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ORIGIN OF MINE WATER BY USING ENVIRONMENTAL ISOTOPE TECHNIQUE IN WATER-LOGGED COAL MINES, PINGDINGSHAN, CHINA

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ABSTRACT

Pingdingshan Coal Mining Area lies in the western part of Henan Province, and the No.7 mine is located at the area of south-west corner. With the increase of the mining depth, the threat of karstwater from aquifer underlying the coal seam become progressively alarming to the mine workings. A research program was undertaken to investigate into the hydrogeological conditions of the coal mine, employing environmental isotopes techniques.

Through the complete and systematic analysis upon the atmospheric precipitation, hydrochemistry of the surface-water and groundwater, oxyhydrogen isotopes, the following factors have been ascertained: a) the creating, distributing and migration laws of the groundwater in No.7 mine; b) the recharge sources and the combination mechanism of the mine-water; and c) the proportion of the surface water in mine water and its age by seperating the component of the minewater.

The research revealed that the major recharge source of the groundwater at No.7 mine is surface-water, and more specifically speaking is the impulsively concentrated, water-release recharge from the draining channels of reservoirs, and the perennial river leakage recharge of which the leakage zone are Cambra limestone exposed in the channels and the river valleys. The surface water recharged during one year accounted for more than 90 percent of the total mine-water discharge, while the ages of water in different aquifers ranged from 1-1.2 year. This research provides scientific basis for making plan of the mine-water control.

INTRODUCTION

The site of investigation, No.7 coal mine is a part of the Pingdingshan Coal Mine Complex located in southwest. of the city of Pingdingshan As the development depth increases the amount of karst water is increasingly large, which may cause considerable difficulties in coal mining operations. Consequently, isotope values of rainwater, surface water and groundwater have been studied systematically by means of environmental isotope and hydrogeological techniques so as to ascertain the following:

1. groundwater formation, distribution and migration laws;
2. recharge source of mine water and its mechanism;
3. differentiation of the other water from mine water; determination of ratio of recent water to groundwater age.

These can provide the scientific basis for working out the overall plan of mine water control.

GENERAL ASPECTS OF GEOLOGY AND HYDROGEOLOGY

Many of strata, consisting of the Sinian, the Cambrian, the Permian, the Carboniferous, the Trassic and the Quaternary systems, are in the mine area. Principal coal beds emerge exactly in the Carboniferous and the Permian strata. There are many fault blocks and upwarded areas around the mine area. The major structure is a great syncline, smooth and wide. For example, the southern Likouji syncline faulted into two parts under the influence of the Guodishan ordinary fault.

Groundwater system in the mine area is dominated mainly by the tectonic, and the faults in western and southern mine areas develop into the water-resisting boundary. In the south the lower water-resisting layer occurs in the Cambrian sandstone or mudstone. In the east is an area of karstic groundwater runoff where it forms water-storage structure, flowing merely to the east because the other three sides are all closed. At present, mining shafts are distributed over the southern syncline. A significant attempt has been carried on to differentiate the groundwater in the deep water-storage structure from those in the Guodishan fault of the mine area with the purpose of making the two subsystems a strikingly contrast. No.7 mine area is located at the western subsystem, the west side of Guodishan fault.

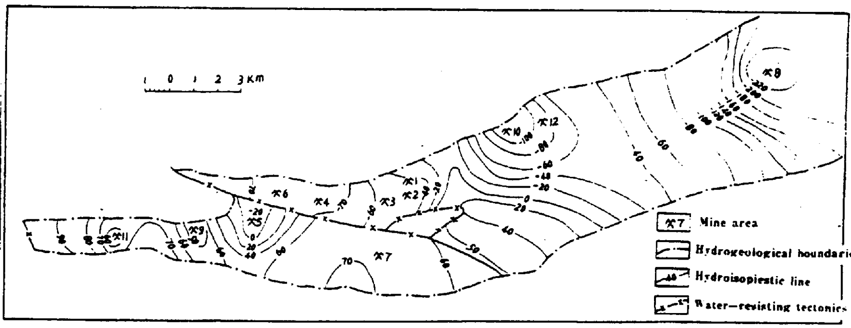

Figure 1. Diagrammatic Sketch of Karstic Groundwater Flow Net in Pingdingshan Mining Complex

The main aquifers are the Cambrian sandstone at the upper and then the Carboniferous and the Teitiary marlite, which all contain karstic fracture water. Groundwater recharge area of the Cambrian limestone is where groundwater is mainly recharged by penetration of precipitation, seepage of northern trunk canal and Zhanhe River water from west to east or from shallow to deep. Groundwater flow field in mine area influenced by the draining will lead to developing a long and narrow cone of exhaustion, extending from west to east. Drainage of each mining shaft can also create much more small cones of exhaustion in that long and narrow cone of exhaustion (Figure l).

HYDROGEOCHEMICAL CHARACTERISTICS AND ITS SIGNIFICANCE OF ENVIRONMENTAL ISOTOPE IN MINE AREA

From 1987 to 1988, 99 samples of isotope were collected during low-water period and high-water period. They received a laboratory analysis which included determination of δD, $\delta^{18}O$ and tritium. In the radioactive isotope decay and the stable isotopic fraction the research on groundwater, migration and distribution laws were respectively conducted.

Characteristics of Stable Oxyhydrogen Isotope

The mine area horizontally borders on the Guodishan fault, and the heavy isotope enrichment occurs much more in the west than in the east, namely, the values of δD, and $\delta^{18}O$ decrease from west to east. No.7 coal mine just is an area of the most heavy isotope enrichment as shown by Table 1.

Table 1. Correlation Analysis of Stable Oxyhydrogen Isotope

Location Correlation equations	δD (‰)	$\delta^{18}O$ (‰)	deviation	coefficent
No.7 $\delta D = 4.78\ \delta^{18}O - 22$	-51.32	-6.79	4.46	0.72
west $\delta D=7.12\ \delta^{18}O - 6.6$	-58.13	-7.24	1.77	0.98
east $\delta D=7.18\ \delta^{18} - 3.06$	-72.9	-9.63	3.02	0.92
whole area $\delta D=6.34\ \delta^{18}O - 9.22$	-56.09	-7.39	4.73	0.89

Vertically, the heavy isotopes turn less from shallow to deep or from surface to underground, i.e. the values of δD and $\delta^{18}O$ are exactly low in turn (Table 2, Figure 2). As seen by Table 2 and Figure 2, their slopes and intercepts indicate an increase tendency along the lines as: surface water<the Tertiary marlite water<the Carboniferous limestone water< the Cambrian limestone water<rainwater. This is because the evaporative effect gives the direct results. Under small area recharge conditions, both slopes and intercepts are increased, which shows the differences of recharge source evaporation and of the relation between groundwater-forming process and groundwater recharge.

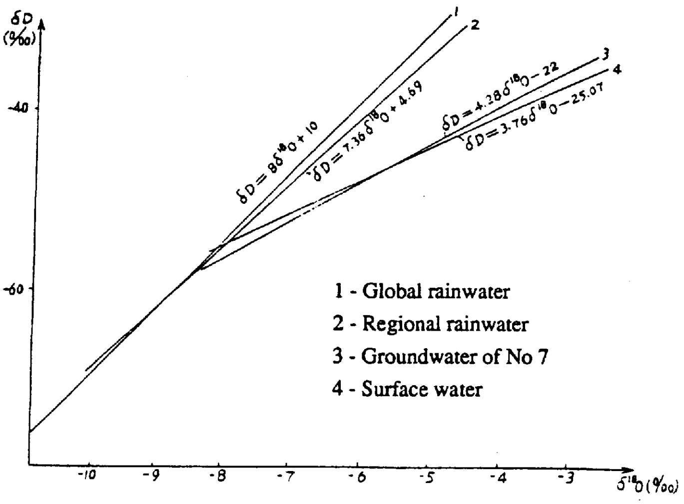

Figure 2. δD - $\delta^{18}O$ Correlation Chart

Table 2. Correlation Analysis of Oxyhydrogen Isotopes

Location correlation equations	δD (‰)	$\delta^{18}O$ (‰)	deviation	coefficient
rainwater $\delta D=7.36\delta^{18}O - 4.69$	-47.29	-7.06	3.88	0.99
surface water $\delta D=3.76\delta^{18}O- 25.07$	-46.43	-5.69	3.24	0.68
Tertiary limestone $\delta D=4.91\delta^{18}O - 17.26$	-51.31	-6.91	2.80	0.78
Carboniferous limestone $\delta D=6.38\delta^{18}O - 9.68$	-53.51	-6.87	3.42	0.91
Cambrian limestone $\delta D=6.44\delta^{18}O - 10$	-62.72	-8.17	2.94	0.96

Distribution Characteristics of Tritium

In the karst water of various mining shafts, the content of tritium becomes low from west to east or from shallow to deep, and the seasonal fluctuation ranges from large to small. The highest tritium content and the largest fluctuation occur in No.7 coal mine. The distribution of the tritium shows groundwater-forming process and migration laws due to the precipitation occurrence in southwestern exposed area of limstone and in the recharge area of surface water body.

ANALYSIS OF GROUNDWATER-FORMING CONDITIONS IN NO.7 COAL MINE

Differentiation of Young Water

In order to ascertain the recharge source of groundwater and its mechanism, the values of stable isotopes $\delta^{18}O$ are used for the differentiation of surface water and the determination of its proportion. Assume that the mine water is composed of two parts but that one part is the relic water over a year and the other belongs to the youthful water recharged within the year. While the drained amount of mine water maintains the stable state, the principle of mass conservation is:

Table 3. Various Values in Mine Water

Tritium content (T.U)	west mine areas			east mine areas		
	No.11	No.5	No.7	No.2	No.1	No.8
range of change	3.5-3.8	5.99-30.54	1.65-45.91	1.45-25.03	14.65	<0.5-19.56
mean value	16.1	16.72	22.2	14.48	14.65	<1.7

$$Q = Q_1 + Q_2 \quad (1)$$

$$Q\,\delta_0 O = Q_1\,\delta_1 + Q_2\,\delta_2 \quad (2)$$

where: Q_1 = total water amount
Q_2 = newly-recharged amount
δ_0 = isotopes $\delta^{18}O$ value of mine water
δ_1 = isotope $\delta^{18}O$ value of relic water
δ_2 = isotope $\delta^{18}O$ value of newly-recharged water

Therefore, the following equation is obtained:

$$Q_2 / Q = (\delta^{18}O - \delta_1) / (\delta_2 - \delta_1) \quad (3)$$

The differentiation of youthful water has been conducted in the seventh and second layers of the Carboniferous limestone and the Tertiary limestone. According to the results of sample analysis, all the mean values measured in 1987-1988 are selected. The mean values of the surface water samples stand for the newly recharged water (δ_2), the mean values of groundwater samples taken in 1987 for the relic water (δ_1) and the mean values of groundwater samples collected in 1988 for the mine water (δ_0) as shown in Table 4.

The Age Calculation of water in No.7 Mine

(1) Tritium Dating

At present there are two methods of groundwater age determination by tritium measurement, one is empirical estimation, the other is quantitative interpretation on the basis of mathematical model. the accidental values and average values for two years (1987-1988) of rainwater, surface water and the No.7 mine groundwater are listed in

Table 5. These values are very close to each other. By empirical estimation method, according to the opinion of Isotope Subcommition of Atomic Energy (ZAEA.1972), tritium value of groundwater in No.7 mine is more than 20 T.U. This indicates that it formed not long ago.

Table 4 Results of Differentiating Young Water

Aquifers for calculation	newly-recharged water 2	relic water 1 (1988)	mine water 0 (1988)	youthful water proportion Q2/Q (%)
Tertiary mar-lite (N)	-5.72	-7.15	-6.52	44.1
Limestone(L2) of No.3 area	-5.72	-7.78	-5.88	92.2
Limestone(L7) of No.3 area	-5.50	-6.40	-5.65	83.3
Limestone(L7) of No.2 area	-5.70	-7.47	-5.76	97.7

Table 5. Tritium Values of Groundwater, Surface Water and Rainwater in No.7 Mine

Tritium unit (T.U)	rainwater	reservior	north main canal	Zhanhe river	No.7 mine
September(1988)	25.80	24.81	25.30	24.85	29.44
average	22.90	24.25	29.01	29.50	22.22

(2) Age determination on the basis of reciprocal of the proportion of new water, i.e.

$$t = 1 / f$$

Where t = the age of groundwater.
f = the proportion of new water (Q_2 / Q)

The results of calculation are listed in Table 6. It can be seen from age values derived by both methods mentioned above that the mine water in No.7 mine is newly-born groundwater, and receives recharge of that year. For example, the age of water in limestone L_2 of Carboniferous system is 1.08 year, and in the limestone L7 is 1-1.2 year. Statistical data show that the water from limestone L7 and L2 of Carboniferous system accounts for 80% of total water yield in mine, that is to say, more than 80% of groundwater in No.7 mine is composed of new water only 1-1.2 year in age.It must be noted, however, that the process of formation of groundwater is far more complicated than that indicated by above mentioned figures. The age of groundwater said by us refers to the average value.

The Source and Pathway of Groundwater Recharge in NO.7 Mine

In the foregoing statement we comprehensively analyzed hydrogeological conditions and isotopic characteristics in Pingdingshan Mine Area and No.7 mine. In our opinion the formation process and recharge pathway of groundwater in No.7 mine principally follows the following regularities.

- o Groundwater receives recharge mainly from surface water body, namely from all year seepage of north main canal and Zhanhe River and from pulsating recharge when water flows out of reservoir through canals. The infiltration recharge from atmospheric precipitation accounts for a smaller amount. The main recharging area is the place where Cambrian limestones outcrop at earth surface and in river valleys.

- o Cambrian limestones compose the basal water-bearing strata in coal formation, and gave recharge upward and laterally to the overlying Carboniferous limestone and Tertiary marl. Among these three formations exists a close hydraulic connection.

- o The concentrated recharging area is in the central part of No.7 mine, as shown on Figure 2, at the water level contour of 70%, from there groundwater flows in two directions: to NE and to NW.

Table 6. The Results of Age Determination of Groundwater at No.7 Mine

Aquifer	Tertiary marl	limestone (L2) of No.3 of No.2 area	limestone (L7)	limestone (L7) area of No.3 area
The age of water (year)	2.27	1.08	1.20	1.006

CONCLUSIONS

As a result of study it can be concluded that environmental isotopic hydrogeological technique is a feasible method for solving mine hydrogeological problems. It is a desirable tool for studying the formation, the mechanism of mixing the movement rules, the real flow velocity and the age of groundwater. With the aid of it we can gain the result which we can not get by a conventional method.

In addition, satisfactory results have been ontained in studying deep circulatory Karst water in mines.

It must be pointed out that before it was decided to proceed with the environmental isotopic hydrogeological research in some areas, it is better to make a feasibility study.

This work can be proceeded only in the conditions when environmental isotopic hydrogeological characteristics in the area of study are appropriate. Otherwise we can hardly attain our purpose in blindness.

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