Facing Challenges of Closure Boom of Underground mines in the Permo-Carboniferous coalfields of the North China: a Medium-size Hydrogeochemical Simulation Experiment

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Abstract

With the shift of coal mining industry from the east Permo-Carboniferous coalfields to the west Jurassic coalfields, there would inevitably appear a boom in coal mine closure in China. However, from the extraordinary mine water problems occurring in the active coal mines, we could anticipate that the hydrogeochemical issues in those abandoned coal mines will also be another case. The paper constructed two medium-size cells to simulate abandoned coal mines with open and close water system respectievly to investigate the hydrogechemical process. The results showed that, after being flooded, the simulated open and close system was medium to light alkaline and had obviously different evolving process for Na+, SO42-, HCO3-, TDS, Sr, Mo, Li and Sb. Most of future abandoned underground coalmines in North China are concealed and would end in relative close water systems and result in a depth-varied hydrogeochemical regime.

Keywords: closure, China, simulation experiment, Permo-Carboniferous coalfields, hydrogeochemistry

Introduction

Nowadays China's coal industry has still been shifting from the eastern Permian-Carboniferous coalfields to the western Jurassic coalfields (National Development and Reform commission 2016), which means more than 3/4 of Permian-Carboniferous underground coalmines in the east China will have to be closed in a very near future. However, there are still no enough experience on mine closure in favor of China to ensure what hydrogeochemical regime would be in those abandoned mining areas and to further answer whether, what extent and when the groundwater in flooded coal mines could be utilized again.

Even for those active coal mines, apart from being notorious for the hazardous inrush accidents (Kailuan Mining Bureau 1986, Bai 1998, Wu 2013), they have also showed the extraordinarily typical mine water features of neutral pH, high TDS, high sulphate, and high alkaline, which is definitely different from those having been widely concerned and investigated in Europe (Wolkersdorfer 2005), North America (Wildeman 2007, Diehl 2012), Australia (Department of Industry Tourism and Resources 2007) and South Africa. So, it can be reasonably imagined that the forthcoming abandoned coalmines would be running on a different track and the closure experience in Europe, North America, etc. might not be simply applicable to China. It is imperative to invest some fundamental investigations to characterize the specific hydrogeological features of flooded Permo-Carboniferous coalmines in north China.

As reported, the methods to investigate the hydrogeochemical features of abandoned mine pool mainly include static methods and dynamic methods. Most popular static methods are ABA and NAG. Dynamic methods are column test and standards HCT test. Considering the representatives, there are also some medium simulation.

Located in the extensive North China alluvial plain, most of the future abandoned coal mines will finally end up as relatively close ground water cycle systems, which controls the process and destiny of the hydrogeochemical environment. This paper is aimed to simulate a pair of flooded closed coal mines with and without consistent water cycle, as open and close system respectively, and to monitor the hydrogeochemically process occurring.

Sampling and Methods

Samples: collected from the Zhangshuanglou coal mine in the Xuzhou Permian-Carboniferous coalfield near eastern side of the North China alluvial plain; made up of coal gangue and overburden dump of the coal bearing Shanxi Formations of the early Permian which are unconformably underlain by the Ordovician-Cambrian marine carbonate deposits; consisting chiefly of typical terrestrial sediments of coal, mudstone, siltstone, quartz sandstone, feldspathic sandstone, lithic sandstone, etc.; and crushed into fragments of grains < 26mm in diameter.

Simulating system: aimed to simultaneously simulate a concealed flooded coalmine with an overall closed water cycle and a half-concealed flooded coalmine with an open water cycle respectively(fig. 1); using two medium size cylinder cells (Φ1.5m × height 2.0m) with built-in dynamic and hydrogeochemical sensing systems which include sensors of water head, temperature, pH, dissolved oxygen (DO), conductivity, Redox, etc.; loaded each with 4≈5 metric tons of crushed samples; initially flooding both of the simulating cells with the chemically known tap water at a flow rate which was determined on the basis of estimated flooding recharge to the Zhangshuanglou coal mine and then only consistently recharging the open system while stopping recharging the close system; at the same time, leachate being periodically collected from the pre-built-in outlets and chemically assayed by ICP-AES.

Figure 1 *the medium-size hydrogeochemical simulation platform*

The simulating system has been in operation since January of 2017 and will run for at least two years.

Results

Flooding process: The two simulated abandoned coal mines were flooded in about two months and therefore it is estimated that the future abandoned Zhangshuangji coal mine will be flooded within 5-6 months.

After being flooded, the simulating open and close systems showed a different hydrogeochemical process and trend in terms of physical parameters of pH, Dissolved Oxygen (DO), Redox and conductivity: (1) after 34 day since the simulating systems were set up on Jan. 18, 2017, the pH value of the open and close systems firstly soared from 7.7 to the peak of 8.61, then gradually sloped down to the lowest point of 7.6 in Aug. 2017, and finally mounted again to 8.0 in April 2018; in general, the pH of the open system is a little higher than that of the closed system; (2) so far, in terms of the average DO of the leachate collected through the pre-built-in outlets at the height of 1.5m, 1.0, and 0.5m in the cylinder cells, while the open system showed in turn a downward trend from 3.47 mg/L, 3.11mg/L to 2.51mg/L respectively, the close system with an overall lower DO, which are 3.12mg/L, 3.19mg/L and 2.14mg/L respectively, presented a relatively higher DO at the medium height; (3) the redox of the leachate in the two simulating system linearly slowed down from the initial +300 mv to the present -200mv in the first four months, then the redox in the open system mount slowly to +100mv again and the redox in the close system fluctuate between +100 to -150mv; (4) initially in a month, the conductivity of the leachate in the open and close systems synchronously rose up to a peak value of 2600 us/cm on April 9, 2017 and then synchronously descend to 2100 us/cm on May 25, 2017; from then on, the conductivity in the open system continuously descended to 1300 us/cm, while the conductivity in the close system rose up again to about 2600us/cm. It proved that the insistent recharge after flooding made the hydrogeochemical difference.

The water quality of the leachates periodically sampled from the open and close systems showed a main difference in the concentrations of Na^{2+}, SO_4^{2-} and HCO^{3-}: (1) the Na^+ in the two simulating systems fairly synchronously rose from the initial concentration of 205mg/L to the peak value of 508 mg/L on April 26, 2017 and then on June 4, 2017 the close system deviated from the downward trend, as the open system was developing, to mount again instead; (2) after being flooded, the SO42- in the two simulating system quickly went up to the highest value of 650 mg/L on April 10, 2017 and then turned into a linearly downward trend to 200mg/L with the close system changing its evolving tendency away from that of the open system on May 18, 2017 to stay around 480mg/L; (3) till May 18, 2017, the concentrations of HCO3- of the two simulating systems were insistently rising from 300 mg/L to 500 mg/L, afterward the HCO3- in the open system reached a plateau around 500mg/L, while the HCO3- in the close system continuously mounted up to 760 mg/L.

There were 16 kinds of metals, including V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Ba, Pb, Mo, Sb, Li and Al , being tested for the leachate. In comparison, the open and close systems showed an obvious common or distinct release features for the trace metals of Sr, Mo, Li and Sb: (1) though, at the early stage, the open and close system released the metal of Sr, Mo and Li in an almost synchronous way, while, after June of 2017, the release process obviously diverted into two trend;(2) since the beginner, the open and the close system showed an ideally simultaneous Sb release process; (3) the concentrate of Mn, Fe, Ni and Sb exceeded the drinking water standards (China).

Conclusions

It is concluded that (1) after being flooded, the abandoned underground coalmines in Permo-Carboniferous coalfield would mainly experience reactions of dissolution, adsorption, etc. of sulfate, Ca, Na and K rather than the oxidation-reduction reactions of Fe, Mn, etc.; (2) the flooded groundwater pool would be medium to light alkaline; (3) most of future abandoned underground coalmines in North China are concealed and will end in relative close water systems and result in a depth-varied hydrogeochemical regime; (4) Sr, Mo, Ni and Sb could be the main potential pollutants; (5) the trend and fate of abandoned coalmines would closely related with the genesis of Permo-Carboniferous coalfield themselves.

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