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ESTIMATION AND TREND ANALYSIS OF WATER DEMAND OF COAL BASES DURING 2015 TO 2020 IN YELLOW RIVER BASIN, CHINA

HE Guo-hua, ZHAO Yong*, Zhu Yong-nan, LI Hai-hong, Jiang Shan

State Key Laboratory of Simulation and Regulation of Water cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing 100038, China

ABSTRACT

The Yellow River basin is an important coal production area in China, where are shortage of water resources also. Analysis water consumption in coal base is an important premise for China's energy sustainable development. Based on the present situation of coal production in Yellow River basin, this paper uses the quota method to calculate the current water consumption of coal bases, and analyzes the trend of future water use. The research results show that coal bases' water demand of Yellow River basin in 2015 and 2020 is 3.384 billion m^3 and 4.315 billion m^3, respectively. Thermal power is still the largest water user in coal bases, water consumption of coal mining and coal chemical industry has not increased significantly in the future. Overall, the increase of coal bases' water demand in the Yellow River basin is not large in the future, water supply of coal bases can be guaranteed. But the contradiction between supply and demand of water resources in Shendong base is prominent, and base development scale need reasonable control according to local water resources.

Keywords: Yellow River basin, Coal base, Water resources, Water and energy nexus

1. INTRODUCTION

Water and energy are inherently linked. At a basic level, energy generation requires water, and water supply, treatment and distribution use energy. Historically, understanding the nature of these links was not considered a priority, primarily because of the assumptions that water-related energy use was not a threat to energy security and that energy-related water use was not a threat to water security[1]. These assumptions are now being challenged, and increasing demand, diminishing resources and recent climate change have led to intensified discussions on the water–energy nexus[2]. In China, the rapid expansion of coal-fired power generation in the Yellow River basin (YRB) illustrates the tension between the agricultural and energy sectors for limited water supplies. Although the total output of coal is about to reach a peak and action has been taken to develop renewable energy in the last decade, China's energy supply is still coal-dominated, and this is unlikely to change in the next 20 years. Provinces rich in coal, located in the middle and upper reaches of the Yellow River, will remain China's primary energy supply in the future[3], which calls for careful assessment of the impacts and policy dimensions of the energy, food and water interlinkages.

An increasing number of studies have quantified the water footprint of coal mines and large-scale construction of coal-fired thermal power plants in China and suggested that water scarcity is a constraint on expansion of coal-fired power generation[4]. For example, in 2011, Circle of Blue released the report "China's Bottleneck: Water Deficit and Energy Demand", which argues that there is a huge contradiction between energy and water resources in China's development process. By 2020, China's coal production will be 1 billion tons higher than it is now, which means an increase of 15 billion m^3 of water[5]. Of course, China has enough coal resources, but can it provide enough water? The international environmental protection organization "Greenpeace" released a research report entitled "Water for Coal" in 2012, which believes that the water

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resources of the 8 coal bases in the Yellow River Basin will reach 8.285 billion m^3, accounting for about one quarter of the water resources available to the Yellow River. However, due to the shortage of water resources in the Yellow River Basin, the energy base will be waterless[6]. In addition, a Hong Kong-based organization has published a series of reports from China's energy bases, arguing that water will be the biggest threat to the energy development of the Yellow River Basin. However, no comprehensive study is currently available for the water balance of the energy bases in the middle and upper reaches of the Yellow River at a time when the basin's water resource allocation plan is fully committed. The purpose of this study is to calculate the amount of water needed for 8 coal bases in the Yellow River Basin in 2015 and 2020, and to determine whether the regional water resources can support the coal base development in the Yellow River Basin.

2. STUDY AREAS

The Yellow River Basin with an area of 745 000 km^2, and the river flows 5464 km, passes through nine provinces and autonomous regions. The Yellow River Basin is rich in coal, oil and natural gas and is known as China's "energy basin". The proven reserves of coal in the basin are 550 billion tons, accounting for 50% of the country's coal reserves. According to the "National 12th Five-Year Plan for Coal Source Development" and the "12th Five-Year Plan for Coal Industry Development", China will build 14 large coal bases in the future, including 8 in the Yellow River basin, which are Shendong, Eastern Ningxia, Northern shaanxi, Northern shanxi, Middle shanxi, Eastern shanxi, Huanglong and Henan (Figure. 1).

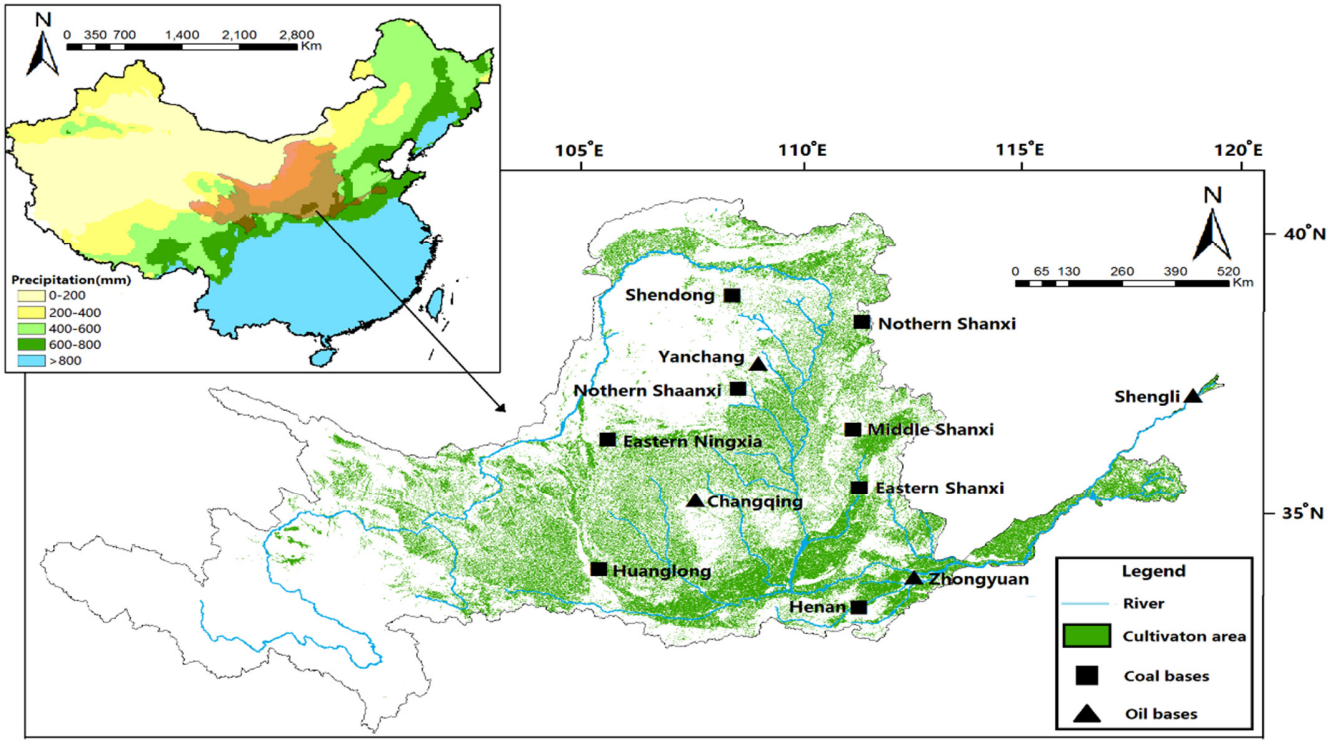

Figure.1 Location map of coal bases and oil bases in Yellow River basin

Referring to the comprehensive water resources planning in the area where the coal base is located, the total water resources in the 8 coal-based areas of the Yellow River Basin is 36.87 billion m^3. Among them, the Eastern Ningxia coal base has less precipitation and mainly draws water directly from the Yellow River, and the coal bases in Northern shaanxi, Northern shanxi, Middle shanxi, Eastern shanxi, and Henan mainly rely on local water resources (Table. 1).

Table.1 Current situation of water resources in 8 coal bases

Name	Precipitation (mm)	Total amount of water resources (10^8 m^3)
Shendong	168～286	37.43
Eastern Ningxia	196～225	1.85
Northern shaanxi	394～534	40.35
Northern shanxi	06～498	48.15

Middle shanxi	67～574	46.64
Eastern shanxi	26～630	28.99
Huanglong	68～610	38.29
Henan	46～821	127.00
Total	68～821	368.70

3. WATER CONSUMPTION OF 8COAL BASES IN 2015

3.1 Water consumed in coal mining and washing

The water used in the coal mining industry can be divided into production water and domestic water; and the water used in the coal washing industry is concentrated in the process of wet coal washing. In 2015, the raw coal output of the 8 coal bases in the Yellow River Basin was 2.324 billion tons, accounting for 61.97% of the country's raw coal production; the clean coal production was 1.531 billion tons (the raw coal washing rate was 65.9%). Referring to the Chinese industry water quota standards, it is estimated that the water consumption of coal mining and coal washing in the Yellow River Basin in 2015 was 652 million m^3 and 237 million m^3 respectively.

3.2 Water consumed in thermal power generation

Cooling water accounts for the majority of water used in thermal power plants. At present, the cooling patterns used by China's thermal power plants are mainly once-through cooling pattern and cyclic cooling pattern. Due to the small amount of water used, the cyclic cooling pattern is widely used in Yellow River basin. Referring to the "Guidelines for Water Efficiency in Key Industrial Industries" implemented in 2013, the average water consumption of circulating cooling in China's thermal power industry is 2.55m^3/MW·h. In 2015, the total thermal power generation of the 8 major coal bases was 772.2 billion KWh. Therefore, the total water consumption of thermal power plants in the Yellow River Basin coal mine in 2015 was 1.969 billion m^3.

3.3 Water consumed in coal chemical industry

Coal chemical industry is divided into traditional coal chemical industry and modern coal chemical industry. Traditional coal chemical products mainly include synthetic ammonia, coke and calcium carbide. China's traditional coal chemical industry has a long history of production and the output of major products ranks first in the world for many years. However, there are only a small number of traditional coal chemical projects in the Yellow River Basin, so the traditional coal chemical water consumption is very small and can be ignored. Therefore, this study only calculates the water used in modern coal chemical industry. With reference to China's coal chemical industry water use quota standards, the coal chemical industry water use in Yellow River basin in 2015 is estimated at 527 million m^3.

Table.2 Scale of coal chemical industry in 8 coal bases

Name	Coal chemical industry products
Shendong	50.9 billion m^3 of coal-based natural gas, 800,000 tons of dimethyl ether, 500,000 tons of coal tar hydrogenation
Eastern Ningxia	4 million tons of coal indirect liquefaction
Northern shaanxi	1 million tons of coal indirect liquefaction, 7 million tons of olefins, 400,000 tons of methanol
Shanxi	3 million tons of methanol 600,000 tons of olefin, 300,000 tons of dimethyl ether 160,000 tons of coal-to-liquid, 100,000 tons of maleic anhydride
Huanglong	800,000 tons of methanol
Henan	750,000 tons of methanol, 400,000 tons of ethylene glycol, 1.8 million tons of olefins

3.4 Total water consumption of 8 coal bases in 2015

In 2015, the total water consumption of the 8 coal bases of the Yellow River Basin was 3.384 billion m^3, of which the thermal power plant consumed 1.969 billion m^3, accounting for 58% of the total coal use, followed by coal consumption, coal chemical consumption and coal washing. From a spatial point of view, Shendong coal base has the largest water consumption, reaching 922 million m^3, followed by Henan base. Due to its small scale of production, the Huanghua coal base has the lowest total water consumption, with 145 million m^3. The water consumption of 8 coal bases in Yellow River basin in 2015 is shown in Figure. 2.

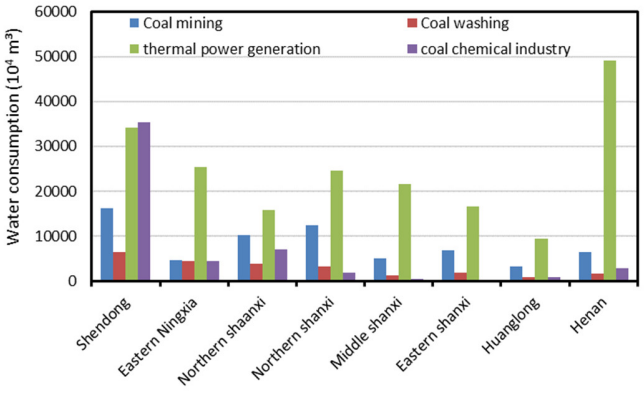

Figure.2 Water consumption of 8 coal bases in 2015

4. WATER CONSUMPTION FORECAST FOR 8 COAL BASES IN 2020

4.1 Water quota forecast

Affected by technology progress and environment protect policy, the water quotas of various coal bases in the future will gradually decrease. Considering that the existing coal chemical projects in Yellow River Basin are generally modern coal chemical projects and the water quota is small, so this study believes that the water use quota for coal chemical projects will remain unchanged in 2020. In addition, during 2010 to 2015, China's raw coal washing rate annually increased by 3%. So, our study predicted that the raw coal washing rate of the 8 major coal bases in the Yellow River Basin will increase from the current 65.9% in 2015 to about 75% in 2020. The forecast results of water use quotas for various energy bases in the Yellow River Basin are shown in Table 3.

Table.3 The comparison of water consumption quota of 8 coal bases in 2015 and 2020

Name	2015 (m^3 /t)			2020 (m^3 /t)		
	Coal mining	Coal washing	thermal power	Coal mining	Coal washing	thermal power
Shendong	0.25	0.15	2.55	0.20	0.10	2.00
Eastern Ningxia	0.70	1.00	2.55	0.50	0.50	2.00
Northern shaanxi	0.25	0.14	2.55	0.15	0.10	2.00
Northern shanxi	0.25	0.10	2.55	0.15	0.08	2.00
Middle shanxi	0.25	0.10	2.55	0.15	0.08	2.00
Eastern shanxi	0.25	0.10	2.55	0.15	0.08	2.00
Huanglong	0.34	0.15	2.55	0.28	0.10	2.00
Henan	0.50	0.20	2.55	0.35	0.15	2.00

4.2 Production forecast

4.2.1 Coal production forecast

According to the "13th Five-Year Plan for Energy Development", China's energy self-sufficiency rate will reach over 80% in 2020, and the production capacity of China's 14 major coal bases will need to reach more than 95% of the country. Due to differences in coal reserves and production costs, the plan proposes that the 8 coal bases in Yellow River Basin will increase coal production in the future. Based on the "13th Five-Year Plan for Energy Development", this study estimates that the coal production in the Yellow River Basin will reach 2.866 billion tons in 2020, an increase of 542 million tons from 2015. The specific forecast results are shown in Figure 3.

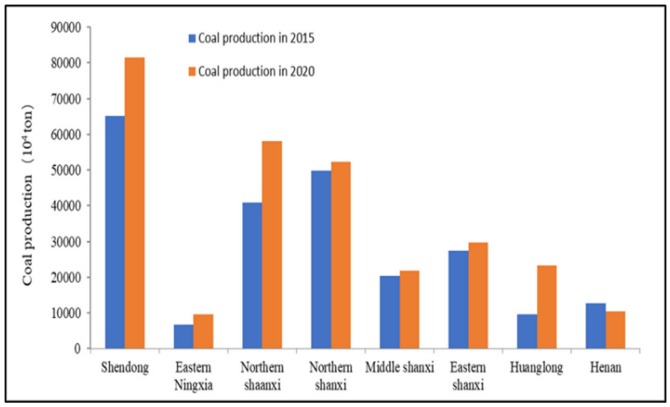

Figure.3 Prediction of coal production in 2020

4.2.2 Prediction of the scale of thermal power generation

Jiang et al[7] predicted the installed capacity of thermal power of China's coal bases in 2020. According to Jiang et al's research, the installed capacity of new thermal power in the country will reach 45.4×104 MW in 2020, and the installed capacity of new thermal power in the Yellow River Basin will reach 23.23×104 MW. Considering the actual working time of the generators and the efficiency of the thermal power unit, this paper predicted that the newly generated power generation in the Yellow River Basin will reach 447.178 billion KWh in 2020. The 2020 thermal power generation of the Yellow River Basin coal base is shown in Figure 4.

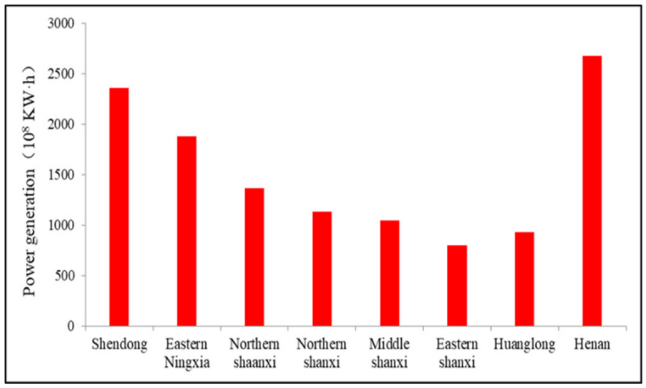

Figure.4 Prediction of thermal power generation in 2020

4.2.3 Prediction of the scale of coal chemical industry

Lin [8] predicted that China will add 7.2 million tons of coal-to-liquids, 18.5 billion m^3 of coal-based natural gas and 6.1 million tons of coal-to-olefins by 2020. According to the China's water use quota of coal chemical industry in 2015, the total amount of water used for coal chemical industry will add 247 million m^3, of which the Yellow River Basin will add 137 million m^3 of water.

4.3 Total water consumption of 8 coal bases in 2020

According to the future water quota and production scale of various industries of 8 coal bases in the Yellow River Basin, it is predicted that the total water consumption of the Yellow River Basin coal bases will be 4.315 billion m^3 in 2020, an increase of 931 million m^3 from 2015. The specific forecast results are shown in Table 4.

Table.4 Water consumption of coal base in the Yellow River Basin in 2020 Unit：10^4m^3

Name	Coal mining	Coal washing	thermal power generation	coal chemical industry	total
Shendong	16296	6111	54487	41996	118889
Eastern Ningxia	4804	3603	43086	4400	55892
Northern shaanxi	8715	4358	30781	12360	56214
Northern shanxi	7836	3134	27948	2580	41499
Middle shanxi	3271	1308	25612	405	30597
Eastern shanxi	4462	1785	19549	115	25911
Huanglong	6507	1743	20707	1780	30737
Henan	3626	1166	64174	2754	71720
Total	55518	23208	286344	66390	431459

5. CONCLUSIONS AND RECOMMENDATIONS

(1) The total water demand of the 8 coal bases in the Yellow River Basin in 2015 was 3.394 billion m^3. Compared with 2015, the water demand of coal bases will increase to 4.315 billion m^3 in 2020. In general, the water demand of the coal bases in the Yellow River Basin has not increased much, and will not have a significant impact on water use in other industries in the Yellow River Basin. According to Greenpeace's calculation, the water consumption of coal mining and washing in the Yellow River Basin is as high as 2.772 billion m^3, but in fact, the water demand for coal mining and coal washing in the coal base of the Yellow River Basin is only below 1 billion m^3.

(2) The water demand for thermal power generation is still the main part of the water demand of the coal base in the Yellow River Basin. In 2015 and 2020, the water consumption of thermal power generation reached 1.969 billion m^3 and 2.863 billion m^3, respectively; accounting for 58% and 66% of the total coal consumption, respectively. The main reason for water use in Yellow River Basin is the increase in coal production.

(3) Overall, the water consumption of the coal bases in the Yellow River Basin will not increase much in the future, and the water used for the development of the base will be guaranteed. However, the Shendong coal base is the region with the largest water demand for coal production in the Yellow River Basin, accounting for about a quarter of the water used in the coal industry in the study area. The severe shortage of water resources will become the main bottleneck restricting the development of the coal industry in Shendong. In the future, it is necessary to reasonably control the scale of coal industry development of Shendong based on local water resources.

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