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Huangshaping mining karst area groundwater pollution propagation modelling and its control, remediation by using monitoring program and microalgae plant

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ABSTRACT

This research aimed to analyze and evaluate the contamination of pollutants in mining karst areas groundwater in Huangshaping, Hunan Province, China. To achieve these aims, the study was involved in data collection and analysis; groundwater environmental assessment grading and simulation modeling. Finite element subsurface FLOW system (FEFLOW) software was mainly used for the analysis. Due to the negative impacts of pollutants in mining karst groundwater, application of environmental mitigation measures for the pollution monitoring program, grid split, geological model and Groundwater seepage modeling was required to evaluate and control groundwater pollution spread. Water monitoring frequency was three times in a month, to test respectively, temperature, pH, chemical oxygen demand, Mn, SO_4^2, Mn, Fe^+, Zn, Pb and other parameters. For remediation and prevention of water pollution problems in study areas, the bactericide technology was used to prevent the formation of acid mine drainage wastewater; and wastewater treatment by microalgae plant culture for the surface wastewater treatment. The results indicate that there are different sources of pollutants in Huangshaping are life sewage wastewater, production wastewater, gushing water, sewage industrial sites producing, processing waste, tailings wastewater, rainwater and other venues. These mining pollutants have negative impacts and influence on the geological environment and groundwater quality such as Circulation of underground water is very poor; Aquifer water tables were changes; natural geological structures are in serious destruction. Pollutions dispersion speed has been three times in 50 y since exploitation project was implemented. The largest migration distance was respectively within 40.7 m (in 50 y ago), 95.2 m (30 y ago), and 99.5 m at this time. The iron tailings wastewater treatment can be purify about 7,706 m^3/d of wastewater which mean have limited impact groundwater environment. Contrarily with lead and zinc mine tailings which are very favorable to contamination. For surface wastewater treatment, the suspended solids removal efficiency was up to 80% and nearly 50% metal removal for a plant of green microalgae in wastewater. Reuse of mining wastewater by hydride water consisting of 50% fresh and 50% mine wastewater was applied for food production in the area. Crop yield was proportional with salinity almost 50%. However, no risk of heavy metals contamination was found in plants and soil.

Keywords: Groundwater; Contamination; Diffusion; Tailing, Aquifer; Remediation

1. Introduction

Hundreds of millions of people worldwide live in karst areas. They are supplied by drinking water from karst aquifers. These aquifers include valuable freshwater resources. Sometimes it difficult to exploit and are almost always vulnerable to contamination, due to their specific hydrological properties. According to the Hunan nonferrous metal company, one million tons/y mineral resources extracted from that exploitation site. Many problems are countered in karst areas and include soil erosion, rock desertification, leakages

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of channel and reservoirs, the collapse of underground cavities, the formation of sinkholes, and flooding. This research has been done in Huangshaping, Hunan province, China. This study has cooperation for using a database originally from Hunan nonferrous Metal Corporation Company which located in the study area.

The main objective of this study was to conduct some specific evaluations to provide a hydrogeological, hydrological, hydrochemical and water quality database for the karst groundwater [1]. Furthermore, it was also to specify the different pollutants, their possible sources and their actual impacts on groundwater resources. However, the karst aquifers must be safe. To achieve that purpose, identification of the pollutant's inflow in groundwater quality at site areas has been done. It's very important to know the groundwater transport modeling in karst areas such as water inflow in mining aquifer and pollutant migration on different tailing zones. To carry out the research, analogies of those methods cited respectively below are required: Sampling method, it was about a collection of water samples from the surface and underground water in the field study. That has been done for water quality monitoring and water table level monitoring. To determine water needs and the potential of water, the grading evaluation method was used. For direct impact in the mining karst area, there is Groundwater environment assessment grading to evaluate the damage of contamination diffusion in all directions. In another hand, the groundwater seepage model and grid split geological model for the prediction of speed contamination spread. To remove and reduce the water contamination in the surface, the bactericides method was introduced for catalyzing the conversion of Fe^{2+} to Fe^{3+} and SO_4^{2-} to S^{2-} and water purification. In the end, open pound culture of microalgae was necessary to treat mining wastewater from the exploitation site.

Seek of development obliged humans for the utilization of mineral resources. It will produce some of the mine geological environment problems; destroyed the natural ecological environment; mining will process of rainfall infiltration runoff water evaporation cycle impact through field investigation. Due to the vulnerability of karst aquifers to pollution, karst areas can be polluted easily. This is because the holes in the ground (like vertical shafts or sinkholes) allow water to run quickly to the underground [2]. The natural filtration system was missing. Contaminants can easily enter karst aquifers through thin soils or via swallow holes. Inside the aquifer, contaminants can rapidly spread over large distances, due to turbulent flow in the conduit network. Natural attenuation processes, such as filtration and retardation, are often less effective than in other aquifers. Water suppliers prefer water sources with stable discharge and water quality, but karst springs often show high variations of both. Periods of excellent water quality may be interrupted by short contamination events in karst areas [3].

2. Materials and methods

2.1. Materials

2.1.1. Study areas: localization and description of site

The study has used some databases originally from Hunan Nonferrous Metal Corporation Company and fieldwork research. It was done to estimate the mining contamination in Huangshaping karst groundwater. The resident's groundwater utilization is more traditional. The main sources of use for living water are irrigation and industrial enterprise. Hunan nonferrous metals company is located in Chenzhou city of Hunan province, China. Huangshaping town is at 9 km from the county town of Guiyang, China. My geographical coordinates: longitude 112°40′20″~42′20″ North latitude 25°38′59″~41′27″ East. According to the survey of the site visit, the town of Huangshaping drinking water source which is the Fangyuan reservoir as well as the east river is associated with the Huangshaping lead–zinc mine groundwater. According to the previous research, all used water dressing workshops, dressing production are outside exploitation area. The dressing wastewater recycling in the region has no function of groundwater remediation. The aquifer reservoir in the district of Fangyuan is ranges about 3.8 km of Huangshaping mine, China. But, the springs and rivers have a distance very close to the mining area.

2.1.2. Conceptual hydrogeological model

The conceptual hydrogeological model is the basis of the actual nature of the boundary permeability performance of the internal structure of the hydraulic characteristics and supply. The discharge condition is facilitating the mathematical and physical simulation of the basic model to evaluate the hydrogeological [4]. The conceptual model is the first step to evaluate prediction in the backfilling area. It is located in the mountain basin. The west and the east were seen at an altitude of 330–345 m bake. In the middle were at an altitude of 290.2 m. The backfilling library landfills located at the north of the backfilling pond has 285 m of water level. Huangshaping lead–zinc backfilling library is out of the outdoor layer quaternary strata carboniferous.

2.1.3. Mining nations-economic complexity

Major mine ore bodies on the ground plane erosion are the following: terrain conducive to natural drainage, deposits mainly filled with water aquifer. The construction broken with rich water and groundwater conditions are relatively good. A hydro-geological boundary is very complex with the mining nations-economic medium. Deposits hydro-geological type is a karstic fissure filled with water-based nations-economic medium type.

Hunan nonferrous metal company, China and iron tailings ponds are located at Kwai Fong, China County town. This means that the road of mining by railway tie Chenzhou and scatter to another city are very convenient traffic and transit-highway transportation. The tailings ponds are located nearby the road. The main dam and road distance is about 600 m. The Main Dam East is located at 300 m from lead, zinc mines, tailings zone. The iron tailings and lead–zinc tailings base relative position as shown in Fig. 1.

2.1.4. Basic characteristics of deep deposit in Huangshaping mining area

The medium-sized state-owned mining enterprise is localized in Huangshaping lead–zinc mine, Hunan province,

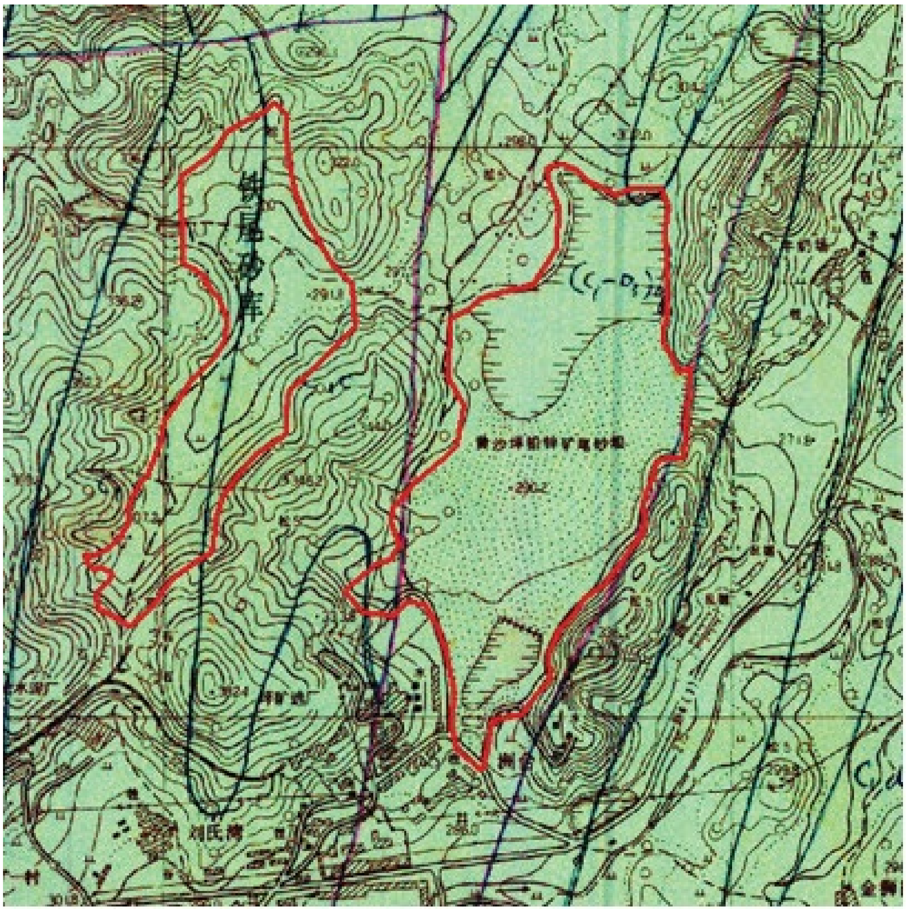

Fig. 1. Iron tailings and lead and zinc tailings base relative placement diagram.

China. The mine was set up in 1959. It completed and put into operation in 1967. It successively was put nonferrous metals industry corporation subordinate enterprise, is now affiliated to the Hunan Province Nonferrous Holding Group Company. Also, through 200 midway were counted in total. But since the actual mining midway was implemented, only some mining working points are available. There are more than 40 mining working points.

Huangshaping ore deposit mining area belongs to a moderate scale. The water filling factors of surrounding rock deep deposits were mainly located in Shi Deng subgroups limestone. The measuring water at catalpa gate bridge-group limestone formation in the vertical depth of development is showed gradually decreasing. In that place, aquifers have an elevation above 200 m. The mining area belongs to the strong aquifer pumping water injection test. According to the results of Shi Deng subgroups rock in deep water is weak.

3. Methods

3.1. Groundwater environmental assessment grading

There are several types of stimulation parameters. This research used to identify the agent movement model, which includes: (1) Mathematical model and (2) Diffusion model [5].

3.1.1. Mathematical model

3.1.1.1. Solute transport model

For solute transport, the three-dimensional mathematical model of hydrodynamic dispersion equation is as follows:

$$\frac{\partial C}{\partial t}=\frac{\partial}{\partial x}\left(D_{xx}\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_{yy}\frac{\partial C}{\partial y}\right)+\frac{\partial}{\partial z}\left(D_{zz}\frac{\partial C}{\partial z}\right)-\frac{\partial(\mu_x c)}{\partial x}-\frac{\partial(\mu_y c)}{\partial y}-\frac{\partial(\mu_z c)}{\partial z}+f \tag{1}$$

$$C(x,y,z,0)=C_0(x,y,z)\quad (x,y,z)\in\Omega,\ t=0 \tag{2}$$

Styles, right-side front three-dimensional are for the diffusion. The last three-dimensional of the convection was the chemical reactions or adsorption to resolve the cause of the agent of the incremental. D_{xx}, D_{yy}, D_{zz} are respectively, for the X, Y, and Z of the direction for the diffusion coefficient. It should be Z–X, Y, and Z direction of the actual flow rate.

where C: agent concentration; Ω: an agent for seepage; dimensionless quantities: L^2; C_0 is the initial concentration, dimensionless quantities: ML^{-3}

Table 1
List of groundwater quality III standard

Number	Project	Class standard value
1	Total Hardness (as $CaCO_3$)	≤450 mg/L
2	Total dissolved solids	≤1,000 mg/L
3	Sulfate	≤250 mg/L
4	Chloride	≤250 mg/L
5	Iron	≤0.3 mg/L
6	Manganese	≤0.1 mg/L
7	Copper	≤1.0 mg/L
8	Zinc	≤1.0 mg/L
9	Molybdenum	≤0.1 mg/L
10	Cobalt	≤0.05 mg/L
11	Permanganate index	≤3.0 mg/L
12	Nitrate (as N)	≤20 mg/L
13	Nitrite	≤0.02 mg/L
14	Fluoride	≤1.0 mg/L
15	Barium	≤1 mg/L
16	Arsenic	≤0.05 mg/L
17	Hexavalent chromium	≤0.05 mg/L
18	Lead	≤0.05 mg/L
19	Nickel	≤0.05 mg/L
20	Selenium	≤0.01 mg/L
21	Cadmium	≤0.01 mg/L
22	Mercury	≤0.001 mg/L

3.1.2. Diffusion

The evaluation of pollutant dispersion degree is the study of pollutant migration, transformation in soil and groundwater rule by some of the most important parameters. The flow of this study was realized into those parameters cited below:

- *Diffusion coefficient (D)*: it was seeping system diffusion characteristics. (*D*) is reflect the dispersion characteristics in a comprehensive seepage of system parameters.
- *Molecular diffusion*: it was the medium dispersion and pore velocity (*V*) function only in the groundwater solute transport equation. In the groundwater agent movement equation, the aquifer medium diffusion characteristic of the parameters is the hydrodynamic dispersion coefficient. It can be represented as:

$$D_{ij} = \alpha_T V \delta_{ij} + \left(\alpha_L - \alpha_T\right)\frac{V_i V_j}{V}$$

where α_L, α_T longitudinal and lateral pore-scale diffusion, which was the only related to medium characteristic parameters.

3.2. Groundwater seepage modeling

3.2.1. Mathematical control equation and solve

Through the analysis of the hydrogeological conceptual model, the basis of the seepage flow continuity equation and Darcy's law was established [6]. That method is applied to evaluate area hydrogeology [7]. The conceptual model of the groundwater system corresponding to the three-dimensional mathematical models was unsteady flow:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial H}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial H}{\partial z}\right)+w=\mu_s\frac{\partial H}{\partial t} \quad (3)$$

$$H\left(x,y,z,0\right)=H_0,\left(x,y,z\right)\in\Omega \quad (4)$$

$$K\frac{\partial H}{\partial n}\bigg|S_2=q\left(x,y,z,t\right),\left(x,y,z\right)\in S_2 \quad (5)$$

$$H\left(x,y,z\right)=H_1,\left(x,y,z\right)\in S_1 \quad (6)$$

Type of Ω: groundwater seepage area, dimension: L^2;
H_0: initial groundwater level, dimension: L;
H_1: a specified level and dimension: L;
S_1: the first kind of boundary;
S_2: the second class boundary;
μs: unit of storage coefficient, dimension: L^{-1};
K_{xx} K_y^y, K_{zz}: *x y z* respectively the main direction of permeability coefficient, dimension: L^{T-1}; *W*: source items, including evaporation, rainfall infiltration, wells, water output dimensions: T^{-1}; *Q* (*x*, *y*, *z*, *t*): according to a different position on the flow of time, the border dimensions: L^3 T^{-1}

3.3. Mine wastewater treatment by using microalgae plant

Studies on algae and their biochemical mechanisms of metal detoxification are growing and are widely accepted but significant contributions are yet to be produced in light of the success of current passive systems to remove heavy metals [8]. To study the chemical characteristics of groundwater, the source of pollutants was analyzed. Water samples were collected from surfaces and underground water bodies, an outcrop of groundwater and pumping test boreholes. PH, mining ions and the main pollutants in water have been measured and identified in the field. Microalgae are great accumulators. They can absorbents and adsorbent with high selectivity for pollutants. They can be generated with high alkalinity which is very essential for precipitation of heavy metals. They also have great potential efficiency for heavy metals removal in acid mining drainage [9].

3.4. Sites implemented wastewater treatment plant and reuse of the mining wastewater

The type of wastewater treatment is the coagulation, flocculation, $^{++}$oxidation, and disinfection. Those processes are applied in tailings overflow water. In another hand, tailings dam overflow water is influent downstream into the wastewater treatment plant station. The regulating tanks and polyacrylamide have the role of coagulant for wastewater purification and disinfection. To make that happen, the use of chlorine oxidation method to remove chemical oxygen demand (COD) pollution in wastewater was necessary. The existing water treatment facilities underground mining engineering. There are two stations:

- One is on the ground (pit wastewater treatment station), responsible for handling discharged to the ground from the underground mine water gushing all over using the "barium". It is called "lime deposits of sludge recycling process".
- Another is standing in the middle of one processing down the whole 200 m. It is using the "Manganese pool adsorption process". The middle of 200 m underground water gushing is for mine water.

For reuse of mining wastewater: water, soil and plant sampling was completed for each plot over different time intervals and analyzed for heavy metals (Cr^{+6}, Ni^{+2}, Zn^{+2}, and Pb^{+2}) in addition to the major ionic composition of the water used for irrigation. Crop yield was estimated at the end of the experiment.

3.5. Bactericide technology

The bacteria catalyzed acid formation by increasing the oxidation rate of pyrite by a factor of one million. The bactericide attacks the source of the problem by preventing the acid formation and metals solubilization [10]. Using in conjunction with the current water treatment system, bactericides can grammatically reduce operating costs. The controlled release of bactericides contributes to successful reclamation by providing assurance against revegetation failure. While any organic compound aids in the establishment of beneficial heterotrophic bacteria that support vegetation, these conditions continue to persist after the bactericide is depleted from the controlled release system. The site was evaluated to determine if bactericide treatment was needed. Microbiological enumeration tests of the site material were determined. Incubation and column leach test were used to assess the bactericide's effectiveness in controlling acid production in Huangshaping mining karst areas [11]. Bactericides appear to work best when used in combination with other control methods and can be useful in preventing acid conditions in pyritic rock piles which remain open for several years until the site is reclaimed. The active operations, the use of bactericides during mining and waste disposal operations could minimize acidity, sulfates and metal runoff water [12]. This improvement in water quality leads to a reduction in the cost of neutralization chemicals, sludge removal and disposal, equipment maintenance, energy, and personnel [13].

4. Results and discussion

4.1. Sources of pollution analysis

4.1.1. Construction of water-type production and emission of pollutants

The construction and exploitation period was mainly a source of wastewater. Construction wastes are including concrete mixing stations produced alkaline waste, gravel and equipment washing waste. Sewage daily washes are construction workers, canteen and toilet wastewater, etc. Concrete mixing station alkaline waste generated major pollutants alkaline substances and suspended solids (SS). The general capacity of wastewater is about 50 m^3/d. Gravel materials and equipment washing are the main pollutants, with a 30 m^3/d capacity of wastewater. Sewage main pollutants are SS, COD and ammonia nitrogen. The water drainage is 80%, with the amount of sewage 28.8 m^3/d.

4.1.2. Production operation and emission of pollutants

Production operations of the project have mainly impact on underground water pollution such as gushing water, sewage industrial sites producing, processing waste, tailings wastewater, rainwater, and other venues.

4.1.2.1. Underground water gushing

The proposed project before construction underground normal water inflow was 7,000 m^3/d. After the construction of the project, underground water inflow was about normal at 15,643 m^3/d. Based on underground water gushing pollutants, there was the lead (Pb), SS, other heavy metals and radioactive element radium. The proposed project was still gushing generated downhole take the existing treatment process. The existing water treatment plant has expanded to Chung underground. The processing capacity is 19,000 m^3/d.

4.1.2.2. Life sewage wastewater

After the project was completed, there is no additional labor capacity. The domestic water and sewage work in the same as with the existing emissions. Water consumption was about 1,970 m^2/d. Sewage efflux of about 1,773 m^3/d. Through the integration of land and new septic tank buried. The sewage treatment station was categorized in "integrated wastewater discharge standard".

4.1.2.3. Production wastewater

The source of production wastewater is from a new polymetallic and molybdenum processing plant. The main pollutants in wastewater are SS, COD, a small number of heavy metals and mineral thickener. Based on the design of the exploitation plan, the tailings ponds, water seepage were the major sources of pollution in groundwater. The tailings volume is 1,254,390 t/d. Since the building construction of the project, the daily loss amount of water is 1,710 m^3. When it completed, the metal-metal tailings make a loss daily 382.5 $m^3$of water.

4.1.2.4. Tailings waste and site rainwater

The proposed project has the existing lead–zinc tailings. It was generated effluent from the existing lead–zinc tailings waste treatment station. The Project release tailings wastewater about capacity up to 9,174 m^3/d. The study area location is adequate for rainfall. After rainwater landing, the SS and amount of major pollutants affect the surface water. The collection system of rainwater was set in the mining exploitation and processing sites. The precipitation was collected through rainwater tanks.

4.1.3. Groundwater environmental features

According to groundwater function zoning, and local environmental protection department approved, the implementation of the project site groundwater GB/T14848-93

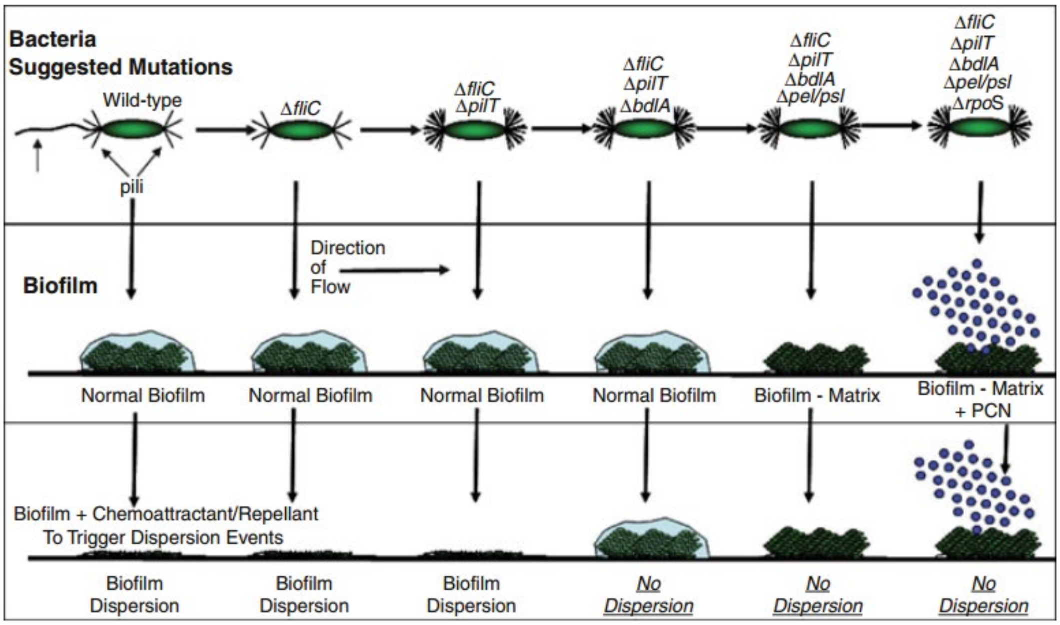

Fig. 2. Schematic diagram of bacterial structure, biofilm formation characteristics, and dispersion properties.

Table 2
Drain test results

Aquifer	Test point elevation (M)	Static water level elevation (M)	Drain points deep (M)	Observation hole down deep (M)	Surge of water quantity (L/S)	Unit surge of water (L/S M)	Permeability coefficient (M/D)	Note
Tze-gate bridge group	200.70	294.0	43.8	13.2	13.94	0.318	0.5643	GK52 observation hole spacing drain center 55.73 m
			60.0	17.2	18.48	0.308	0.6334	
			71.6	19.8	20.75	0.290	0.6755	

Table 3
Stone bench group GK 62 pumping test results

Elevation (m)		Static water level elevation (M)	Down deep (M)	Surge of water quantity (L/S)	Unit surge of water (L/S M)	Permeability coefficient (M/D)	Note
Since	To						
129.39	170.0	150.76	25.59	0.032	0.00125	0.00497	The bore wells, high-pressure air-water pumping, the water volume is less than pumping equipment water capacity.

"groundwater quality standards" III water quality standard. The reference value based on human health, mainly applicable to centralized sources of drinking water, industrial and agricultural water use.

4.2. Groundwater and dry radius impact

Mining exploitation, alienation and scope impact is very large. The groundwater and dry affected areas are importantly wide as shown in Fig. 3. The wellhead southeast side underground pit is the largest decline in the 400 m left and right. The formed artificial groundwater drain dry exhaust is caused by surrounding declining groundwater levels. So, the springs of the well are dry up. The pit minimum groundwater levels get up at 56 m elevation. The original water table, pits and dry funnel groundwater maximum drop the 400 m left and right.

4.3. Mining groundwater and pore water aquifer features

Because of the mining area the terrace formation of water is not the same. The rock and thickness distribution of water-in-fuel are also differences. The east side level of water is good. The thickness is 1 to 20 m from the mine pumping.

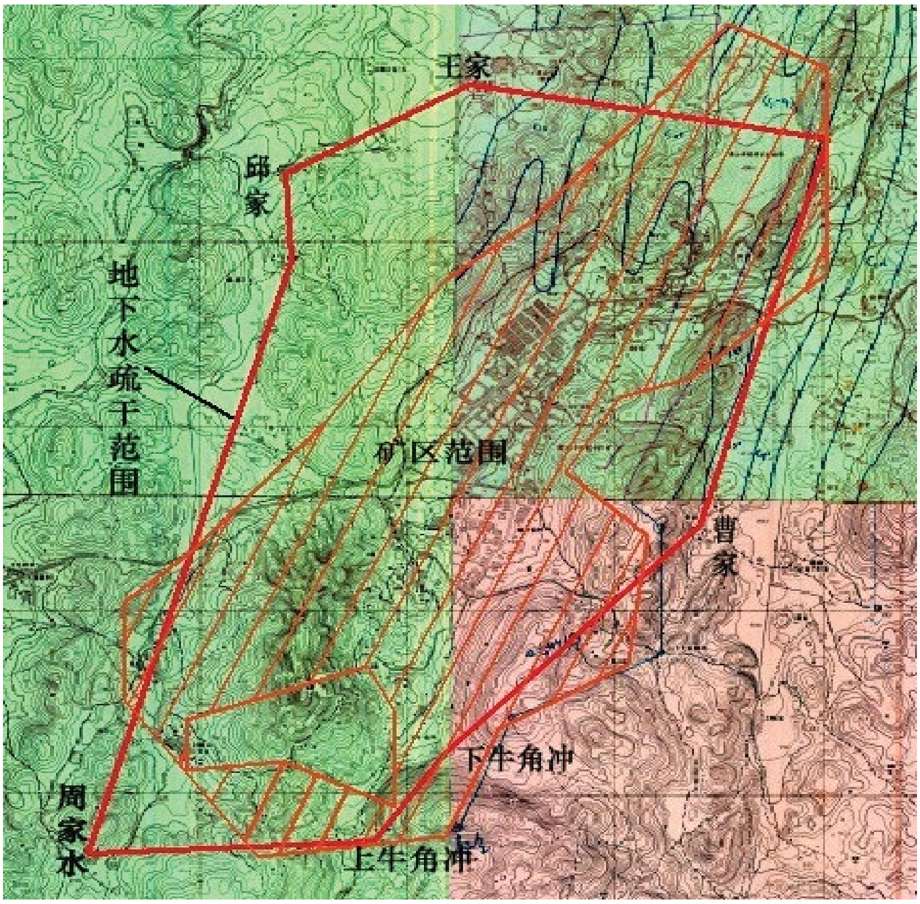

Fig. 3. Mining groundwater drains dry affected area schematic.

The test results in a surge of water are 0.0654–0.1631 L/S. The M, permeability coefficient is 4.774–14.26 m/d. The west side of the water to the east side weak in a surge of water is 0.0306 L/S. (M) the permeability coefficient is 1.088 m/d.

The Po Ling side there are seasonal streams. The streams nearby are low-lying flat strip. The clay, sandy powder qualities are under continued spread to the gravel layer. The thickness is 0.2 to 0.8 m. Gravel content is mainly quartz spots rock, quartz sandstone, manganese. The quality combined with the layer and volt bedrock aquifer hydraulic are closely linked. The pit drainage aquifer springs are all dried up.

4.3.1. JA bridge-group strong karstic fissures water aquifer

JA bridge-group strong karstic fissures water aquifer lithologies are mainly constituted by gray rocks and siliceous. Tze-gate bridge-group aquifer has close ties with a flat surface located in the mining west side. That section is located at 20 m elevation above. Mining areas in the western part of JA Gate Bridge Group siliceous aquifer are pits filled with water. It is the main source of the lava rock formations.

According to the information available statistics by drain test results, well construction and water in the 68 collapses are located in the layering bit. The drill holes in the cave's rate were very high. According to a 166 drill holes tested, which was found: caves drilling 22, the layer 17C, total collapse 77.27%, M 220.47.

The average surge of water is 17.476 L/S. The total surge of water quantity is 94.2%. According to the analysis, the water is drawn from the layer. It can be seen that the JA bridge group for mining is mainly a strong karstic fissure water aquifer.

Tze-gate bridge-group karst development is also uneven. Karst development was more deeply and weaker. According to the statistics 200 m elevation of the caverns is only 8%. The trenches are more visible to deep karst areas of growth and weaker. That's because of the surge of water, the traffic becomes smaller, water-in-fuel, are weak.

4.3.2. The karstic fissures water aquifers

In the mining area, the karstic fissures water aquifer is mainly upper ledge sub-group rock. The gray rocks and mud quality rock are a rock of mudrock mezzanine. The rock quality is not plain. Calcium, magnesium components were relatively decreased to the detriment of the underground water-soluble corrosion. The lava was not developed.

According to statistics, drilling in elevation 129 to 170 m was realized. The caves karst rate was only 0.35%. At 170 m of elevation, karst ceased its growth. That has following the mining area location. Because, it is located in stone the vocational sub-group rock (GK 62 pumping test).

4.4. Groundwater environmental impact scenarios simulation set

The forecasts of the anti-seepage measures have no role. The property conditions for the groundwater changes in the environment. According to the project design, backfilling materials in normal working conditions can accumulate in a backfilling repository. The received chemical composition of rainfall infiltration in the backfilling slag was considered. The effect aquifer seepage prevention measures (natural seepage control) were under the situation of the pollutant diffusion scenario. *Scenario A*: normal work besides artificial impermeable. It has an incident performance in zinc tailings base on part leakage. Normal performance taking into account the sewage pools of normal with leaking of pollutants into groundwater. The accident conditions, take responsibility for the existing sewage system, sewage pollution incidents of leaks into the water.

The simulation, evaluate the straw spreading of pollution factor of Pb, Hg, SO_4^{2-}, and Mn. The appearance of pollution scenario spread specific, are shown as follows:

4.4.1. Scenario A

Normal work besides artificial impermeable play the lead and zinc tailings repository leakage.

Scenario type: normal performance, artificial impermeable measures

Leakage source strong type: continuous strength. Based on lab test results, Hg concentration is 0.0096 mg/L; SO_4^{2-} concentration is 103.3913 mg/L; Mn concentration is 2.668 mg/L. The anti-seepage conditions for entry into force: impermeable membrane permeability coefficient 1×10^{-10} m/s. The spirit at the greatest risk in water is a time of 365 d by taking into account the leakage area of lead and zinc tailings library overall.

- *Leak*: lead and zinc mine tailings in the landfill area.
- *Leak size*: 2 × 105 m^{-2}.
- *Leak time*: 365 d of a year.
- *Leakage*: leakage (m^3) = leakage area (m^2) × permeability coefficient (m/s) × 365 × 24 × 3,600 (*S*) = 0.0063 (M^3/a).

4.4.2. Scenario B

Lead and zinc tailings library impermeable layer is 1% in the failure of natural leakage.

Scenario type: non-normal conditions, do not take artificial impermeable measures (natural anti-seepage)

Leakage source strong type: instantaneous strength. Based on lab test results, the concentration of Hg = 0.0096 mg/L; SO_4^{2-} = 103.3913 mg/L; Mn = 2.668 mg/L. The natural conditions of the impermeable layer overall permeability coefficient are 4×10^{-7} m/s. The spirit is in the water at 365 d. The slightly is about 1% leakage area. Taking into account the leakage weep for 10 d.

- *Leak*: lead and zinc mine tailings the landfill area.
- *Leak size*: 2×10^3 m^{-2}.
- Leak time: 10 d.
- Leakage: leakage (m^3) = leakage area (m^2) × permeability coefficient (m/s) × 10 × 24 × 3,600 (*S*) = 691.2 (m^3).

4.4.3. Natural seepage under backfilling library leakage scenario prediction

The using of finite element subsurface FLOW system (FEFLOW) software for run solute transport model was necessary. The hydro-geological parameters of solute migration and impermeable layer parameters are demonstrated in the model. The model was running for many years of contamination dispersion. The simulation period of 10 to 50 y was predicted result post-processing in ArcGIS. The pollution halo concentration boundary to the groundwater quality is bounded after the leakage pollution halo plan. The pollution halo profile maps are shown in Figs. 4 and 5.

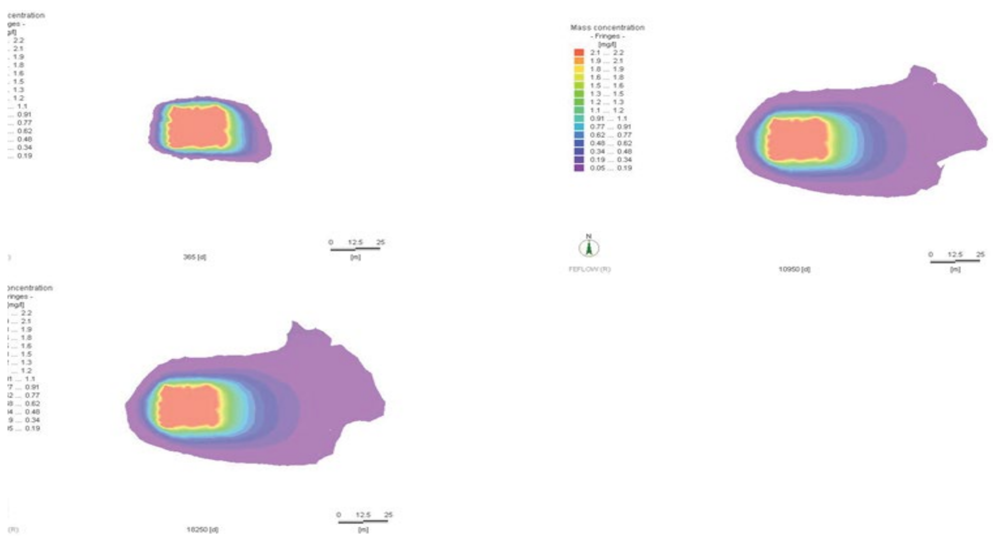

Fig. 4. Pb pollution halo map.

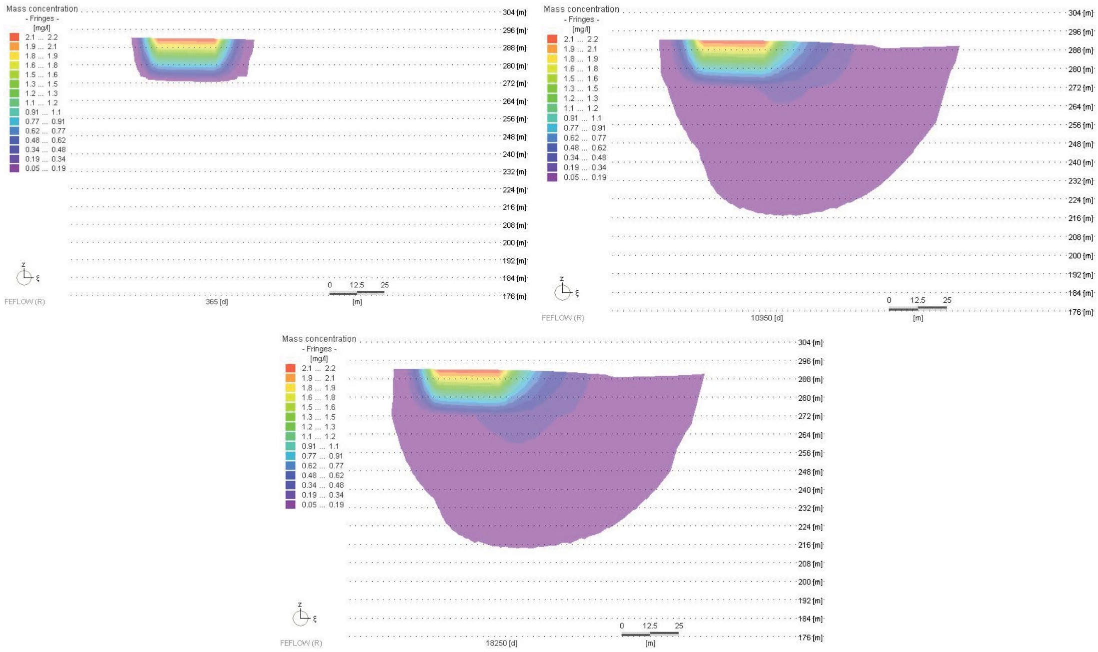

Fig. 5. Pb pollution halo profile map.

A large number of indoor dispersion test results show that the longitudinal disparity in millimeter magnitude commonly, known as the pore-scale hydrodynamic dispersion effect. But in fact the dispersion degree obtained from the field experiment is far greater than in the laboratory. According to the measure of value, the difference can be up to 4–5 orders of magnitude. The field dispersion degree increases along with the research problem scale.

Leakage accident happens, 50 y of Pb pollution halo migration results are also shown in Table 4.

According to the simulation, the results can be seen like this: Pb pollution halo of quaternary pore water in the southeast is overall migration direction. The Pb pollution migration has grown three times since the project was implemented in the area. The pollution halo migration distances are respectively 40.7, 95.2, and 99.5 m within 50 y. And also, the migration of the Pb pollution halo gap is out of the quaternary system aquifer group. The affected devonian and carboniferous karst fissure aquifer in 50 y pollution halo is JieYao east of model 21.4 m. The largest area contaminated by Pb pollution halo backfilling materials in the library was 7,372.7 m^2 of the simulation range.

4.4.4. Grid subdivision and geological model

Area evaluation was covered a 1,270,857 km^2 of surface. The numerical simulation applied triangle mesh subdivision. The triangle subdivision laws manifest by adopting the method of the *T*. Mesh subdivision process strictly follow the rule of the Delaunay. This method must make an acute angle inside the triangular mesh. The length of the trilateral was equal as far as possible. But the triangular net of any triangle circumscribed circle within the scope of other points were not exist. The scattered point set may be formed in the triangle subdivision for the Delaunay triangulation cutting the branch. The minimum Angle of the triangle was formed by the biggest encryption processing for the project scope of these areas. The area evaluation in two-dimensional subdivision results is shown in Fig. 6. The junction points, 3,224,214, count 482,355 geological generalized finite element model is divided into three layers (layer) 4 (slice).

4.5. Determination of hydrogeological parameters

Hydrogeological parameter selection of the initial value reference deep in Huangshaping mine hydrogeology survey report of pumping test data. According to the hydrogeological conditions of evaluation at the same time, the permeability (storage) coefficient and rainfall infiltration coefficient has carried on the generalized partition of its parameters as shown in Fig. 7. The hydrogeological parameters of the initial value as shown in Table 5 was considering the backfilling mining basin on the northern side of the library as the overall flow. The permeability coefficient values for K_{xx} are 0.1 m/s; K_{yy} is 0.1 m/s; K_{zz} is 0.01 m/s; the water level is one and the rainfall infiltration coefficient is one (i.e., rain completely deep ore pond).

4.5.1. Optimal hydrogeological parameter of study area

After getting the steady flow field as shown in Fig. 8, the study needs to inverse a fitting model to validate the flow field. It can be a comprehensive and objective evaluation area by the actual hydrogeological conditions. The characteristics of the model inversion were done by using an evaluation engineering survey and borehole water level measured points. Hydrogeology surveys of measured data use the PEST (Parameter ESTimation) for the parameter estimation module. Each layer of the model K_{xx}, K_{yy}, K_{zz}, infiltration coefficient has in total of six groups of hydrological parameters,

Table 4
Pb pollution halo migration result

Leakage after the year	Migration distance (m)	Contaminated area (m^2)	Vertical diffusion maximum distance (m)	From the east boundary model
1	40.7	1,960.2	18	85.2
30	95.2	6,676.4	76	26.6
50	99.5	7,372.7	78	21.4

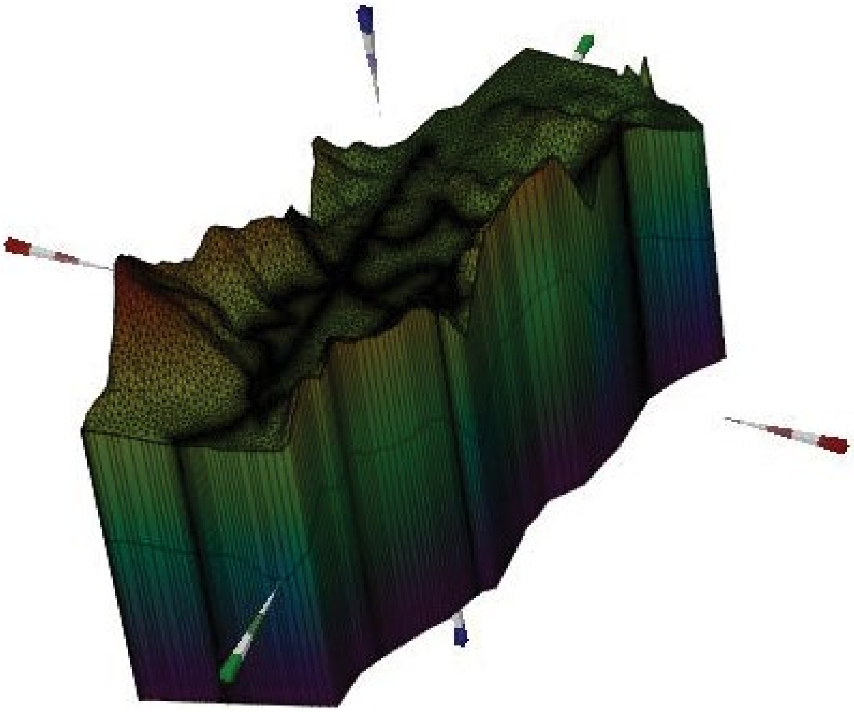

Fig. 6. Evaluation area grid subdivision and two-dimensional subdivision model structure.

by calculation of the resulting optimal. The hydrogeological parameters are shown in Table 6.

Based on optimal inversion parameters are evaluated the district head distribution of the natural groundwater flow field. The simulated water level, lead and zinc backfilling library engineering geological exploration hole, a total of seven analyses fitting the measured water level. The water level of drilling simulation and actual drilling levels were in comparison. As shown in figure diagrams on top, the seven basic evenly distributed simulation values near the line. The reaction between the simulation value and the actual value of the overall trend is consistent. The line above the water level point said analogy value slightly higher than the actual value. The line below the water level point said simulation value is slightly lower than the actual value. And all values basic distribution within the 90% confidence interval can be thought of simulated value. The actual value fitting condition is good. The figure of natural flow water fitting drawings clearly the reflection of overall change rule consistency. The simulated value and actual value by analyzing the fitting, it proved that the simulated groundwater steady flow model is established in line with hydrogeological conditions. In the study area, reflect on the basic flow field a characteristic of the groundwater system is showed in the model.

4.5.2. Solute transport model parameters

The solute transport increases with time and the space medium dispersion degree. The solute transport distance and research problem scale increases by hydrodynamic dispersion phenomenon. In present, people tend to be more consistent view in that field under the condition of a medium inhomogeneity caused by indoor test results with a huge difference from the results of the field experiment.

Water power diffusion scale effects exist in the modeling and prediction in groundwater agents in the media of the movement patterns difficult. The Agent movement model pores in media diffusion. The identification of the principal-agent was based on field diffusion test calculations. The ground diffusion coefficient is mainly based on Geihar

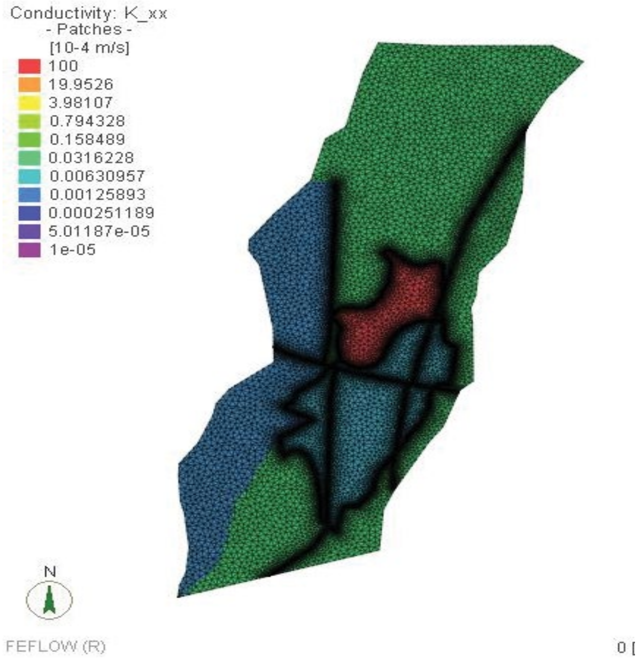

Fig. 7. Evaluation of hydrogeological parameters of the district.

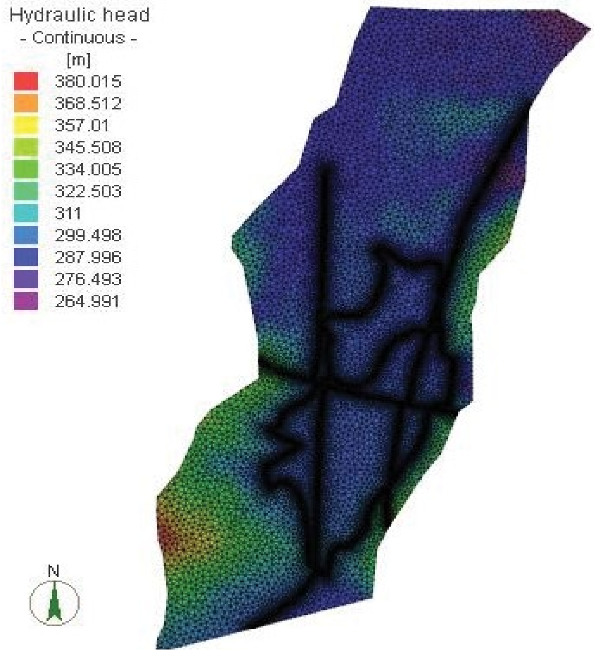

Fig. 8. Layer aquifer in the steady flow field.

etc. (1992) for the world within the collection of 59 major regional diffusion data analyzed. According to the conservative principles, ultimately determine the agent movement model parameters.

4.6. Groundwater environmental impact protection measures

4.6.1. Mining groundwater environmental mitigation measures

Mainly pits filled with water aquifer in JA bridge-group karst fissures aquifers. The mining and mining of groundwater have been fundamental alienation, further in-depth mining will increase groundwater and dry. Therefore, should take the following measures:

- In the mining areas within groundwater monitoring points, the mining aquifer water table changes in monitoring time.
- The hopper landed within the original, the use of groundwater as a production and the life of local residents, to address their living water used for production.
- According to the development of programs and the mining block picking, the mine after the mining area with a waste rock to fill, mining server, the empty area will all be filled, and the damage, the aquifer structure has a role in compensating for groundwater levels of recovery.

4.6.2. Lead and zinc tailings the groundwater pollution monitoring program

The groundwater environment must be dynamic long-term monitoring. According to the foregoing research, the Factory location is very favorable for pollutant source and migration characteristics. Compared with groundwater modeling analysis results, the site surrounding was implemented the long-term monitoring holes. The groundwater monitoring whole locations are shown in Fig. 9. For the site's impact on groundwater, the monitoring of water dynamics and water quality was necessary. In the foregoing analysis, groundwater is an existing condition of the effects of pollution. And now the groundwater qualities have part

Table 5
Evaluation area hydrogeology parameter initial value table

Parameter	Karst fissure aquifer	Bedrock fissure aquifer	Quaternary system
K_{xx} (10^{-4}m/s)	2E-02	4E-05	1E-03
K_{yy} (10^{-4}m/s)	2E-02	4E-05	1E-03
K_{zz} (10^{-4}m/s)	2E-03	4E-06	1E-04
Specific yield	0.3	0.01	0.1
Storage coefficient	2E-04	E-05	2E-05
Rainfall infiltration coefficient	0.4	0.03	0.2

Table 6
Optimal hydrogeological parameter table

Parameter	Karst fissure aquifer	Bedrock fissure aquifer	Quaternary system
K_{xx} (10^{-4}m/s)	5E-02	4E-04	4E-03
K_{yy} (10^{-4}m/s)	5E-02	4E-04	4E-03
K_{zz} (10^{-4}m/s)	5E-03	4E-05	4E-04
Specific yield	0.1	0.025	0.025
Storage coefficient	E-04	E-04	2E-05
Rainfall infiltration coefficient	0.2	0.025	0.05

Table 7
Solute transport parameters

Parameter	Karst fissure aquifer	Bedrock fissure aquifer	Quaternary system
Longitudinal dispersity (m)	120	60	10
Transverse dispersion degree (m)	12	6	1

of indicators beyond the groundwater III such standards [14]. But on the whole, is quite good. Mining exploitation in groundwater systems had a certain impact on the whole tailing zones.

4.6.3. Groundwater monitoring bores

Water Level, water quality monitoring frequency: Water general monthly three times monitoring, respectively, in each month on the 1, 11 and 21. The water quality was in general quarterly. Monitoring parameters are including temperature, pH, COD, Mn and SO_4^2. The lead and zinc mine tailings the drainage on-site sample test results are available. The most serious of the three indicators (Hg, SO_4^{2-} and Mn) were mentioned as analogy indicators. The concentration of Hg is 0.0096 mg/L; the concentration of SO_4^{2-} is 103.3913 mg/L; the concentration of Mn is 2.668 mg/L.

4.7. Remediation and prevention of water pollution problems in mining areas

4.7.1. Using bactericide

Anionic surfactants are used to control bacteria that catalyze the conversion of Fe^{+2} to Fe^{+3} and SO_4^{2-} to S^{2-} which can thereby control pyrite oxidation. If the decision to use bactericides as an integral part of water quality control is made during the design and permitting phases of mining, the total capacity of a water treatment system could be reduced, resulting in considerable saving in up-front capital expenditures. Bactericides are often liquid amendments, which can be applied to refuse conveyor belts or sprayed by trucks on cells of acid-producing materials in the backfill. Bactericides have also been used at metal mines [15]. Surfactant was applied via a hydro seeders at rates of 225 kg/ha initially, then successive amounts were made as fresh deposited. Effluent from the pile showed a 79% reduction in acidity and an 82% decrease in Fe. Surfactants, by themselves are not seen as a permanent solution. Eventually the compounds either leach out of the rock mass or are decomposed. However, slow-release formulations are commercially available and have been successfully used at regraded sites [16].

4.7.2. Microalgae bioremediation for wastewater treatment

The nutrients removal efficiency is up to 80% and nearly 50% metal removal for plant of green microalgae in wastewater. The removal of heavy metals and sulphates by algae is very flexible. It depends on the metal type, the taxon and age of material [17]. Optimum heavy metals and contaminants removal vary with season type [18,19]. Seasons of the year can highly influence the contaminants removal because of parameters such as light and temperatures. Algae are very sensitive when it comes to parameters related to seasons such temperature and light intensity. The absorbency and adsorbency mechanisms are commonly used by algae species to remove nutrients, heavy metals (depending on the specie type) and other minerals from wastewater.

While these elements are removed from wastewater algae growth takes place because species need also nutrient elements to grow. Some are taken by the surface and others taken into the inner cells. According to a researcher, algae in aqueous solutions are very effective for the removal of a low concentration of metal [21].

4.7.3. Wastewater treatment plant

The wastewater treatment plant was processed by the selection of some backwater supernatant before the plant. The rest of the tailings into the existing iron polymetallic plant are back after treatment. It is about 7,294 m^3/d of total return for the processing plant. The iron tailings wastewater treatment station has been expanded to 15,000 m^3/d. The iron tailings wastewater treatment can purify about 7,706 m^3/d of wastewater which mean have limited impact groundwater environment [31].

Table 8
Groundwater monitoring bores in the list

Serial number	Location	*Xy*	Monitoring target
*S*1	Tailings South of the drilling Zk53	3,69,626 2,842,135	Water quality + Water level
*S*2	Tailings North of the drilling Zk1	3,69,907 2,842,528	Water quality + Water level
*S*3	Six springs pool	3,70,207 2,842,474	Water quality
*S*4	Well dairies residents	3,70,302 2,842,730	Water quality + Water level
*S*5	Wo Mau village springs	3,70,102 2,843,777	Water quality
*S*6	Xiàojiāquán point	3,70,402 2,844,050	Water quality

Table 9
Summary on use of some species in acid mining drainage bioremediation [20]

Algal species	Remediation role	Achieved results	Growth method	Reference
Blue-green algae cyanobacterial mat	–	Removal of 2.59 g of Mn/d/m^2	Oxidation pond	[22]
Spirulina sp.	Metal adsorption, realkalization, nutrient for SRB (dead biomass)	Removal of Fe (up to 100%), Zn (86%–98%), Cu (38%–76%), Pb (40%–78%) at retention time of 10 d Rise of pH from 3 to 8.5 for a biomass loading of 3 mg/mL chlorophyll a	HRAP (high rate algal pond)	[23]
Spirulina sp.	Alkalinity generation and metal precipitation	pH rise from 1.8 to 8.18 Reduction of sulfates (SO_4) 89%, Fe 99%, Pb 95%, Zn 93%, Cu 94%.	Bench scale anaerobic digester, primary and secondary treatment	[24]
Mixed algal population	Soluble EPS as carbon source for SRB	Up to 57% of sulphates (SO_4) and 52% COD removal by mixed SRB	High rate algal pond (HRAP)	[25]
Eunotia exigua and *Pinnularia obscura*	Primary production	Chlorophyll a (Chl a) content 52–72 mg/m^2	Mining lake	[8]
Spirulina sp.	Dead biomass as nutrient for SRB	150 mg SO_4 removal/g algal biomass/d	Bench scale anaerobic up flow reactor	[26]
Blue-green algae (predominantly *oscillatoria* spp.) microbial consortium	SO4 removal, metal precipitation by consortium	pH increase from 2.93 to 6.78 Reduction of SO_4 29%, Fe 95%, Pb 88%, Zn 86%, Cu 97%, Co 83%, Ni 62%, Mn 45%	Bench scale test cell	[27]
Chlorella ellipsoidea	Bioremediation potential	–	In situ test using limnocorrals	[28]
Eunotia exigua and *Chlamydomonas* sp.	Enhance primary production thereby SRB growth	Reduction of Fe from 14 to 0.2 mg/L and SO_4 from 344 to 124 mg/L	Microcosm experiment	[29]
Ulothrix	Metal absorption	Absorption of Cu 3,500 mg/L, as 500 mg/L	Acid mining drainage, Sar Cheshmeh copper mine	[30]

4.7.4. Reuse of the mining wastewater

A pilot study was completed in Xinmin Village. Six plots of 50 m^2 each were planted with two types of plant species (*Zea mays* spp. and *Medicago lupulina* spp). The irrigated using three types of water (fresh groundwater, mine wastewater, and hydride water consisting of 50% fresh and 50% mine wastewater) to investigate the suitability of utilizing mine wastewater for food production in the area [32].

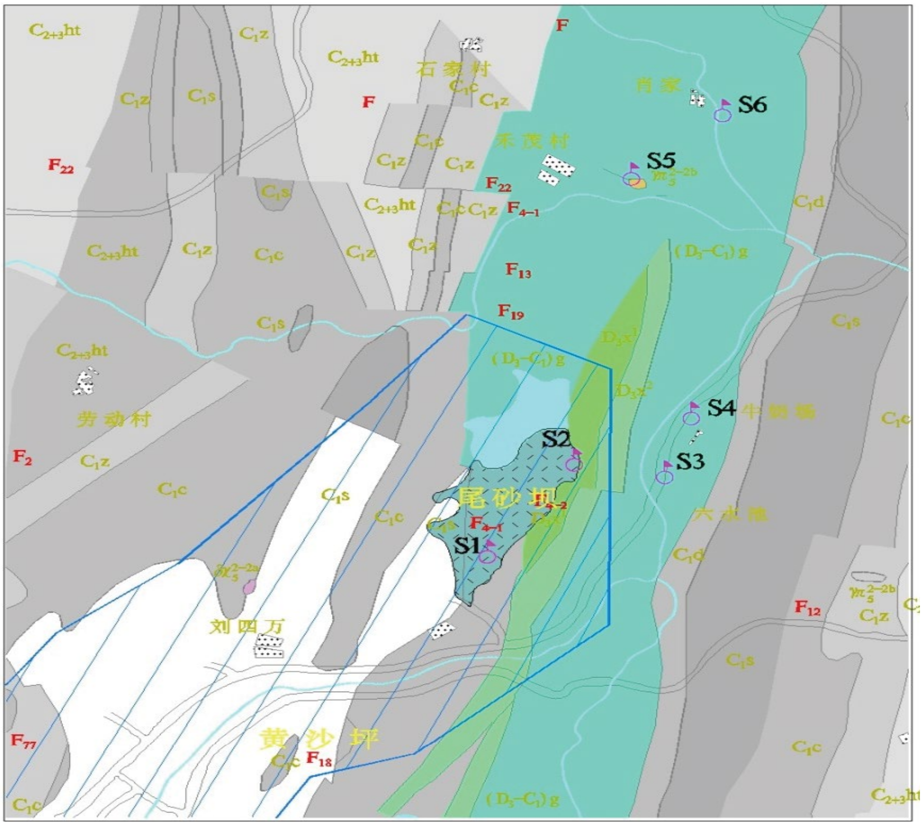

Fig. 9. Groundwater monitoring status bit map.

Fig. 10. Reused of mining wastewater in agricultural activities in Xinmin Village.

Plots irrigated with mine wastewater showed slightly higher heavy metals concentrations and soil salinity during the experiment period was higher for plots irrigated with mine wastewater compared to plots irrigated with fresh water, and it was uniform through the upper 45 cm of the soil profile due to the high amount of irrigation water used during the experiment. Crop yield was inversely proportional to salinity as an increase of salinity by two-folds resulted in reducing yield by almost 50%. However, no risk of heavy metals contamination was found in plants and soil [33–35].

5. Conclusion

Huangshaping mining karst areas environmental have been affected by mining exploitation. The iron tailings zones have a limited impact groundwater environment. But the lead and zinc mine tailings drainage are favorable to contamination. There are sources of pollutants accounted for in Huangshaping: life sewage wastewater, beneficiation production wastewater, gushing water, sewage industrial sites producing, processing waste, tailings wastewater, rainwater and other venues. These mining pollutions have negative impacts on the geological environment and groundwater quality specifically surface water. The circulation of underground water is very poor. Aquifer water tables were changes. Natural geological structures are in serious destruction. In tailing zones, the contaminants were strictly controlled. But these places were also polluted because pollutants moved in the pathway following water inflow from south to the north part. The problem was a mining wastewater dispersion touch domestic water use by the population in the surrounding village. They didn't know about the situation at the time of the study.

Due to these effects negative impacts of pollution in studied mining karst groundwater, this research applied Mining groundwater environmental mitigation measures to evaluate contamination spread. As seen in the groundwater environment impact scenario, the contaminant's migration distance in the area has become more and faster than before. The largest migration distance was respectively within 40.7 m (50 y ago), 95.2 m (30 y ago), 99.5 m at this time. After the evaluation of that problem, the research takes responsibility to informed the population since the situation affected their lives directly. Lead and zinc tailings the groundwater pollution monitoring program to control pollution in karst groundwater. Parameters considered are temperature, pH, COD, Mn and SO_4^{2-} in lead and zinc mine tailings the drainage zone. The most serious of the indicator are Hg, SO_4^{2-}, Mn and have concentration respectively Hg = 0.0096 mg/L; SO_4^{2-} = 103.3913 mg/L; Mn = 2.668 mg/L which are after monitoring.

To remediate and prevent water pollution problems in mining areas, bactericide technology was used to catalyze the formation of acid mining. Wastewater treatment by using microalgae culture plants also applied to treat iron, lead and zinc tailing wastewater. Suspend solids removal efficiency up to 80% and nearly 50% for metal removal for a plant of green microalgae in wastewater. The iron tailings wastewater treatment station can purify about 7,706 m^3/d of wastewater. The reuse of mining wastewater by agricultural activities followed by environmental education continuous and in the long-term was necessarily adopted. Reuse of hydride water consisting of 50% fresh and 50% mine wastewater was used for food production in the area. Crop yield was inversely proportional to salinity as an increase of salinity by two-folds resulted in reducing yield by almost 50%. However, no risk of heavy metals contamination was found in plants and soil.

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