The General Scheme for Hydrogeological and Environment Geological Investigation of Large Scale Coal Bases, in China

Xiangquan Li, Xinwei Hou*, Lingxia Liu, Zhenxing Wang, Ming Gao

*Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences, Shijiazhuang 050061, China, houxinwei2007@163.com, *corresponding author*

Abstract This paper systematically illustrated the overview of the large-scale coal bases. The articles introduced the main coal bearing layers, aquifer types & distribution and the superposition relationship between coal bearing layers and aquifers. Water resources crisis, mine water in-rush, aquifer structures and groundwater resources damage, heavy water pollution and ecological deterioration are the major hydrogeological and environmental-geological issues in the mine areas. Based on the hydrogeological and environmental-geological characteristics, those coal bases can be divided into five major types. The investigation scheme in the next decade has been put forward.

Keywords Hydrogeology; Environmental Geology; Issues; Coal Bases

Introduction

During the 12th "Five-Year Plan", China plans to build 14 key large-scale coal bases: Shendong base, Northern Shanxi base, Huanglong base, Eastern Ningxia base, Northern Jin base, Central Jin base, Eastern Jin base, Central Hebei base, Henan base, Western Shandong base, Huaibei-Huainan base, Eastern Inner Mongolia base, Yunnan-Guizhou-Sichuan base, Xinjiang-Qinghai base.

Currently, the large-scale coal bases in China are universally faced with a series of problems of water shortage, aquifer damages, aggravating mine water in-rush and eco-environmental degradation, which have severely hampered the sustainable development of those coal bases. Therefore, it is of great necessity to thoroughly investigate those aforementioned hydro-geological and environmental-geological problems and come up with corresponding solutions.

Geologic framework

The main coal bearing layers in those coal bases include late Carboniferous-early Permian layer, late Permian layer, lower-middle Jurassic layer, and lower Cretaceous layer.

The late Carboniferous-early Permian layer is mainly distributed around the Erdos basin area, Shanxi base, Hebei-Shandong-Henan-Anhui base. The tectonic element in the area is the main body of North-China Platform, with the coal layers representatives being Taiyuan Formation and lower Permian Shanxi Formation.

The late Permian layer is mainly distributed in the Yunnan-Guizhou-Sichuan base, the tectonic element of which is Yangzi Platform and South-China fold system, with the representatives being upper Permian Longtan Formation.

The lower-middle Jurassic layer is mainly distributed in Erdos basin area and Xinjiang-Qinghai base. Its tectonic elements include Talimu Platform, Tianshan section of western Tianshan-Xingmeng fold system, Qinqi-Kunlun fold belt, Qilian fold belt and western Qinling fold belt.

The lower Cretaceous layer is mainly distributed in eastern Inner Mongolia base, the tectonic element of which is the eastern section of the Xingmeng fold system, north-eastern part of North-China Platform as well as the fold system along the Pacific Ocean.

Hydrogeologic settings

The karst aquifers of carbonate rocks are mainly distributed in the Northern Jin base, Central Jin base, Eastern Jin base, Central Hebei base, Henan base, Huaibei-Huainan base, Huanglong base, Western Shandong base, Eastern Ningxia base, Yunnan-Guizhou-Sichuan base, and Junggar mining area in the Shendong base. The karst aquifers largely belong to the karst fissure aquifer types of the Ordovician upper-lower Majiagou Formation, which boast abundant karst groundwater resources and rich distribution of karst springs. However, the western Henan mining area is lack of Ordovician limestone, the aquifer of which is the Cambrian karst aquifer with weak water-retaining capability, while the aquifer in the Yunnan-Guizhou-Sichuan base is the type of karst aquifer of Triassic Gejiu limestone and Permian Maokou limestone with strong water yield property.

Detrital rock-type fissured aquifers include those aquifers of the Cretaceous, Jurassic, Permian, and Carboniferous Periods, with the sandstone, conglomerate, and sandy conglomerate, which are mainly distributed in the Northern Shanxi base, Shendong base, Huating mining area of Huanglong base, eastern mining area of Greater Khingan Mountains in Eastern Inner Mongolia base and the Xinjiang-Qinghai base. The Northern Shanxi base and Shendong base usually possess fissured aquifers of sandstone and conglomerate in the lower Cretaceous Zhidan Formation with uneven water yield property. The deep fissured aquifers have stronger water yield property with higher pressure-bearing performance. The Huanglong base usually possesses the sandy conglomerate-type aquifers of upper Tertiary and Cretaceous Zhidan Formation with moderate and relatively strong water yield property. The eastern mining area of Greater khingan Mountains in Eastern Inner Mongolia base owns weathering fissured aquifers of early Cretaceous Period, the shallow zones of which are relatively abundant with groundwater resources. The Xinjiang-Qinghai base contains Jurassic fissured aquifers, while the Carboniferous-Permian fissured aquifers are mainly distributed in the North-China region.

Pore aquifers of unconsolidated rocks, consisting of quaternary and unconsolidated tertiary strata with poor diagenesis, can be found in almost each one of those coal bases with the lithology being medium-fine sand and sandy gravel-pebbles. In the Shendong base and Northern Shanxi base, the quaternary unconsolidated pore aquifers are mainly those in the Salawu Formation of the quaternary upper Pleistocene period, which boast strong water yield property and contain a number of separated spring fields. The Western Shandong base, Huaibei-Huainan base, and Central Hebei base all have exceptionally thick Cenozoic coverage, and four aquifer groups can be distinguished from the top to the bottom. The Huaibei-Huainan base, in particular, has unique hydrogeological conditions and possesses unconsolidated Cenozoic pore aquifers, which can be divided into four aquifers and three aquicludes. Besides, the bottom and the third layer of aquifers have great influence on the coal mining. The Huanglong base and Eastern Ningxia base boast quaternary alluvial-proluvial sandy gravel-type aquifers, which are mainly distributed along the river valleys.

The coal-bearing aquifers exist in the fault-subsidence basins of Yimin and Huolin in western Greater Khingan Mountains of the Eastern Inner Mongolia base, where the coal-bearing layers themselves are aquifers that belong to the diagenetic fissured and weathering-fissured aquifer types with shallow depth but strong water field property.

Major Hydrogeological and Environmental-Geological issues

1) Water Resources Crisis

Currently, most of the coal bases are confronted with water scarcity. Statistics show that 70 % of coal bases in China are inflicted by

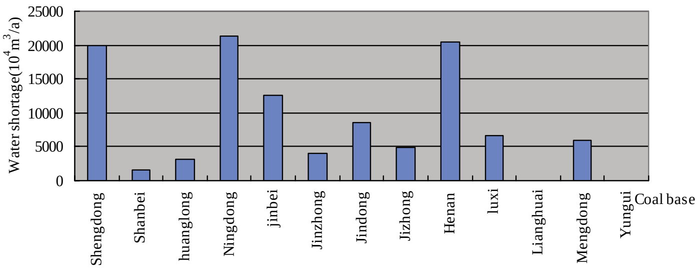

Figure 1 *Histogram of Water Scarcity in Major Coal Bases*

water shortage and 40 % of the coal bases are facing severe water scarcity. Except for the Huaibei-Huainan base and Yunnan-Guizhou-Sichuan base, 12 of the 14 key large-scale bases suffers different degrees of water scarcity. The water scarcity amount is expected to reach 747 Mm^3 in 2020, what' more, the water scarcity of the coal bases in the 4 provinces of Shanxi, Sanxi, Inner Mongolia, and Ningxia will amount to 495 Mm^3, accounting for 66 % of the whole amounts (Fig. 1). Water scarcity for the coal bases in plateau areas, *e.g.* Qinghai Plateau, becomes more acute in winter time. Overall, water scarcity has become a most severe bottleneck that will restrict the development of those coal bases.

2) Mine Water in-rush

With the development of coal mining and increase of mining depth, water-related disasters have frequently occurred, which has badly threatened the safety of coal mining. Among the major mining accidents, water-related disasters have ranked as the second threatening factor for the safety of coal mining following the gas accidents. It's estimated that since the 1980s, about 250 mines have been submerged, leading to a death toll of around 9,000 and an economic loss of more than 35 billion RMB. Specifically speaking, from 1995 to 2011, there have been 1,540 cases of water-related disasters in the coal mines, causing a death toll of around 6,355 and an economic loss of more than 20 billion RMB (Fig. 2).

Major mine water in-rush include floor gushing-out of karst groundwater, gushing-out of roof aquifers, inrush of surface water, and inrush of goaf water. In recent years, goaf water inrush accidents have accounted for 80 % of the total, featuring heavy death tolls and economic losses.

3) Aquifer Structures and Groundwater Resources Damage

Owing to mining activities, the groundwater level has drastically dropped (Qiang *et al.* 2002), altering original structures of coal-bearing layers, groundwater systems, and dynamic fields in the overlying unconsolidated rock strata.

Mining activities have severely destroyed aquifers in coal-bearing layers and adjacent aquifers. In the Shendong base and Northern Shanxi base, shallow aquifers in the Salawu Formation have been damaged by mining, leading to ecological deterioration. In the Huaibei-Huainan base, mining has destroyed deep aquifers of quaternary period. In Qinghai base, groundwater resources above the permafrost have been damaged by mining, causing degradation of alpine meadow. In the Eastern Inner Mongolia base, weathering fissured groundwater and quaternary pore groundwater have been destroyed and drained, leading to ecological deterioration of the grassland in this area (Fu *et al.* 2011).

Mining has aggravated the draining of groundwater, thus causing severe wastes of groundwater resources. In 1989, about 1.3 billion tons of mine water was drained; this Fig. increased to 4 billion tons in 2003; and then it continued to increase to 4.5 billion tons and 5.4 billion tons in 2005 and 2007, respectively, while the utilization rate was as low as 30–40 %. In North-China, more than 80 % of large karst springs have suffered sharp decrease in

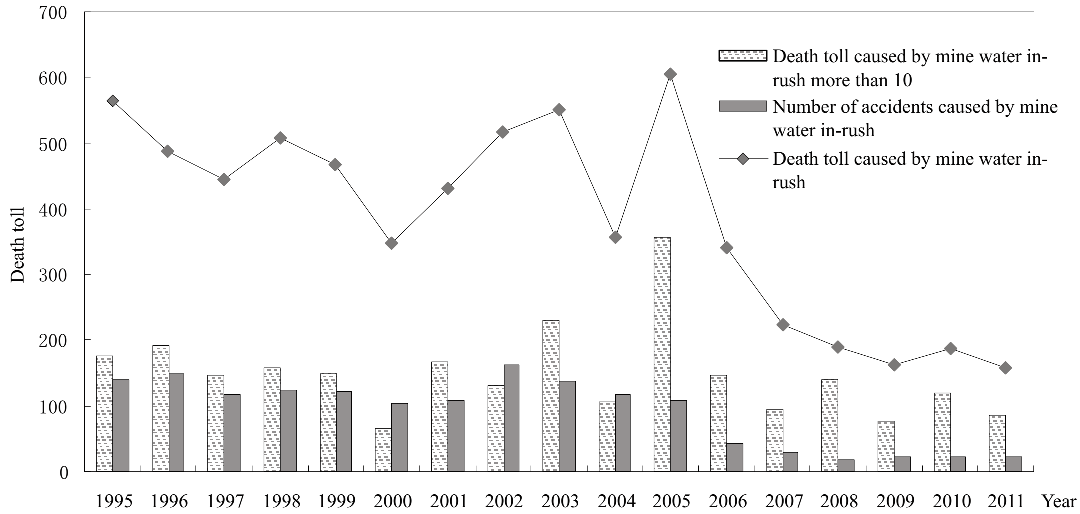

Figure 2 *Death Tolls Caused by Mine Water in-rush since 1995*

the flow amount; moreover, about 30 % have dried up or been on the brink of running dry.

4) Heavy Water Pollution

Long-term mining activities have produced large quantities of waste solids, waste water, and waste gas, resulting in heavy pollution of water environment. Each year, coal mines in China can yield 2.2 billion tons of mine water, 28 Mt of waste water of coal preparation, 30 Mt of industrial waste water, 400 Mt of sewage, and 150–200 Mt of gangue.

5) Ecological Deterioration

Mining-induced subsidence has forced the groundwater level to dramatically drop and exacerbated ecological environment in the mining area. Especially in the Shendong base, Northern Shanxi base, Eastern Ningxia base, and Huanglong base in North-West China with arid climate and poor vegetation covers, the ecological environment is more vulnerable to the problems of desertification, water losses and soil erosion.

Types of Coal Bases

Based on the hydrogeological and environmental-geological features in those coal bases, they can be divided into the following five types:

The first type is the coal bases in northwestern ecologically-fragile area, which includes Shendong base, Northern Shanxi base, Eastern Ningxia base in the Erdos basin area as well as Xinjiang-Qinghai base, featuring fragile ecological environment, severe environmental-geological problems and insufficient water resources.

The second type is coal bases in central & eastern large Karst springs area, which are mainly distributed in the central and eastern parts with karst-geological development in North-China, including the Northern Jin base, Central Jin base, Eastern Jin base, Central Hebei base, Western Shandong base, and Henan base, featuring wide distribution of large karst springs, severe threats of karst groundwater-gushing disasters and obvious damages of karst aquifers and water resources.

The third type is coal bases in eastern plain area, which are distributed in the plain regions in Eastern China, including Central Hebei base, Western Shandong base, Henan base and Huaibei-Huainan base, which suffer gushing disasters of quaternary pore groundwater and karst groundwater and are confronted with damaged aquifers and groundwater resources as well as severe environmental-geological problems.

The fourth type is coal bases in northeastern ecologically-fragile area, which mainly include the Eastern Inner Mongolia base, featuring vulnerable grassland ecological- environment and serious environmental-geological problems caused by mining activities.

The fifth type is coal bases in southwestern Karst area, namely, the Yunnan-Guizhou-Sichuan base in Southwestern China, featuring severe mine water in-rush and serious environmental-geological problems.

Overall scheme of hydrogeological survey

1) General Objective

The general objective is to carry out hydrogeological and environmental-geological survey on the scale of 1:50,000 in key coal bases, and investigate aquifer structures, the conditions of groundwater recharge, runoff and discharge as well as major environmental-geological problems, thus providing scientific basis for protecting aquifers and dealing with water scarcity in the coal bases.

2) Main Tasks

Hydrogeological Investigation on the Scale of 1:50,000 in Coal Bases : Hydrogeological survey on the scale of 1:50,000 should be carried out on the basis of groundwater systems, focusing on the investigation of groundwater types, aquifer structures, reservoir structures, and the characteristics of groundwater recharge, runoff and discharge. Assessment work should be done to evaluate groundwater resources amount and their utilization potential, locate regions with high water-yield property and find out prospective water supply regions. Surveying work needs to be made to probe into the superposition relationship between coal-bearing layers and aquifers in those coal bases, find out distribution of faults, collapse columns and their water transmissibility, inquire into the distribution of goaf and goaf water, and evaluate the risks of mine water inrush.

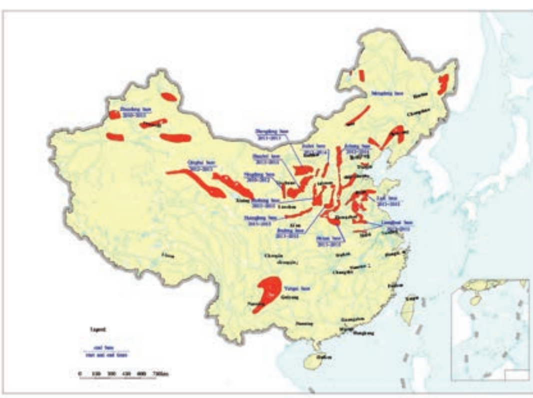

Figure 3 *Overall Scheme of Hydrogeological and Environmental-Geological Survey in National Large-Scale Coal Bases*

Environmental-Geological Investigation on the Scale of 1:50,000 in Coal Bases: The environmental-geological survey is required to evaluate the influences and damages brought to the aquifers and groundwater resources by mining activities, and investigate the types, distribution and developmental trends of such problems as water-soil pollution, ecological degradation. Assessment on groundwater environment and ecological environment quality should also be performed to help make aquifer-protection plans.

Thematic Research on Major Hydrogeological issues : Thematic research needs to be made to investigate the hydrogeological features in the coal bases under the extreme environmental conditions (such as in deep depth and arctic & alpine climate), study the groundwater circulation and evolution regularities under the influence of mining activities, evaluate the risks of serious gushing-out disasters (such as floor karst water gushing-out and goaf water gushing-out) and risks of geological-ecological environment during mining activities, as well as explore the technology of integrated utilization of recharge-discharge-ecology-environmental protection of mine groundwater, thus protecting regional aquifers.

Development of Hydrogeological and Environmental-Geological Database and Information System in Key Coal Bases: Efforts should be made to set up the hydrogeological and environmental-geological database and information system in key coal bases to formulate an information platform, thus providing digital and dynamic management on the hydrogeological and environmental-geological information in coal bases.

3) Prospective achievements

Improving investigation Accuracy and understanding of conditions: By virtue of conducting hydrogeological and environmental-geological survey on the scale of 1:50,000, the surveying accuracy in major mining areas can be improved from the scale of 1:200,000 to the scale of 1:50,000. Besides, thematic research on major problems is expected to improve our understanding on the hydrogeological problems in those coal bases.

Establishing Digital Information Platform: We need to develop the hydrogeological and environmental-geological database and information system in key coal bases to realize dynamic management on digital information.

Compiling Hydrogeological Maps on the Scale of 1:50,000: By carrying out the work of mapping on the scale of 1:50,000, a compilation of hydrogeological maps on the scale of 1:50,000 is expected to be yielded.

Establishing a Comprehensive Technological System of Groundwater Utilization, Aquifer Protection, and Disasters Prediction in Coal Bases: Efforts need to be made to set up a comprehensive technological supporting system by assessing the groundwater resources and their utilization potential, evaluating the integrated utilization of recharge-discharge-ecology-environmental protection of mine groundwater and predicting & assessing the risks of mine water in-rush, thus providing scientific basis for aquifer protection.

Determining a number of prospective water-supply regions.

Summary

In brief, this paper has introduced the status quo of those large-scale coal bases, the main coal bearing layers, aquifer types & distribution and the superposition relationship between coal bearing layers and aquifers. Currently, the major hydrogeological and environmental-geological problems those large-scale coal bases are facing consist of water scarcity, mining-induced aquifer damages, aggravating threats from mine water in-rush and deteriorating ecological environment. Based on the hydrogeological and environmental-geological characteristics, those coal bases can be divided into five major types: coal bases in western ecologically-fragile area, coal bases in central large-scale Karst springs area, coal bases in eastern plain area, coal bases in northeastern ecologically-fragile area and coal bases in southwestern Karst area. The investigation scheme in the next decade has been put forward, which requires carrying out hydrogeological and environmental-geological survey on a scale of 1:50,000, identifying aquifer structures and major environmental-geological problems, performing thematic research on major hydrogeological problems, establishing information system, determining a number of prospective water supply regions, as well as setting up a comprehensive technological support system with integration of comprehensive utilization of groundwater, aquifer protection and disasters prediction.

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