi mined 7.7 billion tons of coal and lost 19.1 billion tons of water (Niu 2003).

(2) The natural runoff of the river has been sharply reduced, and the problem of river break-off discharge is prominent

The average runoff of the Yellow River decreased from 19.03 billion m^3 in 1950–1959 to 5.82 billion m^3 in 2000–2010 (Li *et al.* 2014; Liu *et al.* 2019). In the 28 years from 1972–1999, the flow of the lower reaches of the Yellow River was break-off discharge for 22 years due to the decrease of inflow and the intensification of water resources and coal resources development.

(3) The ecological environment is fragile and soil erosion is aggravated

The biggest characteristic of the Yellow River is different from other big rivers: less water and more sediment, different sources of water and sediment, resulting in the "over-ground river" of the lower reaches. These characteristics are related to the ecological environment of the Yellow River basin.

Serious soil erosion has brought serious ecological environment problems to the

Loess Plateau, such as the destruction of vegetation and the decline of ecological function, and the deterioration of ecological environment has been aggravated by the unreasonable economic activities of human beings. From 1949–2004, the area of land damaged by coal mining in Shanxi Province was 1151.95 km^2.

(4) Serious pollution of water environment

Along the Yellow River, there are many industrial enterprises with high pollution, such as energy, heavy chemical industry, non-ferrous metal and paper making, and the discharge of wastewater is increasing year by year. Since the 1980s, about 40% of the water quality monitoring sections in the main stream and tributaries of the Yellow River are worse than the third grade water quality in the Chinese Environmental Quality Standards for Surface Water (GB3838-2002), rising to 60% in the late 1990s, and as high as 70–80% in the 21st century (An XD 2007).

The influence of coal mining on the middle reaches of the Yellow River

(1) Destruction of water resources

Coal mining will lead to the destruction of the hydrological underlying surface. Under the influence of the "three zones" (namely caving zone, fracture zone and bending subsidence zone) of the mining overburden, a large amount of surface runoff leaks along the mining-induced fissures, resulting in the decrease of surface water resources.

Influenced by the mining of coal resources, the runoff of Kuye River, the main tributary of the Yellow River, has been sharply reduced in the past 10 years. In addition to climate change and other natural causes, the high intensity coal mining since the 1990s is the main reason for the discharge attenuation and flow interruption of the Kuye River (Fan 2007). From 1997–2005, the contribution rate of coal mining to runoff reduction in Kuye River Basin reached 52.27% (Liu *et al.* 2013)

(2) Polluted water environment

In the process of mining coal resources, a large number of mine wastewater will be produced, such as mine water, coal slime water and coal gangue leachate water, which contains a variety of high-concentration pollutants, such as SS, COD, metals and semi-metals, which will cause water resource pollution if treated improperly.

The discharge of coal mine wastewater in the upper and middle reaches of the Yellow River in China is about 86.17 million t/a, among which the 7 coal mine bases discharge about 81.94 million t/a, accounting for about 95% of the total discharge of coal mine wastewater in the upper and middle reaches of the Yellow River.

As shown in Table 2, the water quality of V and bad grade in the main Yellow River reaches 1761 km, accounting for 48.7% of the evaluated river length. The water quality of V tributaries and inferior parts of the Yellow River reaches 2963 river lengths, accounting for 76.3% of the evaluated river lengths.

(3) Soil and water loss

The Loess Plateau, located in the upper and middle reaches of the Yellow River, is the most serious area of soil and water loss in China. Coal mining will severely disturb the surface, often leading to surface collapse and vegetation destruction. At the same time, soil structure is loosened, soil is more vulnerable to erosion and desertification, which leads to serious soil and water loss. The area in the middle reaches of the Yellow River belongs to the semi-arid continental monsoon climate in the north temperate zone, with low vegetation coverage rate and loess and aeolian sand as the main surface materials. The middle reaches of the Yellow River itself is very easy to produce soil and water loss, and the large-scale mining of coal resources in the basin induces and intensifies the process of soil and water loss of the original landform and intensifies the desertification of the land.

Problems that should be paid attention to in the process of mining coal resources

(1) Explore new development models

Taking "ecological environment, water resources protection and mineral exploitation" and other factors as an organic whole, we should take all factors into consideration to achieve coordinated development.

(2) Control water consumption

We will strengthen the management of red lines for the development and utilization of water resources and strictly control the total amount of water used. The layout and scale of the coal base development in the basin and the coal industry projects are reassessed according to the principle of "depending on water to determine the production", and scientific adjustment is made. Strictly restrict the development of coal mining, coal power generation and coal chemical projects that exceed the carrying capacity of regional water resources and water environment. We will strictly control the increase of coal production capacity, speed up the elimination of outdated coal production capacity, and support the development of renewable energy.

(3) Resource utilization of mine drainage

The mine water should be regarded as mineral resources, and the resource utilization of mine water should be realized, and the comprehensive utilization rate of mine water should be improved, especially the resource utilization of low temperature mine hot water in shallow and middle level.

(4) Prevent and control the damage of aquifer and implement coal mining with water conservation

According to the characteristics of aquifer, impermeable layer and coal seam, the threshold value of groundwater level control is determined to reduce the movement and deformation process and damage degree of mining overburden. To study the evolution process of groundwater, stress, and fissure under mining conditions, and to study the evolution process and mechanism of groundwater level during mining. At the same time, the change process of groundwater level, water quality and water temperature in the process of mining is monitored, and the evolution process of stress field, fracture field and seepage field in the coal face and the affected area is monitored.

(5) Optimize well design to reduce the destruction of water resources

In order to reduce the damage to the aquifer, no well and roadway should be arranged in the aquifer or the engineering across the aquifer should be reduced by optimizing the design of the well and roadway engineering. The exposed aquifer outlet points should be blocked by grouting or chemical plugging in time to reduce groundwater leakage. For the boreholes with water conduction structure and poor sealing, exploration work should be done well, and avoidance measures should be taken in the design to prevent the exposure or conduction of aquifers and water storage structures.

References

An XD (2007) Current status of management and regulation of Yellow River water resources and future prospect. China Water Resources 13:16-19 (In Chinese)

Cao JF, Wang KJ, Jiang JY (2007) Impact of lower Yellow River cutoff on the formation and exploitation of groundwater in alongside areas. Journal of Jilin University (Earth Science Edition) 37(5):937-942 (In Chinese)

Fan LM (2007) Analysis of groundwater leakage caused by coal mining in the northern area of Shaanxi Province and its prevention. Mining Safety & Environmental Protection 34(5):62-64 (In Chinese)

Li EH, Mu XM, Zhao GJ (2014) Temporal changes in annual runoff and influential factors in the upper and middle reaches of Yellow River from 1919-2010. Advances In Water Science 25(2): 155-163 (In Chinese)

Liu CM, Tian W, Liu XM (2019) Analsis and understanding on runoff variation of the Yellow River in recent 100 years. Yellow River 41(10):11-15 (In Chinese)

Liu EJ Zhang XP, Zhang JJ (2013) Variation of annual streamflow and the effect of human activity in the Kuye River during 1956 to 2005. Journal of Natural Resources 28(7):1159-1168 (In Chinese)

Niu RL (2003) Impact and evaluation of coal mining on water resources in Shanxi Province. Science and Technology of China Press, Beijing (In Chinese)

Wang AJ, Zhu C (2002) Response of water break-off in the Yellow River to global climate change. Journal of Natural Disasters 11(2):103-107 (In Chinese)

Zhang FW Hou XW (2000) The influence of coal exploitation on water and soil resources and its protection technology. Hydrogeology & Engineering Geology 2:52-53 (In Chinese)

Zhang Fw Wang GL Hou XW (2001) Environment geology chain due to mine exploitation and methods for control. Earth Science Frontiers 8(1):107-111 (In Chinese)

Zhang FW Zhao HM Song YX Chen L (2007) The effect of coal-mining subsidence on water environment in the Shenfu-Dongsheng mining area. Acta Geoscientica Sinica 28(6):521-527 (In Chinese)

Zhang RY Yang XL (1998) Historical review and analysis of the Yellow River cutoff. Yellow River 20(10):38-40 (In Chinese)