Vinnytsia National Technical University

Faculty of Construction, Civil and Environmental Engineering

Department of Ecology, Chemistry and Environmental Protection Technologies

MASTER THESIS

«Environmental safety of mine wasteland remediation»

Student of 2ТЗД-21м group
specialty 183 "Environmental protection technologies"
Wang Haiyan Haiyan
Supervisor: Prof R. Petruk
«20» 06 2024
Reviewer: PhD, Dr. T. Titov
«20» 06 2024

Accepted for defense
Head of the Department ECEPT
Dr. V. Ishchenko
«20» червня (06) 2024

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INDIVIDUAL TASK

Vinnytsia National Technical University
Faculty Construction, Civil and Environmental Engineering
Department Ecology, Chemistry and Environmental Protection Technologies
Level of study II (master)
Field of knowledge – 18 "Production and technologies"
Specialty –183 "Environmental Protection Technologies"
Study program – "Environmental Protection Technologies"

APPROVED
Head of the Department ECEPT
Prof. V. Petruk
21.09 2022

TASK
FOR MASTER THESIS

Wang Haiyan

1. Topic «Environmental safety of mine wasteland remediation»
supervisor Vitalii Ishchenko
approved by the order of VNTU on «14» 09 2022 No. 203

2. Deadline for thesis subsmission – 20.06.2024

3. Input data: iron ore reserves of China as of 2021 are 16.124 billion tons.

4. Content:
Introduction
1. Overview of China's mineral resources
2. Adverse impact of mining on the environment
3. Smart mine safety management model and system
4. Mine reutilization for environment restoration
5. Economic effectiveness of environmental measures
Conclusions
References

5. Illustrations
1. Evaluation index system of mine ecological environment protection and restoration
2. Standard 3D Framework Structure of Smart Mine
3. Schematic diagram for blasting leveling of residual hillock

4. The process diagram of tailwater collection and utilization treatment plant

6. Consultants

Chapter	Name and title of the consultant	Signature	
		task is assigned	task is accepted
5 Economical feasibility of environmental measures	Alla Kraevska	[signature]	[signature]

6. Data of task acceptance "21" 09. 2022

CALENDAR PLAN

No.	Stages of master thesis	Deadline	Notes
1.	Technical task	30.09.2022	виконано
2.	Literature review	08.10.2022	виконано
3.	Overview of China's mineral resources	15.10.2022	виконано
4.	Adverse impact of mining on the environment	15.11.2022	виконано
5.	Smart mine safety management model and system	25.11.2022	виконано
6.	Mine reutilization for environment restoration	20.12.2022	виконано
7.	Conclusions, literature list		

Student Haiyan (signature) Wang Haiyan

Supervisor [signature] (signature) R. Petruk

ABSTRACT

UDC 504.054

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English language. Bibliogr.: 19 references; 24 figures;16 tables.

China has a relatively complete range of mineral resources, continuously rich geological resources and in-depth social services. Mine ecological restoration and green development have been steadily promoted, and new progress has been made in the construction of ecological civilization in the mining sector. Promoting mine ecological restoration and treatment will still be an important environmental treatment issue in the future. In this work, methods of environment restoration for mine wastelands are analyzed.

Keywords: environment, pollution, ecological restoration, mining, mine wasteland

SUPERVISOR'S REVIEW OF MASTER THESIS

Wang Haiyan «Environmental safety of mine wasteland remediation»

The problem of reclamation and restoration of mining areas is extremely urgent and will continue to gain importance over time. Territories disturbed by mining exist in all countries of the world without exception, which leads to the disruption of connections in ecosystems, their simplification, and a decrease in their stability. Finding ways to reduce the negative impact on the environment during mineral extraction and after extraction is an extremely urgent task.

The master's thesis thoroughly analyzes the current situation of scientific research in the reclamation and restoration of ecosystems destroyed by mining, including China. The mechanisms of combating soil pollution by mining (conditions, factors, etc.) were analyzed. Mechanical and biological reclamation methods with minimal capital investment and maximum efficiency were investigated in the work.

In addition, it should be noted that measures have been developed to reduce mining through more efficient extraction of minerals from ore.

The master's thesis is written at a high level and has scientific and practical relevance. Master Wang Haiyan completed all tasks on time. Therefore, I recommend rating the master's thesis at "A".

Scientific supervisor,
DSc, Professor of the Department of Ecology,
Chemistry and Environmental Protection Technologies Roman PETRUK

MASTER THESIS REVIEWER'S REPORT

Student: Wang Haiyan

Thesis title: Environmental safety of mine wasteland remediation

Developments in the field of reclamation and restoration of lands damaged by mining activities are an urgent task.

The output data is quite enough to do the job. Practical recommendations and conclusions are well-founded. The work includes a multifaceted analysis of the research object (tables, figures, formulas).

The adopted decisions are sufficiently substantiated, environmental safety factors are taken into account.

Environmental safety of mine wasteland remediation was analyzed in the master's qualification work, and measures to increase environmental safety during the production of mining products, their storage and transportation were developed.

Master thesis has practical use and a sufficient cognitive and educational level.

Model computer programs were used to perform the work. The explanatory note is drawn up in accordance with current standards, decisions and recommendations are well-founded. The illustrative material presented in this work reflects the main content of the work, designed according to current standards and corresponds to the object of the study.

The master thesis has practical value, as it contains analytical studies on the safety of mining production processes for the environment, which makes it possible to increase the environmental safety of such enterprises and develop a number of recommendations.

The following shortcomings can be noted in the master thesis:

- For a more detailed study of the problem of reclamation of contaminated soils, several model objects should be used;

The master thesis as a whole was performed at a high level and deserves an excellent rating.

Reviewer,
Ph.D., Associate Professor of the
Department of Ecology, chemistry and
environmental protection technologies

Taras TITOV

CONTENT

INTRODUCTION

Relevance. Mineral resources are indispensable natural resources for human survival. People's mining and development of mining areas release a large number of pollutants, resulting in man-made pollution. In the past 10 years, with the development of science and technology and the unprecedented large-scale mining of mineral resources, the problem of mine pollution has become increasingly serious, and many disadvantages of development have emerged. The initial concern for economic interests has caused serious damage to the ecological environment, forcing us to reflect on the ecological environment and pay attention to the important role of the ecological environment in development. Therefore, after mining, how to effectively repair the mine and how to play the value of the remaining mine is a problem worth pondering.

Connection of master thesis with scientific programs, plans, topics. The master thesis was prepared according to research area of the Department of Ecology, Chemistry and Environmental Protection Technologies in Vinnytsia National Technical University.

The goal of master thesis is to assess environmental impact of mining industry in China and to analyze the methods of mine wasteland restoration.

Tasks of master thesis:

1. Introduction to China's mineral resources
2. Adverse impact of mining on the environment
3. Smart mine and digital mine safety management mode
4. Mine recycling and environment restoration in China

Object of the research – environmental impact of mining industry.

Subject of the research – environment restoration of mine wasteland.

Novelty of the results. Further development of scientific substantiation of environmental restoration methods for mine wastelands. This helps to reduce the environmental impact of mining industry.

Practical value includes preparing the recommendations on reducing the negative impact of mining industry through mine wasteland remediation.

Approbation of research results. Results of the master thesis were presented at LII Conference of Vinnytsia National Technical University.

Publications. The materials of this master thesis were published in:

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1 OVERVIEW OF CHINA'S MINERAL RESOURCES

China is rich in vast territory and natural resources. Many mineral resources rank first in the world. For example, China still ranks first among the proven rare earth reserves, accounting for 43% of the world's total reserves of 210 million tons. China's rare earth output accounts for nearly two thirds of the total international output. In 1999, China exported 50000 tons of rare earth and consumed 16000 tons domestically. The total output of the two items was 66000 tons, and the global consumption of rare earth in that year was 75000 tons. Therefore, China provides 88% of the rare earth needed by the world, and China's rare earth mainly comes from Baotou [1].

1.1 Tungsten

Dayu County is located in the south of Jiangxi Province, in the upper reaches of Zhangshui River, the west source of Ganjiang River. It covers an area of 1368 square kilometers and has a population of 243000. The county has a long history. In the Qin Dynasty, it belonged to Nangao County, in the Sui Dynasty, it belonged to Nankang County, and in the Tang Dynasty, it belonged to Dayu County. After the Song Dynasty, he served as Nan'an Army, Lu and Fu. It was changed to Dayu County in 1957. It is named because it is located at the north foot of Dayu Mountain. Dayu County is rich in tungsten resources, known as the "City of Tungsten", and the largest tungsten mining base in China. Use: Tungsten, a metal element, is hard and brittle crystal, resistant to high temperature and widely used. It is an important raw material for steel, electrical appliances, chemical industry and national defense industry. Especially in recent years, tungsten has shown its important role in the field of cutting-edge science and technology. China is the country with the largest tungsten reserves and output, and is known as the "tungsten producing kingdom". According to relevant data in 1977, China ranks first in the world's tungsten reserves, accounting for 53.6% (Fig. 1.1)

Figure 1.1 – Location map of tungsten mines in China

1.2 Tin

Located in the southwest border of China, it is famous at home and abroad for its long history of tin ore development (more than 2000 years), rich reserves, advanced smelting technology and high purity of refined tin, and enjoys the reputation of "Tin Capital". After the founding of New China, 1.92 million tons of non-ferrous metals were produced, including 920000 tons of tin, accounting for more than 70% of the national tin output. It is the largest tin modern production and processing base in China. Application: Tin is mainly used to produce tinplate and various alloys in metallurgical industry. Tin plate is the main consumption area of tin, accounting for about 40% of tin consumption. It can be used as containers for food and beverages, various packaging materials, household appliances and dry battery shells. Tin is mainly used in chemical industry to produce tin compounds and chemical reagents. The organic compounds of tin are mainly used as wood preservatives and pesticides, while the inorganic compounds of tin are mainly used as catalysts, stabilizers, additives and emulsifiers in the ceramic industry.

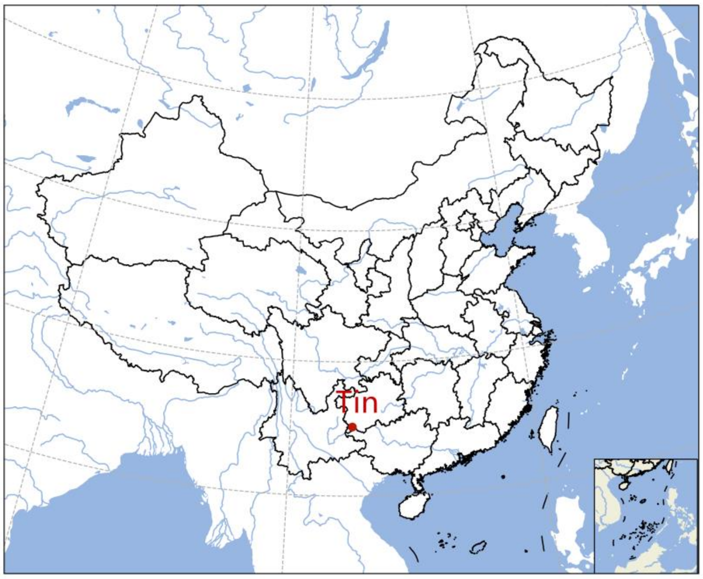

Figure 1.2 – Location map of tin mines in China

1.3 Zinc

The mineral resources of Lanping are advantaged and have long been famous at home and abroad. At present, the proven and discovered mineral deposits include more than 10 kinds of lead, zinc, copper, silver, salt, chromium, mercury, antimony, sulfur, iron, gypsum, mica, pyrophyllite, iceland stone, crystal stone and more than 150 ore deposits. Among them, Jinding Fenghuangshan super large lead-zinc mine ranks the first in the country and the second in the world for its large reserves, high grade, concentrated mineralization and easy mining, with a reserves of 14.29 million metal tons and a potential value of more than 200 billion yuan. Use: Zinc has good calendering, corrosion resistance and wear resistance, and is the third important non-ferrous metal among the 10 commonly used non-ferrous metals. At present, zinc is second only to copper and aluminum in the consumption of non-ferrous metals, and is widely used in non-ferrous, metallurgy, building materials, light industry, electromechanical, chemical, automotive, military, coal and petroleum industries and departments.

Figure 1.3 – Location map of zinc mines in China

1.4 Nickel

Jinchang Nickel Mine is located in the north of Yongchang County, Hexi Corridor, Gansu Province. The Longshoushan deposit is a rare nickel dominated nonferrous metal intergrowth deposit in the world, which is rich in nickel sulfide, copper, cobalt, gold, silver and platinum group metals. After the Jinchang Nickel Mine was put into operation in the 1960s, the history of no nickel production in China ended, making China one of the countries with the largest nickel resources in the world. Now Jinchang Nickel Mine has built a large-scale joint enterprise with comprehensive operation of mining, dressing and refining, which can directly extract more than ten kinds of products from ores, of which nickel and platinum group metals account for more than 85% and 90% of the national total respectively. Jinchang has become the largest nickel production base in China, the refining center of copper, cobalt, gold, silver and platinum group metals, and is known as the "Nickel Capital of China".

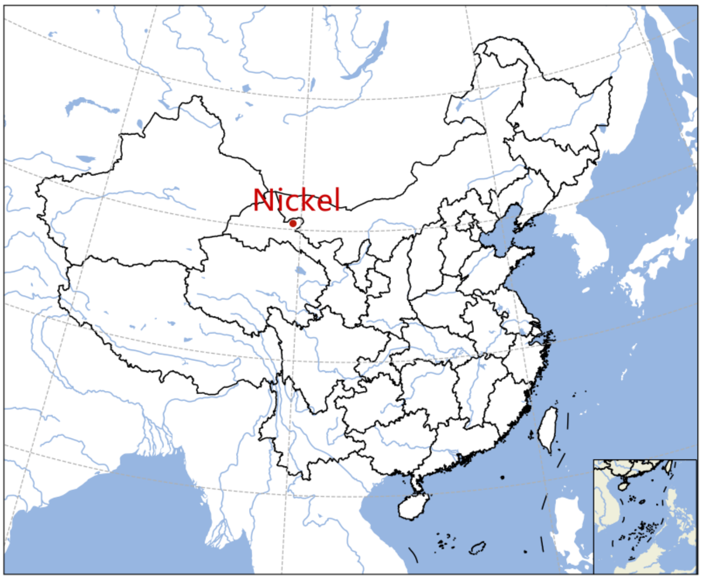

Figure 1.4 – Location map of nickel mines in China

1.5 Antimony

At the end of the Ming Dynasty (1541), Hunan Tin Mine, the largest antimony mine in the world, was discovered, but antimony was mistaken for tin at that time, so Tin Mine got its name from this. It was known to be antimony after testing in the 16th year of Guangxu (1890) of the Qing Dynasty. In the 23rd year of Guangxu's reign (1897), the "Jishan" factory was founded as the earliest antimony refinery in tin mines, which turned China's "continuous tin" into an era of antimony production. In 1908, Hunan Huachang Company introduced the volatile roasting method from France and began to refine antimony with this method. With the rise of machinery manufacturing industry, the use and demand of antimony have expanded. Following the development of tin mines, antimony mines in Banxi, Taojiang, Xinshao, Longshan, Taoyuan, Woxi and other places have been successively developed, making Hunan's antimony industry top in the country. Then, Guizhou, Yunnan, Guangxi and other provinces and regions also successively exploited some antimony ores. In the decades since 1908, China's antimony production has often accounted for more than 50% of the world's total output. Only the output of antimony products in tin mines from 1912 to 1935 accounted for 36.6% of the world's output, accounting for 60.9% of the national output. Application: Antimony is a silver gray metal, which is an acid resistant substance at room temperature. Its specific gravity is 6.68, melting point is 630.5ºC, and boiling point is 1590ºC. It is brittle and has no ductility. It is a poor conductor of electricity and heat. It is not easy to be oxidized at room temperature and has corrosion resistance. The main role of antimony in alloys is to increase hardness, which is often called the hardener of metals or alloys. Antimony and antimony compounds were first used in wear-resistant alloys, printing type alloys and the arms industry. With the development of science and technology, it has been widely used in the production of various flame retardants, enamel, glass, rubber, coatings, pigments, ceramics, plastics, semiconductor components, fireworks, medicine and chemical products.

Figure 1.5 – Location map of antimony mines in China

1.6 Molybdenum

China is rich in molybdenum resources. By the end of 1999, China's total molybdenum reserves were 8.336 million tons, ranking second in the world. China has an annual output of nearly 30000 tons of metal molybdenum, ranking second in the world. There are 222 molybdenum mines, distributed in 28 provinces (districts and cities). Mainly Jilin Daheishan; Yangjiazhangzi, Lanjiagou, Liaoning; Jinduicheng, Shaanxi Province; Molybdenum ores in Luanchuan, Henan Province. Henan Province is the richest in molybdenum resources, with molybdenum reserves accounting for 30.1% of the total national reserves Application: Pure molybdenum wire is used for high temperature electric furnace, electric spark machining and wire cutting; Molybdenum sheets are used to manufacture radio equipment and X-ray equipment; Molybdenum is resistant to high temperature ablation. It is mainly used in the manufacture of gun bore, rocket nozzle and tungsten wire bracket of electric bulb. Adding molybdenum to alloy steel can improve the elastic limit, corrosion resistance and maintain permanent magnetism.

Figure 1.6 – Location map of molybdenum mines in China

1.7 Coke

Qitaihe City is located in the east of Heilongjiang Province, with a total area of 6221 square kilometers. It now governs 21 towns and townships in Taoshan District, Xinxing District, Qiezihe District and Boli County, with a population of 860000. Qitaihe City is rich in natural resources, with more than 30 kinds of proven metal and non-metallic mineral deposits. Among them, coal is one of the three major protective mining coalfields in China, with proven reserves of 5.26 billion tons and retained reserves of 1.7 billion tons. It has become an important national main coking coal production base and the largest anthracite production base in northeast China.

Figure 1.7 – Location map of coke mines in China

1.8 Phosphorus

Jinning County is famous for its phosphate rock resources with large reserves (800 million tons of proven reserves), shallow burial, concentrated ore bodies, good quality, good processing performance, and easy mining, and is known as the "Phosphorus Capital of China". Application: phosphate rock is also an important chemical mineral raw material. Part of the phosphate rock is used to produce pure phosphorus (yellow phosphorus, red phosphorus) and chemical raw materials, and a small amount is used as animal feed. Red phosphorus is used to make matches and phosphides. Yellow phosphorus is highly toxic and can be used to make pesticides, as well as incendiary bombs, tracer bombs, signal bombs, smoke bombs and incendiary agents; Phosphorus and phosphides of boron, indium and gallium are used in the semiconductor industry. In metallurgical industry, it is used for refining phosphor bronze, phosphorous pig iron, cast iron, etc. Zirconium phosphate, titanium phosphate, silicon phosphate, etc. can be used as coatings, pigments, adhesives, ion exchangers, adsorbents, etc. Sodium phosphate and disodium hydrogen phosphate are used to purify boiler water. The latter can also be made of rayon. Sodium hexametaphosphate can be used as water softener and metal preservative, calcium phosphate is used as animal feed additive, and phosphorus derivative is used in medicine. Aluminum dihydrogen phosphate adhesive material has high fire resistance, good impact resistance, strong corrosion resistance and superior electrical performance, and is used in cutting-edge technologies. Fluoroapatite crystal is the most ideal laser emission material, and phosphate glass laser has been applied.

Figure 1.8 – Location map of phosphate mines in China

1.9 Talc

There are 51 kinds of proven mineral resources in Anshan. The proven reserves of iron ore are 10 billion tons, accounting for one fourth of the country. The proven reserves of magnesite are 2.3 billion tons, accounting for 80% of the national reserves and one fourth of the world reserves. The proven reserves of talc ore are 60 million tons, accounting for 40% of the whole country. Xiuyan Jade, with the proved reserves of about 2060000 tons, accounting for 60% of the world's total, has been identified as the first candidate stone for China's "national stone". In December 2006, Xiuyan County was named as the "Jade Capital of China" by the China Mining Association. Use: Talc is a common silicate mineral, which is very soft and has a greasy feel. Ten minerals have been selected to represent ten hardness levels, called Moss hardness. Among the ten levels, the first (that is, the softest) is talc. Soft talc can replace chalk to draw white marks. Talc is generally in block, leaf, fiber or radial shape, and its color is white or gray, and it will have various colors because of other impurities. Talc has many uses, such as refractory, paper making, rubber filler, insulating material, lubricant, pesticide absorbent, leather coating, cosmetic material and carving material.

Figure 1.9 – Location map of talc mines in China

1.10 Rare earth metals

The world's rare earth comes from the East, the East's rare earth comes from China, and China's rare earth comes from Baotou. Baotou's rare earth reserves account for 76% of the world's total rare earth reserves, making China an absolute "rare earth power" in the world. Baotou is also the world center of rare earth industry. Chinese rare earths account for the first place in the world: its reserves account for the first place in the world's total reserves, especially the medium and heavy rare earths, which are of great significance in the military field and are relatively scarce; The production scale is the first. In 2005, China's rare earth output accounted for 96% of the world's total; The export volume ranks first in the world. 60% of China's output is used for export, accounting for more than 63% of international trade. China is the only country in the world that supplies a large number of rare earth products of different grades and varieties.

Figure 1.10 – Location map of rare earth mines in China

2 THE ADVERSE EFFECTS OF MINING ON THE LOCAL ENVIRONMENT

Mineral resources are an important part of natural resources and an important energy source to promote the development of human society. With the rapid development of social economy, the mining of mineral resources is increasingly intense, which has caused serious damage to the ecological environment of the mining area, and even buried a huge hidden danger to the regional ecological security[2].

2.1 Subsidence of the mining area

Here, we first analyze several important causes of surface subsidence. In fact, surface subsidence is mainly affected by two factors: one is the geological condition of the mining area itself, which is the natural cause, and the other is the mining method used by the mining team, which is the human factor. From these two reasons, we can easily find the breakthrough of this kind of problem. From the natural causes, we can refine the two factors that affect the land subsidence in the mining area. The first is the mining thickness. Obviously, if the mining thickness is large, then we have to use a lot of other materials to fill the upper goaf. In this way, the surface morphology will be affected. The second is the mining depth, which is inversely proportional to the degree of surface deformation. This is because, while the surface moves more and more as the depth of the mine increases, the level of subsidence below the surface increases. The degree of control, so that the surface shape is relatively stable. The different mining methods chosen by the mining team not only affect the quality of the stone mined, that is, the quality of the ore produced, but also affect the settlement of the mining area to a large extent. Here, we take caving method as an example to illustrate: this method is suitable for long wall working face, and it is necessary to carefully select appropriate and scientific mining methods when using it. If there is no standard operation in the mining process, it may cause subsidence.

2.2 Waste water pollution problem

In many aspects of mineral mining, we use water resources. For example, it is necessary to dust with sprinkling water, and in the process of drilling, it is also necessary to inject a large amount of water. If a large amount of waste water produced in these processes is discharged at will without treatment, it will cause a certain harm. In the process of mining, many mining owners blindly pursue the maximization of economic benefits and ignore the treatment of wastewater. This harmful wastewater containing a large amount of heavy metal ions will not only flow into rivers, but also pose a threat to aquatic animals and plants in rivers.

Mine waste water, mine sending waste water, coal washing waste water and smelting waste water, collectively called mining waste water. The quality of mine wastewater may vary according to the geological conditions of the mining area, the types of ore deposits, the conditions of the tunnel, the operation mode, and the production process and technology. Generally speaking, it is characterized by high acidity, large concentration of suspended matter and high content of heavy metals. Acidic groundwater is a natural pollutant formed by oxidation and hydrolysis of sulfide metal minerals under natural conditions and during a long geological history. Due to the artificial mining development, the sulfide ore gets sufficient oxidation conditions, and the formation of acid water is accelerated on the basis of natural pollution. In addition to the sulfide ore wastewater in limestone area, the general sulfide ore wastewater has this characteristic. In Japan, the most acidic wastewater from a metal mine is from Matsuo Copper mine, with a pH of 1-2. In coal mines, because the coal seams themselves contain more pyrite components (for example, Taiyuan Series coal seams, most of which contain layered pyrite nodules, sometimes as high as 4%-6%), the underground coal mine wastewater also has high acidity. This acid water has a strong corrosive effect on metal equipment in mines. Workers exposed to acid water for a long time are prone to eye pain, itching, foot cracks and other diseases. If not treated, directly discharged into environmental waters or farmland, it will cause serious pollution to the environment. For example, the length of rivers polluted by coal mine acid in the United States has reached 16,000 km. In the metal mining area, the concentration of suspended matter is relatively large in the underground waste water with tailings as filler, beneficiation waste water, refinery waste water with fire smelting and wet dust collection, and coal washing waste water from coal mine, which contains a large amount of rock powder or coal powder, tailings, soot and micro powder. These suspended solids often contain high metal components, and acidic water has a strong ability to dissolve metal minerals, so the content of heavy metals in mine wastewater is relatively high.

At present, the heavy metal toxicants have been recognized by people, including mercury, cadmium, lead, zinc, nickel, cobalt, chromium, and uranium series, niobium series metals.

2.3 Solid waste pollution

There are a lot of solid wastes brought by ore mining, which mainly come from four sources: waste rock and tailings, which account for the largest proportion, and a large amount of dust produced in the process of mining. Shanxi Province is the most famous province for mining mineral resources. The accumulative quantity of mine solid waste in Shanxi Province alone can reach hundreds of millions of tons. Solid waste pollution is not only an important manifestation of the waste of mineral resources, but also has a serious impact on the ecological environment. For example, a lot of mine solid wastes without timely treatment are directly and randomly stacked on the surface, making many places with beautiful scenery become devastated and smoky. Solid waste can also contribute to soil erosion, worsening local soil quality and losing soil nutrients. In addition, solid wastes may be washed into the surrounding river by rainwater or waste water, and accumulate in the river, causing river congestion and affecting river water quality. In dry weather conditions, solid waste may also produce a large number of floating dust, dust, make the air quality worse.

Heavy metal pollution is a common problem in abandoned tailings of metal mines, and the content of heavy metals obviously exceeds the soil background value. For example, the total copper content of Dexing Copper mine in Jiangxi Province is

102 times higher than the local soil background value, 50 times higher than the soil environmental standard, and chromium exceeds the background value by 50%. Most heavy metal ions are not essential elements for plants. Cd, Pb, Hg, As, Cu and other heavy metal elements can not only prevent the normal growth of plants, but also cause harm to plant growth and development if the concentration exceeds the tolerance range of plants. For example, if Cu content exceeds 0.25 mg/L, it will inhibit the rooting, delay the germination of seeds, and even cause the death of seedlings.

Mine waste slag includes waste rock, tailings, smelting waste slag, ash slag of power plant in mine and household garbage, etc. Many metal mines, coal mines and non-metal mines, in order to build fast, low production costs, good working conditions, high ore recovery rate, safety and other reasons, open-pit mining is used, and the amount of waste rock stripped by open-pit mining is the largest. For example, the Siattari open-pit copper mine in the United States, in the infrastructure project to remove more than one billion tons of waste rock and soil, more than the Panama Canal excavation project. The amount of waste rock in open pit depends on the stripping ratio. China has a copper mine, according to open-pit mining, the production of 200 thousand tons of copper, the annual waste rock volume will be: 100 million tons. Pit mining has much less waste rock than open-pit mining, but the waste rock has a high metal content sometimes mixed with high-grade rich ore), and a large amount of waste rock stacked on the surface causes harm to the environment. It not only occupies a large area of land, but also pollutes the environment with acid wastewater containing heavy metals after long-term leaching by rainwater. Tailings is is the waste produced in the process of beneficiation, especially non-ferrous metal ore and rare metal ore, because of the low grade of ore, after beneficiation and separation, most of them are discharged into the environment in the form of tailings. Even if stored in the tail deposit, it is not the most suitable method, which has the following disadvantages:

1) After the storage of the tailings pond, the underground water level will be raised, resulting in secondary salinization of the upstream land, resulting in land desolation and forced relocation of villages.

2) After drying, the tailings fly in the wind and pollute the atmosphere, and the ash from the power plant is the same, so that the cultivated land near the tailings pond or ash pond is covered by a very thick layer of tailings powder or ash powder, which affects the growth of crops.

3) Pollution from smelting slag and domestic garbage. The environmental pollution of smelting waste slag is similar to the waste rock and tail dam mentioned above. Household waste will also bring organic pollution to the environment. In general mining areas, the clay overburden is relatively thin, and the leachate water is easy to infiltrate into the ground through rock cracks or karst caves, resulting in secondary pollution.

2.4 Radioactive contamination

The mining and smelting process of uranium and thorium ores and their associated mineral deposits will produce a large amount of radioactive waste water, waste gas, waste residue (waste rock and tailings). These radioactive "three wastes" can pollute the environment through various ways and bring potential harm. For example, in the early 1950s, due to the lack of understanding of the hazard of uranium tailings, the improper disposal of tailings resulted in serious pollution of the environment around some mines. Most uranium water smelting plants in the United States are built near rivers (mainly in the Colorado River Valley). Due to the lack of tailings storage facilities, the river is directly discharged into the river, resulting in extremely serious pollution and the extinction of aquatic life. Subsequently, the tailings dam (reservoir) was gradually built to store the tailings for a long time. However, in the late 1960s, tailings from the decommissioned URANIUM WATER smelting plant were used as building materials in Grand Junction, USA, causing extensive pollution. As a result, the indoor γ-radiation level in some of the 670 houses was more than 100 μm /h, which was 5 times of the general indoor γ-radiation level. Indoor radon progeny concentration exceeds the working level of 0.05, exceeding the background of more than 100 times. Finally, measures have to be taken to remove and rebuild, costing a lot of money. Because uranium tailings of harmful elements such as sodium compounds and nitrate can be over various ions in groundwater under the action of migrated to quite far, formed in the soil, uranium and radium diffusion halo, from the tailings in the range of 100 m deep within 1 km can observe uranium, radium, along with the food chain into the organism, finally transferred to the human body, cause harm to people.

3 SMART MINE SAFETY MANAGEMENT MODEL AND SYSTEM

3.1 Construction of evaluation index system for mine ecological environment protection and restoration

3.1.1 Principles of constructing indicator system

1) Scientific principle

Comprehensively and objectively reflect the possible ecological environment impact of mineral resources development on various environmental factors and the ecological system formed by them, and the ecological environment of the mining area that meets the standard after restoration and treatment. The indicators have clear meanings, standard calculation methods, and relatively independent functions.

2) Principle of integrity

The destruction of the mine ecological environment reflects the state of the entire mining area ecosystem. Therefore, the establishment of the protection and restoration management evaluation index system should consider the integrity of the system. It is necessary to select not only the specific indicators in each subsystem, but also the indicators that can reflect the state of the entire ecosystem.

3) Principle of comparability

It includes three meanings: first, regional comparability, that is, the indicator system can comprehensively reflect the ecological environment quality characteristics of the mining area in the country or the same region; Second, different mine types can be compared, that is, each index can reflect the commonness of ecological environment assessment of different minerals and different mining methods; The third is the comparability between indicators, that is, through normalization, the evaluation indicators of different orders of magnitude are within the specified value range.

3) Principle of comparability

It includes three meanings: first, regional comparability, that is, the indicator system can comprehensively reflect the ecological environment quality

characteristics of the mining area in the country or the same region; Second, different mine types can be compared, that is, each index can reflect the commonness of ecological environment assessment of different minerals and different mining methods; The third is the comparability between indicators, that is, through normalization, the evaluation indicators of different orders of magnitude are within the specified value range.

3.1.2 Construction of index system

The research on evaluation of mine ecological environment protection and restoration is a complex system involving human society, economy and natural ecology. There are many influencing factors in this large system, so representative and typical indicators should be selected to establish the hierarchy of evaluation indicator system. Therefore, taking Chengzhuang Coal Mine of Yangquan Yanniche Coal Industry Co., Ltd. as an example, this paper discusses the construction of the evaluation index system for the protection and restoration of the mine ecological environment. According to the specific situation and characteristics of Chengzhuang Coal Mine of Yangquan Yanniche Coal Industry Co., Ltd., a hierarchical framework evaluation model is established as shown in Figure 1. The evaluation model takes the mine ecological environment protection and restoration as the evaluation target layer (O); Take ecological environment protection, ecological restoration and management, and ecological monitoring capacity building as the overall objective evaluation criteria layer (A); Waste water treatment, solid waste treatment and flue gas dust raising place in the mining area The protection of water resources in the mining area is regarded as the four representative factors of ecological environment protection. The greening measures in the mining area, ecological restoration and treatment of subsidence fissure area, ecological restoration and treatment of abandoned wasteland, ecological restoration and treatment of waste rock field, and ecological restoration and treatment of borrow pit are regarded as the five representative factors of ecological restoration and treatment. The allocation of monitoring facilities, online monitoring of pollutant discharge, and monitoring of surface deformation subsidence fissure are regarded as the three representative factors of ecological monitoring capacity construction, The sub criteria layer (B) constituting the evaluation index system. After establishing the evaluation framework of mine ecological environment protection and restoration, 22 evaluation indicators were selected as the indicator layer, and the index system of mine ecological environment protection and restoration evaluation was constructed, as shown in Table 3.1.

Table 3.1 – Evaluation index system of mine ecological environment protection and restoration

Target layer O	Criteria layer A	Sub criteria layer B	Indicator layer C
			Domestic wastewater treatment rate C1
		Mine wastewater treatment B1	Domestic wastewater treatment rate C2
			Comprehensive disposal rate of production solid wastes C3
		Solid waste treatment B2	Boiler slag safety disposal rate C4
	Ecological environment protection A1		domestic waste disposal rate C5
		Treatment of flue gas and dust in mining area B3	Boiler flue gas desulfurization and dust removal compliance rate C6
			Compliance rate of production dust control C7
mine		Water resource protection in mining area B4	dust control rate of transportation C8
ecology			Compliance rate of surface water protection C9
environment			Compliance rate of environmental groundwater protection C10
protect		Greening measures in mining area B5	Greening rate of industrial square C11
And			Greening rate of dedicated road C12
recovery		Ecological restoration and control of subsidence crack area B6	greening rate of suitable forest land C13
government	Ecological restoration and management A2		Ecological restoration and control rate of historical subsidence crack area C14
		Ecological restoration and rehabilitation of abandoned wasteland B7	Recovery and control rate C15
			Recovery and treatment rate of village relocation site C16
		Ecological restoration and control of gangue yard B8	Ecological restoration and control rate of slope protection and top of gangue yard C17
		Ecological restoration of borrow pit Ecological restoration control rate of borrow pit B9	Ecological restoration of borrow pit Ecological restoration control rate of borrow pit C18
			Allocation rate of monitoring facilities C19
	Capacity building	Monitoring facilities equipped with B10	online monitoring rate of wastewater discharge after treatment C20
	of ecological monitoring A3	On line monitoring rate of pollutant emission B11	On line monitoring rate of pollutant emission B11 boiler desulfurization and dedusting C21
		Surface deformation and subsidence monitoring Surface deformation in B12	Monitoring rate of surface deformation and subsidence in mining area C22

3.2 Determination of weight of evaluation index for mine ecological environment protection and restoration based on analytic hierarchy process

3.2.1 Analytic hierarchy process

Analytic hierarchy process (AHP for short) is a qualitative and quantitative multi-objective decision-making analysis method proposed by T.L. Saaty, a famous American operations researcher at the University of Pittsburgh, in the early 1970s. The core of this method is to use the integer between 1 and 9 and its reciprocal as the scale to construct the judgment matrix for pairwise comparison.

3.2.2 Establish comparison judgment matrix and calculate weight

By referring to relevant literature and expert consultation, a judgment matrix is established and the weight W of each influencing factor is determined according to the influence degree of each factor index corresponding to the index of the previous level. The specific process is as follows: 1) Calculate the product of elements in each row of a half matrix, 2) Calculate the root n of Mi, 3) If Wi is standardized[3], 4) To find the maximum eigenvalue of the judgment matrix, 5) Conduct consistency test, that is, judge whether the ratio CR between the consistency index CI of the matrix and the average random consistency index RI (see Table 3.2) of the same order is consistent. When CR<0.1, the matrix has difficult consistency. Otherwise, correction is required. According to the above steps, the weights of each index determined by the final comparison judgment matrix are shown in Table 3.3 – Table 3.13.

Table 3.2 – RI values

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Table 3.3 – O-A Judgment Matrix

O	A1	A2	A3	W
A1	1	2	1/3	0.20976
A2	1/2	1	1/5	0.011149
A3	3	5	1	0.059125
λmax = 3.003967, CI = 0.001848, RI = 0.58, CR = 0.03187<0.1				

Table 3.4 – A1-B Judgment Matrix

A1	B1	B2	B3	B4	W
B1	1	3	3	4	0.273481
B2	1/3	1	1	3	0.113617
B3	1	1	1	2	0.100143
B4	1/4	1/3	1/2	1	0.051719
λmax = 4.062707， CI = 0.020902, RI = 0.90, CR = 0.023225<0.1					

Table 3.5 – A2-B Judgment Matrix

A2	B5	B6	B7	B8	B9	W
B5	1	1/2	4	3	3	0.239448
B6	2	1	7	5	5	0.734886
B7	1/4	1/7	1	1/2	1/3	0.016558
B8	1/3	1/5	2	1	1	0.045677
B9	1/3	1/5	3	1	1	0.053431
λmax = 5.073902， CI = 0.018476, RI = 1.12, CR = 0.016772<0.1						

Table 3.6 – A3-B Judgment Matrix

A3	B10	B11	B12	W
B10	1	3	2	0.54946
B11	1/3	1	1	0.209844
B12	1/2	1	1	0.24021
λmax = 3.018295， CI = 0.009148, RI = 0.58, CR = 0.015772<0.1				

Table 3.7 – B1-C Judgment Matrix

B1	C1	C2	W
C1	1	1	0.026224
C2	1	1	0.026224
λmax =2， CI = 0, RI =0			

Table 3.8 – B2-C Judgment Matrix

B2	C3	C4	C5	W
C3	1	3	1/2	0.308996
C4	1/3	1	1/5	0.109452
C5	2	5	1	0.581552
λmax = 3.003695， CI = 0.001847, RI = 0.58, CR = 0.003185<0.1				

Table 3.9 – B3-C Judgment Matrix

B3	C6	C7	C8	W
C6	1	1/5	1/3	0.012451
C7	5	1	2	0.066042
C8	3	1/2	1	0.035125
λmax = 3.003696， CI = 0.001848, RI = 0.58, CR = 0.003186<0.1				

Table 3.10 – B4-C Judgment Matrix

B4	C9	C10	W
C9	1	1	0.026224
C10	1	1	0.026224
λmax =2， CI = 0, RI =0			

Table 3.11 – B5-C Judgment Matrix

B5	C11	C12	C13	W
C11	1	1/4	1/3	0.20083
C12	4	1	2	0.91249
C13	3	1/2	1	0.52449
λmax = 3.018325， CI = 0.009162， RI = 0.58, CR = 0.015797<0.1				

Table 3.12 – B7-C Judgment Matrix

B7	C15	C16	W
C15	1	1/3	0.01293
C16	3	1	0.038789
λmax = 2， CI =0, RI =0			

Table 3.13 – B11-C Judgment Matrix

B11	C20	C21	W
C20	1	2	0.198172
C21	1/2	1	0.099086
λmax = 2， CI =0, RI =0			

Table 3.14 – Overall ranking of weights of each rating index

Index	Weight （W）	Sort	Index	Weight （W）	Sort	Index	Weight （W）	Sort
C1	0.026224	19	C9	0.026224	17	C17	0.046677	13
C2	0.026224	18	C10	0.026224	16	C18	0.053431	11
C3	0.308996	4	C11	0.020083	20	C19	0.549946	2
C4	0.109452	7	C12	0.091249	9	C20	0.198172	6
C5	0.581552	2	C13	0.052449	12	C21	0.099086	8
C6	0.012451	22	C14	0.064389	1	C22	0.24021	5
C7	0.066042	10	C15	0.01293	21			
C8	0.035125	15	C16	0.038789	14			

On the basis of analyzing and sorting out the characteristics of the mine ecosystem, combined with the characteristics of the mines in North China, an evaluation index system for the protection and restoration of the mine ecological environment was established, and the influence degree of each influencing factor was quantitatively analyzed by using the AHP method, and the satisfactory consistency was obtained through testing. It can be seen from the evaluation results that the mine ecological environment protection and The factors that have a greater impact on the assessment of restoration and treatment are the ecological restoration and treatment rate, the disposal rate of domestic waste, the allocation rate of monitoring facilities, the comprehensive disposal rate of production solid waste and the monitoring rate of surface deformation and subsidence in the mining area in the area left over by history[4]. Obviously, the ecological restoration and control of the historical subsidence fracture area is the primary condition for the protection and restoration of the mine ecological environment.

3.3 Standard intelligent mine safety management model and system

In the 1990s, IBM (International Business Machines) of the United States put forward the concept of "SmarterPlanet" for the first time, which means that earth informatization is undergoing an important transformation from "digital earth" to "smart earth" [5]. Since the 18th National Congress of the Communist Party of China (CPC), the reform has been comprehensively deepened into the deep-water area, and the economic development has entered the critical period of transforming the mode, adjusting the structure and changing the driving force. Achieving high-quality economic development has become the main goal at this stage [6]. The 19th National Congress of the Communist Party of China defined the "overall national security concept" as a component of the basic strategy of socialism with Chinese characteristics in the new period. More and more scholars are studying national security. Coal resources are an important material basis for national development and people's survival [7]. Mine safety concerns the overall national security, is the core of energy security, and is closely related to economic security, ecological security, military security, political security and social security. At the same time, the rapid development of high-tech, such as the Internet of Things, the Internet and artificial intelligence, is an organic combination of high-tech and traditional industry equipment, equipment and management concepts, and an effective way to achieve the transformation and upgrading of traditional industries. In this context, the concept of smart mine was proposed and rapidly constructed and developed. A smart mine must first be a safe mine. On the one hand, under the national security concept and background of "people first, life first" of the General Secretary, security issues are increasingly closely related to people, property and life; On the other hand, safety is the source of wisdom and vitality of mines and the basis for orderly operation of coal mining, tunneling, electromechanical, transportation and ventilation, as well as the basis for orderly operation of ground transportation and ventilation of mines in China. Moreover, the mine geological environment in China is complex, the mining environment is changeable, and the process system is complex. Miners face huge risks in operation safety, which also brings great challenges to the efficient production of mining. The research of mine safety coal mine system is one of the important topics of building intelligent mine. In reality, we live in a "society with no choice but risk". Against the background of big data, the mine safety management mode is facing innovation, and the mine safety management gradually tends to be standardized, integrated, collaborative and intelligent, which also ushers in unprecedented opportunities and challenges for the construction of smart mines. At this stage, there are still many problems in the construction and research of the smart mine safety management system. Safety standards are the basis and booster for the realization of smart mine safety management. Carry out mine safety management work In particular, the safety management of smart mines urgently needs standard empowerment. First of all, the defects of mine safety management mode are prominent. At present, the level of mine safety management is relatively lagging behind. With the increasing mining depth, there is a major contradiction between the low level of mining intelligence and the increasingly complex mining geological conditions. The main aspect of the contradiction is that the traditional mine safety management mode does not match the mining mode under the new geological conditions; At the present stage, the mine safety management system is relatively simple, the safety management means are not rich enough, the management mode mostly depends on the experience of the underground staff, and the mine safety management has the same effect on the safety level; With the deepening of coal mining depth, the hidden danger of mine safety is increasing and becoming the main inducement of mine safety problems; The number of safety management talents at the group level is insufficient, the talent training mode is not perfect, the research and development investment is insufficient, and the assessment mechanism is not mature. "Secondly, the development of the safety standard system is the key point to reduce the mine safety accident rate. As a basic industry, the mining industry plays a key role in supporting the rapid development of the country." The demand for coal resources in China increases with the economic development and the expansion of social production scale. The coal mine must establish a safety standard system to meet the needs of economic development and social production. Finally, from the perspective of the concept of intelligent mines, under the vision of artificial intelligence and big data, the mine space has gradually changed from the traditional binary space (referring to the human social space, namely the space for human decision-making and social interaction) to the ternary space (cyberspace, namely the "network information" space composed of computers and the Internet). Combined with intelligent governance and intelligent supervision technology, the application of safety standards to mine safety management has ushered in a major opportunity. The development of artificial intelligence, big data and 5G technology has solved the problems of poor security and low transmission efficiency of mine information transmission in the past. At the same time, the massive mine safety information resources are accompanied by a large amount of information redundancy and lack of systematicness, so it is necessary to develop mine safety standards to solve the problem of inefficiency or failure of the mine safety management system, and optimize the traditional extensive mine safety management mode focusing on experience.

To sum up, it is of urgent need and practical value to build a standard based intelligent mine safety management system. Based on the concept of smart mines, this paper explores and describes the safety management process of smart mines in the perspective of safety standardization, builds and improves the safety management model of Smart F Mountain based on standards, proposes and optimizes the safety management system of smart mines based on standards, and promotes the transformation of mine safety management from coal mine process to standardization, from traditional experience to wisdom, and from passive safety management to active safety management.

3.3.1 Analysis of safety management in smart mines from the perspective of standards

Overview of smart mine safety

From the perspective of system theory, safety refers to a stable and reliable state in which the system is free from the adverse effects of unacceptable internal and external factors. As a dynamic complex system, mine safety can be defined as a stable and reliable state in which the mine system is free from the adverse effects of unacceptable internal and external factors from the perspective of system safety. The "adverse impact" of the mine system specifically refers to the process of abnormal mine operation, reduced production efficiency, potential safety hazards, accidents and economic losses. Further analyze the basic concept of mine safety. First of all, the essence of a mine is a system. It is feasible to carry out mine safety research and management based on system theory, that is, mine safety is a typical system safety problem. Secondly, the analysis of mine safety risk can be started from two aspects: "Safety risk" and "Security risk", which are closely related, interacted and transformed in coordination. It can be said that mine safety is a typical "safety integration" problem. Finally, since mine safety is regarded as a typical system safety problem, the theory, method, model and system of mine safety management should be explored based on the system safety theory. Smart mine refers to the perception, analysis, prediction and decision-making of mine production and management, so as to achieve the goal of "less people, unmanned, intelligent and green mining". In practice, since 2012 Since China Smart Mine Industry and Technology Alliance put forward the concept of smart mine, scholars have built a four horizontal (basic application layer, data support layer, network communication layer, and perception control layer) and three vertical (management and operation system, information security system, and information standardization system) smart mine system architecture based on system theory. However, in the era of big data, with the blowout growth of data and information, how to quickly mine useful information from massive information and achieve the goal of knowledge discovery has become the focus of mining enterprises. The existing four horizontal and three vertical safety management system lacks systematic and standardized thinking.

Connotation analysis of standard intelligent mine safety management

From the perspective of standard science and management science, the core function of standards is to provide strong support and guarantee for the management system. In short, the target in management It is information, but also tools, methods and mechanisms. Massive mine safety information and multi-source heterogeneous mine safety big data will be generated in the safety management of smart mines, covering mining equipment, equipment, hazard sources and other contents, as well as dynamic safety information and data generated during the operation of smart mine systems and mine safety management, Together constitute the mine safety bit space ". The safety standard runs through all aspects of the safety management of smart mines. The core goal of the safety standard is to provide effective services and scientific support for the safety management of smart mines. The goal of the development of the safety standard of smart mines is to refine the objects of mine safety management on the basis of the identification of mine safety hazard sources, and achieve the control of mine safety hazard sources by applying countermeasures to the management objects Based on the above analysis The meaning of the standard intelligent mine safety management refers to the safety management behaviors and activities "'carried out by developing intelligent mine safety standards to serve and ensure mine safety, with the mine system as the management object and the improvement of mine safety level as the focus. In other words, according to the" multi stream integration "theory of system safety, the safety standards have the integration function. The safety material flow, safety energy flow Safety behavior flow and safety economic flow can be unified into safety standard representation, that is, safety standard can represent the overall safety state of the system. In addition, safety standards are analyzed safety information and safety big data. Mine safety information and safety big data are generated from coal mining, tunneling, electromechanical, transportation, ventilation and other links. They are mines Information source of safety management standards. The essence of intelligent mine safety management is to carry out mine safety management activities based on safety standards. The development of safety standards is the core context of intelligent mine safety management. With reference to Hall's three-dimensional structure, three core dimensions of safety management in smart mines, namely time dimension (T), value dimension (V) and standard dimension (S), are condensed, and a three-dimensional framework structure (T-V-S) of "time dimension, value dimension and standard dimension" for safety management in smart mines is further constructed, as shown in Figure 3.1. See Table 3.15 for the definition of each dimension.

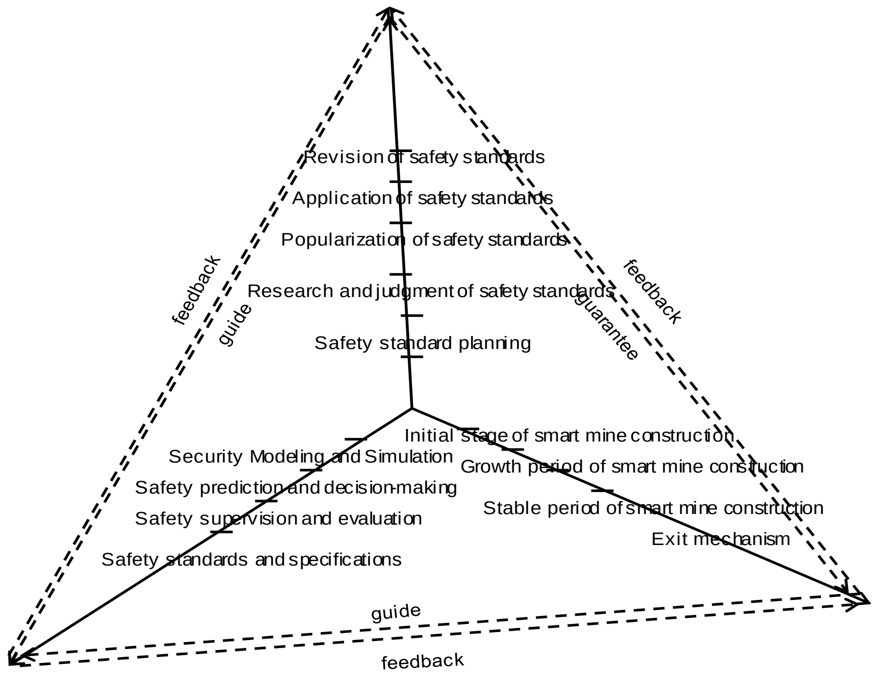

Figure 3.1 – Standard 3D framework structure of smart mine (T-V-S)

Table 3.15 – Interpretation of standard 3D framework structure of Smart Mine (T-V-S)

（T- V-S）dimension	primary coverage
Time dimension（T）	The life cycle of intelligent mine safety management includes three stages: mine construction planning safety management in the initial period, mine production safety management in the growing period, and mine operation and shutdown safety management in the stable period
Value dimension（V）	Combined with system engineering thinking, the safety management process of smart mines includes clarifying safety issues, safety modeling and simulation, safety prediction and decision-making, safety supervision and evaluation, safety standards and specifications, etc
Standard dimension（S）	Standard dimension refers to the support and guarantee of safety standard work necessary for carrying out value dimension and time dimension activities of safety management in smart mines. According to the work path of safety standard development, safety standard work mainly includes safety standard planning, safety standard development, safety standard promotion, safety standard popularization, safety standard application and safety standard revision

From a macro perspective, time dimension, value dimension and standard dimension in the framework are the three basic dimensions of smart mine safety management, and the content of smart mine safety management in the standard dimension is the foundation of smart mine safety management in time dimension and value dimension; The safety management of smart mines in time dimension and value dimension has a certain time sequence. The basic mine safety information and big mine safety data generated by them form the main reference materials for the development of smart mine safety standards in standard dimension through the feedback mechanism; The safety management of smart mines in the value dimension provides the guidance of logical methodology and the index of management tools for the safety management of smart mines in each link of the time dimension; The safety management of smart mines in each link of the time dimension supports and affects the safety management of smart mines in the value dimension through the feedback mechanism.

From a micro perspective, under the background of modern governance capacity and governance system, big data and artificial intelligence, the generation of massive mine big data makes the construction of smart mines more emphasis on the support and application of big data, and relying on big data for smart mine safety management becomes more and more feasible. However, because the theoretical support of big data and the theoretical methods of standard science are interlinked, the big data thinking, technology and standard scientific thinking, theory and methods need to be integrated in the process of carrying out smart mine safety management based on big data.

3.3.2 Standard intelligent mine safety management model

Macro model of smart mine safety management

Smart mine safety management in the standard view needs not many and miscellaneous mine safety information and mine safety big data, but effective information and big data, that is, standardized safety information and mine safety big data need to be formed. Therefore, according to the general paradigm of solving safety management problems, namely "safety analysis - safety prediction - safety decision-making and safety implementation", a macro model of safety management in smart mines is built.

The macro model of smart mine safety management is divided into two layers: internal and external, and the internal layer is the mine safety management cycle path, including safety information and big data acquisition, safety level analysis and prediction, safety event decision-making and implementation; The outer layer is the safety standard cycle path, including the development of safety standards Analysis of safety standards, application and promotion of safety standards, and revision of safety standards. Combined with the theory of mine safety life cycle, the macro model of smart mine safety management based on standards is defined as a two-layer cycle model. First, the inner and outer two-layer paths complement each other: the outer layer safety standard cycle path supports the inner layer safety management cycle path, and the inner layer safety management cycle path feeds back the outer layer safety standard cycle path, that is, the safety management of smart mines is carried out with safety standards as the core, and the overall planning and guidance of safety standards provide for the safety management of smart mines Methods and tools, enabling the improvement of safety management efficiency. Second, the dynamic adaptability of the inner and outer two-layer circulation paths: every time the inner circulation path is cycled, the security status of the intelligent mine changes dynamically. The mine safety problems that are difficult to solve adaptively will be solved in the next inner circulation path. If any link in the inner circulation path fails, the security situation of the intelligent mine cannot be improved in time, which requires the support of the outer circulation path.

Micro model of smart mine safety management

According to the macro model of smart mine safety management based on standards, further explore the essence of smart mine safety management, and build a micro model of smart mine safety management based on standards. On the whole, the four links of safety analysis, safety prediction, safety decision-making and safety implementation of smart mines coordinate and assist each other to improve the linkage ability and work efficiency of safety management of smart mines.

(1) From the perspective of safety management, the safety management of smart mines hopes to improve the safety level of smart mines and the emergency response capability of accidents, improve the safety toughness of mines and reduce the vulnerability of mine safety through fault monitoring, accident analysis and early warning. Therefore, the safety management path of smart mines consists of safety analysis, safety prediction, safety decision-making and safety implementation. First, safety analysis: the purpose of safety analysis is to identify mine safety hazard sources and accident disaster points with sudden, hidden, complex and dynamic characteristics, monitor the safety situation of intelligent mines in real time based on hazard sources and disaster points, and give real-time warning to mine safety accidents. The second is safety prediction: the core of intelligent mine safety prediction is to speculate the future safety situation of the mine system, and its prediction focus is determined by the future attributes of the mine safety management itself, that is, to make the intelligent mine system in a safe situation during operation or to minimize the direct economic losses and casualties caused by accidents during the operation of the intelligent mine system. Third, safety decision-making: decision-makers of safety management in smart mines combine Marxist value orientation, integrate mine safety risks and safety opportunities, solve safety problems and obtain policy recommendations. Essentially, safety decision-makers have decision-making

power over the success or failure of decision-making, which requires improving the information acquisition, data analysis and knowledge discovery capabilities of safety decision-makers in smart mines. Fourth, safety implementation: safety implementation refers to the implementation of safety plans and policy recommendations, avoiding unsafe events, delaying the state of vulnerability fracture, improving the handling efficiency of mine safety accidents, and reducing direct economic losses and casualties.

(2) From the perspective of safety standardization, the foundation of safety management in smart mines is to acquire, store, mine and analyze safety data in combination with basic mine safety information. The essence of safety management in smart mines is an activity based on safety standard management. The mine safety big data, mine safety standards and mine safety management behaviors in the standards based smart mine safety management micro model complement each other. Among them, mine safety big data is the source and foundation of mine safety standards, and mine safety management behavior is a smart mine safety management activity based on mine safety big data and mine safety standards. Mine safety standards play a guiding and supporting role in smart mine safety management.

(3) From the perspective of wisdom concept: information and data are resources, and more importantly, they are our way of thinking to understand and transform the world Tools for. The huge amount of big data resources in the smart mine has provided a quantitative basis for the safety analysis of all links in the construction process of the smart mine. Pass Large data, cloud computing, machine learning and other high-tech means are used to collect, store, analyze and discover the safety big data of massive smart mines and develop safety standards, enabling accurate disaster analysis, scientific fault early warning and effective accident disposal.

3.3.3 Intelligent mine safety standard subsystem

At this stage, the safety management of smart mines does not require many and complicated primary mine safety information and safety big data, Instead, security information and security big data "Safety standards recognized both inside and outside the industry have been developed. That is, in the safety management of smart mines, the output of basic mine safety information and big data of mine safety is a safety standard, and also a solid foundation for safety analysis, safety prediction, safety decision-making and safety implementation in safety management. However, the development of safety standards of smart mines is subject to the safety knowledge, safety values and safety of safety managers Due to the constraints of the whole culture concept and other factors, it is necessary to clarify the critical path of the development of smart mine standards, point out the main direction and key pain points of the development of smart mine standards, and create a comprehensive platform for the development of mine safety standards.

3.3.4 Intelligent mine safety management subsystem

(1) As for the safety analysis of intelligent mines, after the development of valuable safety standards for intelligent mines, further safety analysis of intelligent mines is required. Its main purpose is to provide the basic information of mine hazard sources, analyze the evolution direction of personnel, machines, environment and management in the system, explain the mechanism of changes in things related to mine safety, analyze the consequences of mine safety accidents, and predict the safety trend of the development of intelligent mines, The possible results of the mine dangerous objects are evaluated, and the decision-making scheme of the safety decision-making link is put forward accordingly.

(2) Smart mine safety prediction link. Safety prediction is the basis of safety decision-making. It presents the current safety state of the intelligent mine system and gives the future safety situation change of the intelligent mine system. First, the serialized, systematized and standardized safety standards after systematic analysis characterize the mine safety problems, and predict the short-term situation of mine hazard sources and the medium and long-term safety situation of the mine. Secondly, modeling and numerical simulation are carried out through the mine safety standards

to predict the future safety situation of the intelligent mine system, and explain the factors that affect the safety of the intelligent mine system.

(3) The safety decision-making link of smart mines is the embodiment of the front-end management ability in the safety management system of smart mines, which mainly includes two aspects of mine safety risk decision-making and mine safety opportunity decision-making. Risk decision-making is to assess whether there is a mine security threat, what kind of security threat exists, whether security countermeasures need to be taken, and what kind of security countermeasures should be taken. Opportunity decision-making requires mine safety management decision-makers to make decisions according to the current mine safety situation and their own safety value tendency.

(4) The safety implementation link of smart mines is a direct link for the success of the safety management of smart mines. The pre plan planning, emergency disposal in safety incidents, and accident handling after incidents of smart mines are all mine safety implementation behaviors. It is necessary to establish a three-dimensional safe space of time, space and value for smart mines, and form a dynamic system structure with flexible disaster adaptation and post disaster recovery.

Smart mine safety management is one of the key requirements and core paths of smart mine construction. From the perspective of safety standards, mine safety management. The connotation of is the management activity based on safety standards. The improvement of safety management level of smart mines needs to rely on the guidance, specification and guarantee of safety standards. Therefore, the research on safety management of smart mines based on standards is of great value. Based on the construction background and current situation of smart mines, this paper first analyzes the implementation path and cycle process of standards based smart mine safety management, which is mainly composed of four closed-loop paths: safety analysis, safety prediction, safety decision-making and safety implementation, and is supported by the safety standard cycle to ensure its orderly operation; On this basis, the paper organically integrates the mine safety management activities with the mine safety standard system, builds a standard based intelligent mine safety management model, and uses the mine safety standards to guide the safety management of coal mining, tunneling, electromechanical, transportation and ventilation in intelligent mines based on the whole life cycle; Finally, based on the system theory, build a smart mine safety management system from the perspective of standards, which is formed from the technical subsystem of smart mine deployment and construction model, specifically divided into smart mine safety big data subsystem Smart mine safety standard subsystem, three subsystems of mine safety management subsystem or smart mine safety big data management layer, smart mine safety big data planning and deployment layer, smart mine safety big data infrastructure layer, smart mine safety standard content layer, smart mine safety standard platform layer, smart mine safety standard path layer, smart mine safety analysis layer, smart mine safety prediction layer Smart mine safety decision-making layer and smart mine.

4 MINE REUTILIZATION FOR ENVIRONMENT RESTORATION

4.1 Research on mine reuse model from the perspective of ecological environment restoration -- A case study of Tongling City

Tongling is rich in mineral resources, has a long history of development, and the distribution of mineral sites is relatively concentrated. Copper, gold, silver, iron and other metal minerals and pyrite are mainly distributed in Tongguan Mountain, Shizishan Xinqiao, Fenghuang Mountain and other areas, and limestone is mainly distributed in the south of Tongling River, Tongshan Town, Jiangbei and other places. With the depletion of mineral resources, the number of abandoned mines is increasing, environmental problems are prominent, governance is difficult, and the contradiction between man and nature is increasingly prominent [10].

In order to improve the seriously deteriorated mine ecological environment, in combination with the transformation policy of resource exhausted cities, Tongling has carried out the restoration and control of geological environment of nearly 100 mines (including some production mines) since 2013, with a total investment of about 90 million yuan, and completed the restoration and control of the mine geological environment of more than 20000 mu, mainly through the third phase of the project. In 2017, candidates from Tongling City [11].

Phase I project: mainly carry out slag backfilling, sorting and reclamation of the mine waste dump, complete the flood interception and drainage ditch project, and restore it to public building land and green land, so that the reclamation rate is more than 95% and the greening rate is more than 30%, as shown in the figure above.

Figure 4.1 – Comparison before and after phase I project

Phase II project: basically complete the earthwork backfilling of the abandoned mining area, carry out land subsidence engineering treatment, and plant grass. After the treatment, geological hazards such as goaf collapse and landslide can be eliminated, with a greening rate of more than 50%, as shown in the figure.

Figure 4.2 – Comparison before and after Phase II Project

Phase III project: road hardening, tree planting in areas prone to landslides, slope care and other projects will be completed. After treatment, forestry greening and road land can be restored, basically eliminating the impact of land subsidence, as shown in the figure.

Figure 4.3 – Comparison before and after Phase III Project

4.2 Problems existing in the treatment of abandoned mines

Some mines in Tongling City are overexploited. There are 53 mines of various types in Tongling City. In recent years, the average annual output value of the mining industry is nearly 10 billion yuan, accounting for 8%~10% of the regional GDP. At the same time, the General Plan of Mineral Resources in Tongling City (2016-202) proposed that the total amount of ore mining in the planning period will increase by 2%~5% annually, and the total output value of the mining industry will increase by 5%~7% annually. As a result, the existing mine management has not been completed and many new mine environmental problems have been added, which makes the environmental management of the mining area a vicious circle.

The mine restoration work in Tongling City mainly comes from the government's work deployment, and the mine restoration plan is mainly designed by the county and district governments and enterprises, lacking of urban planning guidance. At present, Sanya City and Jinan City, which have carried out better mine ecological restoration work in China, have carried out special planning preparation based on comprehensive survey and overall land and space planning. Due to the lack of land space planning guidance for mine management in Tongling City, there is no organic connection between mine management and construction. At the same time, it is difficult to effectively integrate mine ecological restoration and urban and rural construction.

At present, Tongling City only pays attention to the mine site in the mine management and restoration work The quality environment control and ecological function recovery emphasize the elimination of geological hazard safety hazards and the greening work. The vegetation recovery standard is relatively low and the control standard is not high. There is also a lack of overall planning for the mine management work, which fails to conduct classified guidance and work according to the concept of "urban double repair", and lacks research on the function play and reuse of the mine after repair.

In addition to mines and bare mountains, there are also a large number of tailings reservoirs in Tongling City, which have not been solved in terms of ecological restoration and reuse, and the control effect is not obvious. The safety impact of some tailings ponds is difficult to eliminate in a short time, such as Shuimuchong Tailings Pond in Wumu Mountain Park and Xiangshuichong Tailings Pond in National Mine Park, which also has long plagued the development and utilization of surrounding land.

In order to speed up the transformation and development of resource-based cities and efficiently complete the improvement of the mineral environment, Tongling urban area accepts abandoned mines and the exposed mountain environment improvement project, except for two mines that have not been carried out due to safety and other reasons, the rest of the mines have been completed or are in the process of cleaning, ensuring that the urban area has been fully covered by the improvement of abandoned mines. However, the mine geological control work of Zongyang County in the north of the Yangtze River has not been started yet, and the work foundation is relatively weak. The progress of mine control work on both banks of the Yangtze River is quite different.

4.3 Planning guidance for abandoned mine treatment

Through sorting out the actual situation of the abandoned mines in Tongling City and the problems faced in the current treatment process, drawing on the successful experience in the treatment of abandoned mines at home and abroad, and combining the conditions of mine location, type and terrain, the following three mine treatment models are proposed.

4.3.1 Ecological restoration governance

Based on the principle of "agriculture is suitable for agriculture, forests are suitable for forests, and grass is suitable for grass", ecological restoration of mines is carried out in accordance with the idea of giving priority to agricultural land reclamation, in order to achieve the purpose of ecological restoration, emphasize ecological greening, improve the geological environment and ecological landscape of mines, and reconstruct the biological habitat by restoring the damaged ecosystem. Mainly for abandoned mines located outside the urban area, within the ecological protection red line and nature reserves, scenic spots, and mines using underground mining or composite mining, in principle, the ecological recovery mode is adopted.

4.3.2 Scenic and recreational governance

The landscape recreation type management emphasizes the replacement of site functions and the creation of public open space through the management of mine geological environment and the reconstruction of green landscape. The treatment method is mainly to achieve the ecological recovery function of the mine through reasonable planting, irrigation and maintenance means. On this basis, appropriate, distinctive and distinctive theme content is formulated to transform the site from the original industrial mining site into a public open space with functions such as public leisure, site display, plant exhibition, and rural recreation, and integrate into the overall social and economic development of the region. For abandoned mines located in or around the urban area with high requirements for landscape environment, the mining areas are relatively concentrated or have a certain scale. In principle, the landscape recreation mode is adopted.

4.3.3 Recycling governance

Recycling governance focuses on the redevelopment and utilization of damaged mountains after restoration, creating social and economic value again. The mine management method is mainly through the use of the unique environment of the quarry and pit to transform the landscape, making it a unique place, turning the disadvantages into advantages, which can have vacation, leisure, commercial operation, public activities and other functions, becoming a new engine of regional social and economic development, reinvigorating new vitality, and realizing a win-win situation between environmental management and tourism development. For those located around or inside the city, as well as scenic names. In principle, the abandoned mines near the scenic area with high landscape environment requirements shall adopt the recycling model.

4.4 Geological environment problems of abandoned mines and ecological restoration measures - Yantai City as an example

Since the 1980s, Yantai has exploited various mineral resources on a large scale, and the number of mines has increased linearly. The development of mineral resources not only provides important material guarantee for the local economic and social development, but also has a great impact on the ecological and geological environment of Yantai. In the later period, due to the enhanced awareness of environmental protection, the standardized management of mining development and other factors, especially after the country vigorously promoted the construction of ecological civilization, many mines were shut down one after another. However, various geological environmental problems arising during the mine development have not been fully addressed, restricting the development of the local economy and society. The study area is located in Shuidao Town, Muping District, Yantai City, and belongs to hilly area. The area mainly exposes the Mesozoic Jurassic Linglong sequence Jiuqu unit monzonite, with medium coarse grain structure and massive structure. The fresh rock fissure is not developed and has good integrity. The terrain is high in the south and low in the north, and the terrain is relatively simple. Due to over excavation and arbitrary stacking of resources, most of the mountains are incomplete, forming open pits, monadnocks, quarries, etc. Some cliffs are up to 40 m high, with an angle of nearly 80°. The soil is mainly brown sandy loam with a thickness of about 10~40cm and good texture. The soil is acidic to slightly acidic, with a pH of 5.5~6.3. The content of organic matter in the soil is relatively rich, which is 1%~2%. Vegetation in the treatment area is mostly found on slopes and field gaps, and artificial vegetation is cultivated in farmland [12].

4.4.1 Geological environment problems in the study area

Geological environment status

The destruction units in this area are mainly 2 mining pits (hereinafter referred to as CK1 and CK2), 2 monadnocks (hereinafter referred to as CQ1 and CQ2) and 3 borrow areas (hereinafter referred to as LC1, LC2 and LC3). The types of land destroyed are dry land, other forest land and bare rock gravel land, with the destruction area of 80,611.66m^2. The area of dry land destroyed is 1329.62 m^2, the area of other forest land is 25986.75 m^2, and the area of bare rock gravel land is 53 295.29 m^2.

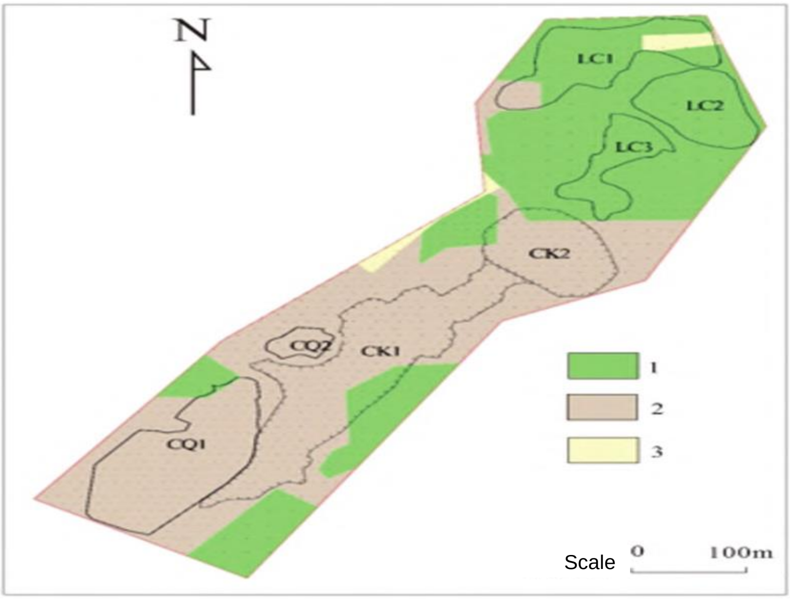

Figure 4.4 – Land types in the governance area

(1) Current status of mining pit

The past mining activities in the governance area have formed two mining pits (CK1 and CK2) of different sizes, and CK1 and CK2 are interconnected. The open pit has destroyed the land vegetation resources and the local landform landscape. Part of the slope in the south of CK2 is located within the visual range of "three areas and two lines", causing serious visual pollution. CK1 is located in the middle of the governance area. The mining pit is approximately elliptical, about 210~400 m long from east to west, 73~98 m wide from south to north, and covers an area of about 26,961 m^2. The slope in the east of the mining pit is steep, 22~34 m high, and 65°~80° slope. There is accumulated water at the bottom of CK1. The accumulated water is deep and the water depth is about 12~16 m. The source of ponding is atmospheric precipitation. CK2 is located in the north of the governance area, covering an area of about 10308 m^2. The slope in the west of the pit is steep, and some slopes are almost vertical, with a slope height of 8~31 m and a slope of about 65°~85°. There is accumulated water at the bottom of CK2, with water surface area of 1545 m and water depth of about 1 m. The source of accumulated water is atmospheric precipitation.

Figure 4.5 – Current situation of pit (CK1. CK2) in the treatment area

(2) Status quo of monadnock

According to the field survey, there are two monadnocks in the west of CK1, numbered CQ1 and CQ2. CQ1 is located in the southwest of CK1. The upper bedrock is exposed. The thickness of the weathered layer is about 2 m, without topsoil coverage. CQ1 is 85~228 m long from north to south, 45~100 m wide from east to west, 24 m high, and 14 178 m^2 in area. CQ2 is located in the northwest of CK1. The upper bedrock is exposed. The thickness of the weathered layer is about 2 m, without topsoil coverage. CQ2 is about 25~48 m long from north to south, 23~33 m wide from east to west, 17 m high, and 2156 m^2 in area.

(3) Current situation of stockyard

According to the field survey, there are three stockyards in the governance area, numbered LC1, LC2 and LC3 respectively. LC1 is located in the north of the governance area, 185~210 m long, 58~96 m wide, and covers an area of 11631.82 m^2. There are stones stacked in the west of LC1 with irregular shape, height of 1~5 m and volume of about 20530 m^3. LC2 is located in the northeast of the governance area. There are stones in the yard, which are stacked in a ladder shape in the whole yard. The yard is 118~123 m long, 56~88 m wide, covers an area of 8 113.21 m^2, and the height of the stone pile is 8~10 m, with a volume of about 199 040 m^3. LC3 is located in the north of the governance area. The quarry is mainly stacked on the east and west sides of the quarry and the south area. The quarry is 120~125 m long, 57~65 m wide, covers an area of 5660.06 m^2, has a height of 8~13 m, and a volume of about 53941 m^3.

Figure 4.6 – Current situation of quarry (LC) in the control area

Based on the full analysis of the existing mine geological environment data in the governance area, the mine geological environment survey has been carried out in the area, mainly by means of ground survey, topographic mapping, geological environment survey, etc. Through investigation, the geological environment background of the mine in the governance area, the distribution, scale, hazard objects and hazard degree of the geological environment problems are basically found out, and the development trend of the geological environment problems of the mine is further analyzed and predicted, which provides a basic basis for determining the subsequent construction engineering means, engineering layout and quantities [13]. The field survey results show that the main geological environment problems in the governance area are the destruction of landform and landscape, land resources and vegetation.

Geological environment problems

(1) Destruction of landform and landscape

The mining pits formed due to historical mining activities have changed the original terrain and geomorphic characteristics of the governance area, causing damage and exposure of mountains, which are extremely uncoordinated with the surrounding ecological environment, and causing serious visual pollution.

(2) Destroy land resources

The direct excavation of pits and disordered slopes in the treatment area has damaged the surface soil layer and vegetation. The types of damaged land are dry land, other forest land and bare rock gravel land, with an area of 80611 m^2. It has seriously affected the original function of land resources in this area.

(3) Vegetation damage, water and soil loss

The overburden layer of residual soil on the surface of most areas in the control area has been stripped, the original trees, grasses and other vegetation with water and soil conservation functions have been damaged, the regeneration vegetation is poorly developed, the pit and slope are mostly exposed directly, the erosion resistance is reduced, the water and soil loss is serious, and the surface soil with strong fertility and fine particles has been taken away, resulting in the loss of soil fertility, the thinning of soil layer, the exposure of bedrock, and the degradation of land functions.

(4) The slope of the pit in the control area where geological hazards are hidden is steep, the rock mass in some parts is broken, and some parts are upright. There is a hidden danger of collapse.

4.4.2 Mine restoration plan

The restoration schemes adopted in the study area mainly include blasting leveling of residual hills, pit backfilling, slope continuation backfilling and site leveling. The blasting leveling of residual hills is aimed at giving priority to the restoration of farmland, grassland and forest land in order to maintain the adaptability of the geological conditions after treatment to the surrounding environment. The residual parts above 216 m of CQ1 and above 203 m of CQ2 are completely stripped, and the construction is carried out mainly by blasting, supplemented by mechanical stripping. The blasting construction adopts the construction method of combining shallow hole blasting, deep hole bench blasting and millisecond controlled blasting between holes. After blasting, the slope rock mass shall be inspected, repaired and treated in time to ensure that the slope must be flat and solid, and black pine and Parthenocissus tricuspidata shall be planted to ensure its beauty.

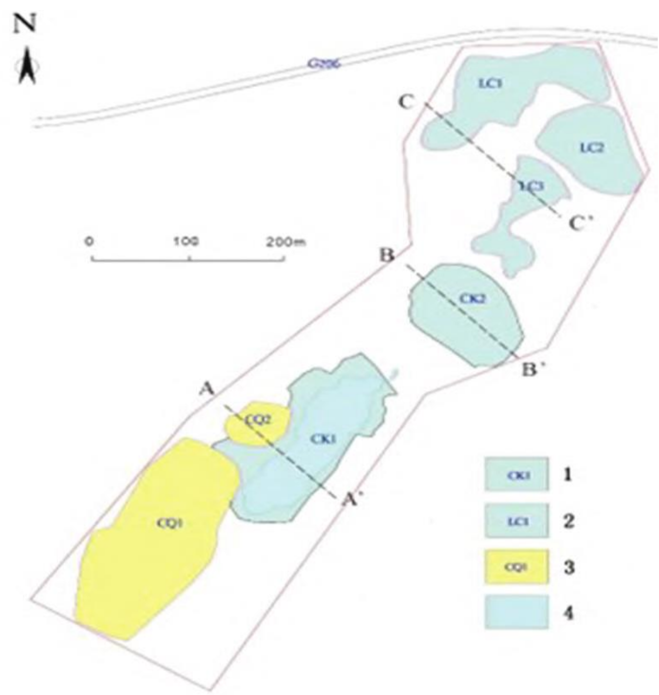

Figure 4.7 – Distribution of damaged units in the governance area: 1 – Pit location and number; 2 – Location and number of stockyard; 3 – Location and number of monadnock; 4 – Pond surface

Backfill CK2 to the same elevation as the northern road. The materials used for backfilling are from weathered stone slags and stones produced during the blasting leveling of CQ1 and CQ2. The weathered stone slags stripped by blasting are preferred for backfilling materials, and the stones after blasting are used for the missing parts. The cost is controlled according to local conditions, and the repair efficiency is improved. As the south of CK2 is within the visual range of "three zones and two lines", it has caused serious visual pollution. When CK2 is backfilled to the elevation of +190m, it is designed to use the stones produced by CQ1 and CQ2 blasting leveling to backfill the south slope of CK2. After the clearing and transportation of the quarry stones, the site needs to be leveled. The flat areas in the governance area are: LC1, LC2, LC3, CQ1, CQ2, CK2 and the damaged platform in the south of CK1. After the clearing and transportation of the stones, the site shall be leveled and compacted by combining machinery and labor.

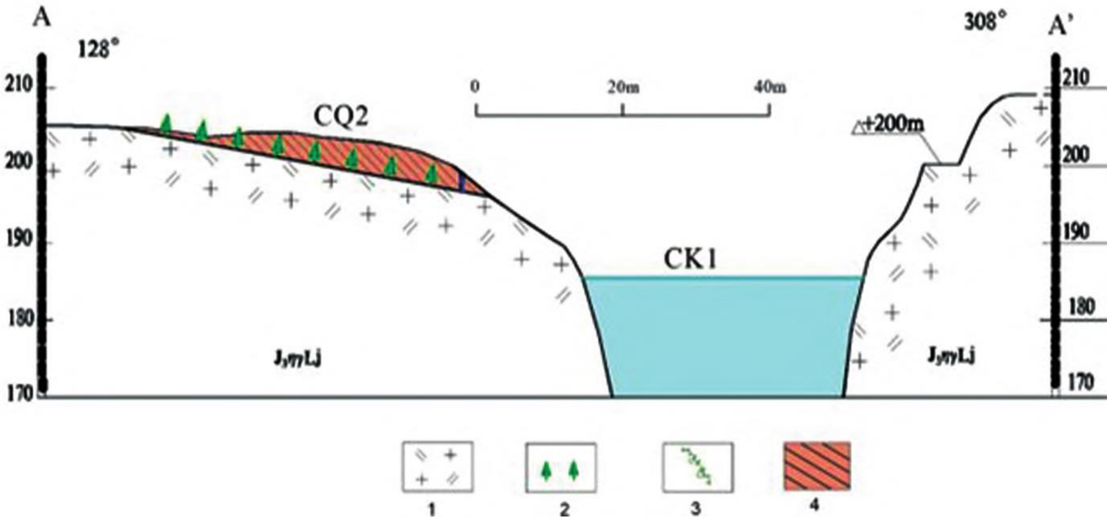

Figure 4.8 – Schematic diagram for blasting leveling of residual hillock: 1 – monzogranite; 2 – Planting black pine; 3 - Planting Parthenocissus tricuspidata; 4 - Blasting leveling part of monadnock

4.5 Ecological protection of ion type rare earth mines: a case study of Xiuyi Ganjiang River basin

4.5.1 Technology and ecological environment problems of ionic rare earth mining

China has rich reserves of rare earth resources and is a key area for rare earth development. Since the late 1970s, the development and production of rare earth has made significant contributions to national construction and export to earn foreign exchange. Although the mining process of ionic rare earth ore has gone through the technological development path of barrel leaching, pool leaching, heap leaching and in-situ leaching, and the process efficiency has been continuously improved, the associated problems of difficult pollutant reduction and serious ecological damage have not been completely solved. The principles of different ore leaching processes have different impacts on the ecological environment.

The specific performance is as follows:

1) Barrel leaching process. After screening, the ore is put into a wooden container, and 6%~8% sodium chloride is used as the main leaching solvent to extract rare earth. The waste liquid directly causes acidification of the surrounding water; The NaCl residue in the industrial waste residue will also lead to the salinization of the surrounding land, and more seriously, it will inhibit the growth and development of animals and plants.

2) Pool leaching and heap leaching process. As the barrel leaching process has the disadvantages of high cost and low efficiency, the pool leaching and heap leaching processes have been improved. The specific process is as follows: after removing the vegetation on the mine surface, strip the topsoil, move the excavated ore away from the original place, input $(NH_4)_2SO_4$ as the leaching agent, and then conduct a series of treatments such as impurity removal, precipitation, burning, etc. on the leaching solution. The end product is ionic rare earth products. As the process requires a large amount of topsoil stripping, it will inevitably damage the vegetation of the mine ecosystem. The destructive power to the surface vegetation is as high as

160~200 m^2/t of rare earth, which seriously disturbs the stability of the mine's original landform and ecosystem. Therefore, it is also called "mountain moving movement". The resulting large amount of tailings and waste liquid also cause irreversible damage to the surface ecosystem. Not only will the residual leachate bring soil pollution, but also the risk of soil salinization. The leakage of tailings dam will also cause the migration of rare earth elements, bringing ecological risks to the surrounding groundwater [14].

3) In situ leaching process. Instead of stripping all the topsoil and excavating the ore body, this process directly lays a liquid injection well pattern on the surface of the damaged mountain, adds ammonium sulfate leaching agent aqueous solution, conducts exchange reaction between ammonium ions and rare earth ions, penetrates and transforms the rare earth ion resources leached from the soil, and then uses the liquid accumulation ditch or liquid collection tunnel at the foot of the mountain to collect, so as to realize the resource recovery and utilization of ion type rare earth ores. Although the in-situ leaching process has the advantages compared with the first two processes, it still has a high probability of environmental impact risks, such as leaching liquid leaking into water and soil, causing plant roots to shrink ", thus reducing the ability of surface vegetation to prevent water and soil loss; Nitrate nitrogen in leaching solution may infiltrate with rainwater, causing groundwater pollution. The pollutants go down the river basin and pollute the agricultural irrigation water. The growth of crops is limited, and the crops only grow wildly without bearing fruit. Therefore, the domestic water of the people is also seriously affected; At the same time, the injection of long-term in-situ mining leaching fluid disturbs the ore body structure, which is very easy to induce landslides [15].

To sum up, special rare earth mining processes such as barrel leaching, pool leaching, heap leaching, in-situ leaching and the use of leaching agents have changed the structure of the mine ecosystem due to excessive ammonia sulfate and sulfuric acid leaching solution. Enrichment of ammonia nitrogen in the deep soil layer and water and soil loss have led to nutrient deficiency such as soil nitrogen and excessive heavy metal content, and it is difficult for the vegetation community in the ecosystem to grow naturally. In addition to the limitations of the above processes and technologies, the acid, sticky, thin and other characteristics of the southern red soil have also aggravated the environmental problems of ion type rare earth mines, resulting in topsoil erosion, landslide, vegetation destruction, soil salinization and alkalization, and water. Soil loss, water acidification, ecosystem damage and other ecological damage phenomena seriously affect the safety of the mine and surrounding ecosystems.

4.5.2 Current situation and applicability analysis of ecological restoration technology for ionic rare earth mines

In view of the ecological damage of ionic rare earth mines, the main types of remediation technologies can be classified into three categories. Among them, physical repair mainly includes electric repair method and soil modification method; Chemical remediation mainly includes soil leaching; Bioremediation includes animal microbial remediation, plant remediation and combined remediation.

The main repair methods, technical characteristics and application of different types of repair technologies are described as follows:

1) The main technical feature of the electric repair method is to use the principle of electrodialysis, electrophoresis, etc. to energize the electrode in the soil, so as to promote the migration of pollutants to a specific electrical level. This method is not suitable for remediation of large area contaminated soil because of its high requirements for soil purity and high energy consumption and cost of electrodes.

2) The soil improvement method mainly adopts physical disturbance methods such as soil removal, soil replacement, topsoil removal and deep tillage to reduce the concentration of heavy metals by removing or dispersing heavy metals to the bottom layer. In view of the fact that there are almost no technical barriers, the symptoms are not treated, and the risk of secondary pollution is high, it is only limited to small-scale sites.

3) The soil leaching method mainly uses clean water for irrigation, or easily degradable and less toxic soil amendments to wash away heavy metal ions or organic

substances, so that they can migrate to deeper soil layers. However, this method has the risk of secondary pollution and is applicable to sites with small pollution area but high pollution degree.

4) Microbial remediation of soil animals makes use of the metabolic capacity of functional microorganisms in soil animals or soil to reduce the activity of toxic pollutants and even degrade them through biological growth, reproduction and other life activities. This method is not suitable for the case of small soil microbial population, and it puts forward certain requirements for the transformation and fixation capacity of heavy metals of microorganisms. As a promising development field and direction, microbial remediation of soil animals has obvious advantages in remediation efficiency.

5) Phytoremediation uses plants' own physiological and biochemical processes to adsorb and eliminate toxic substances. However, the differences in soil physical and chemical properties, plant species, etc. will greatly affect the efficiency of remediation, so it is necessary to consider using it together with other methods.

6) The combination of physical chemical, plant chemical, microbial chemical and plant microbial remediation technologies can achieve better remediation effect and reduce the disturbance of soil and ecosystem through the combination of the above measures. Its application scope is wider than that of single repair technology, and its effect is more significant.

4.5.3 Cases of ecological protection and restoration of ionic rare earth mine basin

Basic information of ionic rare earth mines in Ganjiang River basin

Ganjiang River is located on the south bank of the middle and lower reaches of the Yangtze River, originates at the west foot of Wuyi Mountain, runs through Jiangxi Province from north to south, and the whole basin contains 13 tributaries. As the largest river in the Poyang Lake basin, the trunk stream of Ganjiang River is 766.0km long, with a drainage area of $8.35\times10^{*}$ km^2, covering 44 counties (districts) under the jurisdiction of Ganzhou and other cities. Ganjiang River system has many tributaries. There are nearly 2000 rivers with a catchment area of more than 10 square kilometers. The amount of surface water resources in the basin is 702.89×10^8 m^3, accounting for 48.2% of the total surface water resources in the basin. Mountains and hills account for 64.7% of the area of Ganjiang River basin. The west of Ganjiang River basin is Luoxiao Mountains, the south end is adjacent to Nanling, the east end is Wuyi Mountain, and the north end is Yushan Mountain; The southern part of the basin is a hilly area with hills and basins. The forest area of Ganjiang River basin is $541.4 \times 10^*$ m^3, and the forest coverage is 63.6%. In addition to natural resource endowment, mineral resources are also very rich, including rare metals (tantalum, niobium), non-ferrous metals (tungsten), coal and other mineral resources are distributed here, and the reserves and varieties are among the top in China. It can be seen that the Ganjiang River basin presents a natural geographical pattern of typical landscape, forest, farmland, lake and grass along the basin, in which rare earth mines play an important role.

Practice and successful experience

As one of the first batch of "pilot projects for the ecological protection and restoration of mountains, forests, fields, lakes and grasses" in China, Ganzhou City has successively implemented the ecological protection and restoration projects of mountains, forests, fields, lakes and grasses with Shipai, Keshutang and Hanshui districts as the core since 2017, with a total investment of about 955 million yuan. Over the past three years, Ganzhou City has accumulated rich experience in exploring new tailwater treatment processes, innovating new ecological protection models, and promoting ecological protection and restoration of rare earth mines. Its practices are representative and exemplary.

Small watershed management "ecological clean" model

Guanxi small watershed in Longnan County, Ganzhou City adopts the combined water management model of "ecological, diversified and biological" to ensure stable and good water quality. The first is ecological "drainage". Vegetation restoration on the bank, ecological slope protection, silt removal and dredging under the bank, and step sand retaining dam; Water_ Fishery regulation, garbage removal, underwater proliferation and release, human cultivation in the sky, improve the biodiversity of the water body, and stimulate the self purification ability of the water body. Second, diversified "clean water for pollution control". According to the characteristics of the living environment of single family living alone, multi family living scattered and concentrated living in areas in southern rural areas, the rural domestic sewage treatment adopts different treatment forms such as integrated sewage anaerobic treatment, multi family oxidation pond biochemical treatment and centralized treatment according to local conditions, which improves the sewage treatment efficiency and improves the living environment of residents. The third is biological "water purification". Bionet biological treatment process and two-stage filtration coupling technology are innovatively adopted to treat rare earth tail water with biological pollution reduction and nitrogen removal, so as to ensure that the water quality in the basin reaches the discharge standard. In this mode, the pretreatment+membrane concentration+concentrated water treatment process route and biochemical treatment process (BIONET biological treatment technology) have innovated the new process for ecological restoration and treatment of ion type rare earth mines, and solved the problem of treatment of surface ammonia nitrogen tailwater with large water volume and low concentration. The process flow is shown in Figure 4.9.

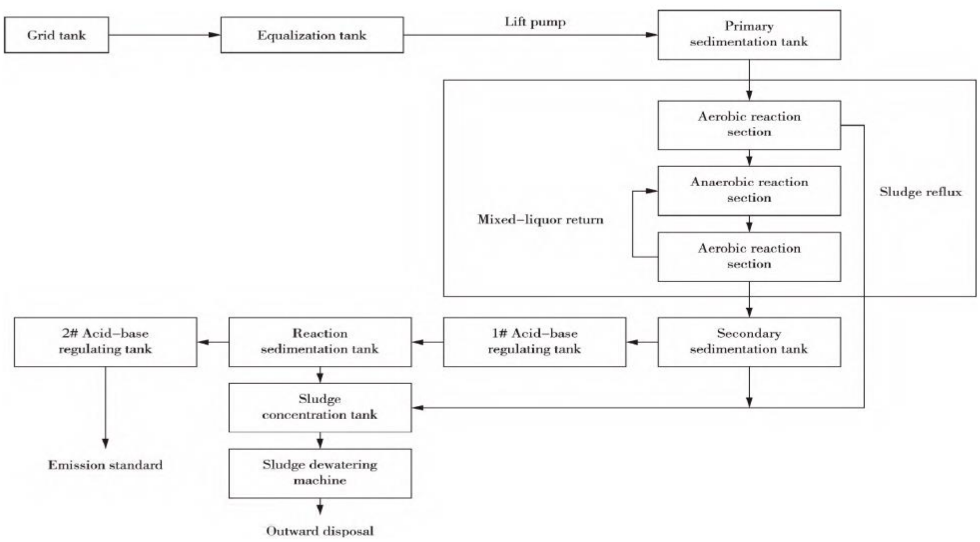

Figure 4.9 – The process diagram of tailwater collection and utilization treatment plant

The process flow is mainly as follows: the rare earth tailwater is filtered off the suspended impurities through the grid, and then enters the regulating tank. After a certain period of stabilization in the regulating tank, it is lifted by the lift pump to the primary sedimentation tank for sedimentation. After most of the suspended solids are filtered, the wastewater enters the BIONET biological treatment system. After the ammonia nitrogen and total nitrogen in the wastewater are removed by the acclimated microorganisms in the system, the wastewater is transferred to the secondary sedimentation tank for sludge water separation treatment. According to whether the effluent reaches the standard, it is decided to enter the discharge link or further the treatment process of the chemical precipitation guarantee system. The treated water enters the safeguard process system. First, the pH value in 1 # acid-base regulating tank is adjusted to alkaline, and then the effluent enters the ammonia chemical sedimentation tank. The ammonia nitrogen in the wastewater reacts with the precipitation agent magnesium chloride and sodium monohydrogen phosphate to form magnesium ammonium phosphate, which realizes the removal of ammonia nitrogen and total nitrogen in the waste liquid in the form of precipitation. After the function of the precipitator is completed, the solid and liquid separation is realized: the solid sludge is re concentrated and precipitated, and then transported out through the stacked snail dehydrator for further treatment; The supernatant enters 2 # acid-base regulating tank, and the water quality regulator is added externally to meet the qualified discharge standard after the water quality becomes neutral. 2 According to this process, a tail water collection and utilization treatment station has a daily capacity of 6000 m 'to treat the surface tail water in the mining area where the ammonia nitrogen exceeds the standard. At present, seven small watershed tailwater collection and utilization treatment stations have been built in Ganzhou, with good operation effect. The treated tailwater basically meets the discharge standard, greatly reducing the ammonia nitrogen tailwater discharge [16].

Ecological restoration "Three Harmonies" model

Through exploration and practice, Ganzhou abandoned the previous restoration concept of "separation of elements and consideration of one and the other", Thoroughly implement the systematic restoration idea of "river basin management and policy implementation in different regions", organically combine the comprehensive river basin management and mine ecological restoration, and create a set of "three simultaneous governance" models, that is, "mountain up and mountain down, ground up and underground, river basin up and down" . Biological and engineering measures, such as planting trees and grass, fixing soil and sand, and cleaning water and purifying flow, will be taken to implement five types of ecological projects, including mine ecological restoration, comprehensive land improvement, water and soil loss control, biodiversity protection, and watershed water environment protection, to achieve landform reconstruction, soil reconstruction, vegetation reconstruction, and landscape reproduction. The specific performance is as follows: 1) Mountain, uphill and downhill governance, that is, terrain improvement and vegetation restoration on the mountain; Fill gullies at the foot of the mountain to control water and soil loss. 2) Ground and underground governance, that is, improve the soil and plant cash crops on the ground; Water interception, sand blocking and biological nitrogen reduction and pollution reduction shall be carried out underground. 3) Watershed Tongzhi upstream and downstream, around the restoration goal of "fertile soil, increasing green quantity and improving water quality", stabilize the sand slope in the upstream, lock the soil, and build a cascade constructed wetland; In the downstream, silt removal, river dredging, construction of water terminal treatment facilities, and multiple measures should be taken to promote the realization of the goal of ecological protection and restoration of the whole basin.

Through the promotion of comprehensive treatment and ecological restoration, the ecological situation of Ganjiang River basin has been significantly improved, and it has become a national demonstration area for ecological functions of water conservation. By the end of 2020, 34.1 km^2 of abandoned mines will be treated, accounting for 171% of the target task of 20 km^2. The once scarred abandoned mining areas will return to green waters and green mountains. The water quality of rivers has improved significantly, and the water quality of centralized drinking water sources in cities above the county level has reached the standard rate of 100%. More than 50000 mu of land improvement and soil improvement have been completed, and about $33.3\times10^{*}m^{2}$ of core demonstration area for fertilizer reduction and efficiency enhancement has been established, so as to realize the overall improvement of land quantity, quality and ecology. The vegetation coverage rate increased from 10.2% to 95%, the forest quality and ecological function were further improved, the water and soil loss was effectively controlled, and the biological habitat was effectively protected.

4.6 Main modes and paths for realizing the value of ecological products based on mine ecological restoration

4.6.1 Main modes of value realization of ecological products based on mine ecological restoration

Utilization of waste resources

Wastes left over from mining occupy a large amount of land and space, which not only directly cause damage to vegetation and soil, but also easily cause secondary problems of ecological environment such as water and soil loss and environmental pollution Recycling waste can not only release land resources, space resources and ecological resources necessary for realizing the value of mine ecological products, but also reduce production costs, energy consumption intensity and carbon emission intensity The way of waste recycling is usually to backfill the mined out area of the mine, serve as the raw materials for building and the base material for road construction, and manufacture fertilizers and soil improvers The Dabanqiao Mine in Yunnan Province in China has realized the comprehensive utilization of all solid waste resources in the process of ecological restoration. The stripped topsoil from production is used for mine green covering, the waste earth and rock are used as cement ingredients, and the rest are used as aggregates, road paving and green covering ingredients according to different particle sizes; Shanxi Province transforms coal gangue waste into power generation materials and new wall materials, improving the utilization efficiency of coal mine solid waste resources Bolt Town, Ontario, Canada, was once a famous silver producing place. With the closure of the silver mine, it was once known as the "ghost town" [17]. However, as the abandoned silver mine contains the main raw material cobalt needed for the manufacture of electric vehicle batteries, this area is reviving According to the statistics of the 2020 Annual Report on the Prevention and Control of Environmental Pollution by Solid Wastes in Large and Medium sized Cities issued by the Ministry of Ecology and Environment, in 2019, the comprehensive utilization rate of tailings of industrial enterprises that China focuses on publishing and investigating was 27.0% With the continuous increase of new processes and technologies and the increasingly extensive utilization ways, waste recycling is expected to become an important starting point to promote the extension and transformation of the industrial chain of mining enterprises [18].

Indicator ownership transaction

The indicator ownership transaction mainly depends on the strong policy support of the government department, which is the main form of realizing the value of quasi public ecological products, and also an important way to realize the transfer of rights and interests. The index ownership transactions related to mine restoration mainly include land ticket transaction, equity transfer, carbon sequestration transaction, etc. In 2012, the former Ministry of Land and Resources put forward in the pilot project of reclamation and utilization of industrial and mining wastelands, linking the reclamation land of historical industrial and mining wastelands with new construction land, and issued the Administrative Measures for the Pilot Project of Reclamation and Utilization of Historical Industrial and Mining Wastelands in 2015 In 2017, the Implementation Opinions on Accelerating the Construction of Green Mines issued by the former Ministry of Land and Resources proposed that "green mining enterprises should be supported to reclaim and revitalize the existing industrial and mining land in a timely manner, and be linked with the new construction land" In 2019, the Ministry of Natural Resources issued the Opinions on Exploring and Utilizing the Marketization Method to Promote the Ecological

Restoration of Mines, which clearly stipulated the restoration, transformation, transfer and utilization of various ownership and types of land in terms of encouraging the comprehensive restoration and utilization of mine land, implementing the differentiated land supply, and vitalizing the stock construction land of mines, Stimulate the ecological restoration of mines and the diversified development and utilization of land resources by means of marketization Through policy support, the local government can bundle the use right or ecological product management right of the mine ecological restoration and the land after restoration by means of bidding, auction and listing. Farmers can transfer the land use right to enterprises or cooperatives for overall development by means of land subcontracting or dividends. Enterprises can obtain all or part of the land use right after mine restoration by means of direct investment or equity participation The right to operate or participate in ecological products For example, Chongqing encourages the reclamation of construction land for abandoned mines left over from history into farmland, forest land or grassland according to local conditions. The indicators of construction land vacated can refer to the land ticket for market-oriented transactions, and the income distribution method has been clarified; According to the regulations of Jiangxi Province, the surplus indicators after the restoration of abandoned construction land for mines left over from history and production mines into agricultural land can be adjusted and used in the province, and can also be used as collateral or pledge to apply for loan financing from policy banks and development financial institutions. The social capital input can obtain the indicator circulation income as agreed Since then, the "double carbon" strategy has been incorporated into the national economy and ecological civilization construction plan as China's medium - and long-term development goals Because of its high energy consumption and high carbon emissions, the mining industry has become a key area for China to deeply implement the "dual carbon" strategy It is estimated that at the beginning of the 21st century, the reserves of various types of metal tailings in China reached 60%, and the rate of 108 t is increasing, and the accumulated tailings reserves reached 146 at the end of 2013 × 108 t, its occupation of land resources has greatly lost the carbon sequestration capacity of the original vegetation Studies have shown that if iron tailings are used to prepare silicon fertilizer, CO_2 emissions can be reduced by 1904.8 t per 10000 tons of iron tailings, and if soil conditioner is prepared, CO_2 emissions can be reduced by up to 7619.0 t per 10000 tons; The increase of soil organic carbon after the remediation of coal mines in Ohio is about equal to the carbon emissions from coal combustion in 50 years; Anhui Huaibei Mining Area 1.05 × After 104 hm^2 of damaged land is reclaimed, the annual fixed CO_2 can be increased by 16.80 × 104 t. If the repaired mines are used to develop clean energy, CO_2 emissions can be reduced by reducing the use of fossil energy For example, Datong, Shanxi Province, China has built the first one million kilowatt photovoltaic leading base in China by using a large amount of idle land in the coal mining subsidence area and the local abundant solar energy, and has all realized grid connected power generation, promoting the transformation and upgrading of the energy structure Under the strategic demand of the national "double carbon" goal, with the continuous improvement of the carbon trading market, as well as the continuous improvement of the carbon sink subject and measurement methodology, the carbon emission reduction and increase from the mine restoration will become an important aspect of carbon sink trading.

Introduction of new industries

The introduction of new industries is the most commonly used model to realize the value of mine ecological products, as well as the model with the most forms and categories Various regions have constructed a series of industrial development models based on natural resource endowments, regional characteristics, social and economic development, which have promoted the transformation of the mining industry and sustainable development The development of new industries mainly includes ecological agriculture, leisure tourism, culture and education, health care and medical care, sports, scientific experiments, storage and protection, low-carbon cycle, etc. The ecological agriculture model is to use the agricultural land reclaimed by mines to develop characteristic agriculture, organic agriculture, etc The Norwich Park Coal Mine in central Queensland, Australia, relies on the local agricultural production mode of mainly grazing and planting, and recovers the mined mines into ecological pastures. By comparing the vegetation status and soil physical and chemical properties of pastures restored by abandoned mines with undisturbed pastures, a more appropriate grazing rate is proposed Through the underground garden experiment in the Flynn Flynn mining area in northern Canada, the problem of limited fruit and rose production due to the cold climate was alleviated The Ukrainian Agricultural Research Institute of the Soviet Union used abandoned coal mines to build underground vegetable planting bases, which not only improved the vegetable yield and nutritional value, but also saved a lot of construction costs The rest tourism mode is to use the landform, space resources, land resources, ecological resources, etc. of the restored mines to build tourist attractions or parks and green spaces Britain has built an Eden with tens of thousands of plants from all over the world by using huge mines left over by clay mining. Since its opening, the number of tourists has exceeded ten million Dangtu County, Ma'anshan City, Anhui Province, has developed and built the Daqingshan Wildlife World Amusement Park based on the landform formed by abandoned mines, which has turned the mines that used to be "riddled with holes" into "tourist attractions"; The abandoned Caojiafang mine in Fangshan District, Beijing has a history of mining for thousands of years. After being closed, after more than ten years of continuous repair, the Bairui Valley Scenic Area has been built, which is "green water, blue mountains, blue sky, and flowers in the west of Beijing", promoting the transformation of traditional mining industry to eco-tourism The mode of culture and education is to develop cultural landscape or popular science education base by using historical culture of mines, leftover production equipment, mining relics, restoration and development history, etc Bohong City, Ruhr District, Germany, Huangshi City, Hubei Province, China, Huai'an City, Jiangsu Province and other regions have built a mining museum or national mining park based on the mining culture, human history, natural scenery, etc. of the mining area, displaying the historical mining technology and other cultural relics of the mining area Huaxia City, Weihai City, Shandong Province, China has built a full angle rotary walking show using large area of mines to show 5000 years of Chinese civilization and national spirit; The ecological civilization exhibition hall was built according to the mountain to show the ecological restoration process of Huaxia City and its achievements The health care model is to use the unique health care resources and environmental resources of the mine to develop the health care industry and build medical and health facilities A salt mine sanatorium has been built in the salt mine theme park in Transylvania, Romania Karbashi State of Ukraine has opened a hospital for treating asthma by using abandoned salt mines with a depth of 206~282 m. According to statistics, the cure rate can reach 84% The mode of sports is to develop sports, leisure and competitive events by using the landscape, natural climate and landscape resources of mines In Illinois, the United States, some open-pit mines have been developed and built into clubs integrating swimming, skiing, hiking and picnicking Michigan has built golf courses with abandoned limestone mines, and developed yacht docks and resort hotels The unique geology, topography and terrain of abandoned quarries have been used in Ningbo, Zhejiang Province, China to build the world's only mountain platform racetrack. The scientific experiment mode is to carry out scientific experiments using the unique deep space formed by mining There is an abandoned gold mine with a mining depth of 2400 m in South Dakota, the United States, which meets the environmental requirements of very deep geological experiments and is used to carry out direct dark matter detection experiments in the field of particle physics The University of Minnesota in the United States uses the underground space resources of abandoned iron ores in Sudan to build a sensitive physics laboratory for dark matter experiments and neutrino experiments Storage protection mode is to use stable temperature and humidity conditions in the mine and concealed and isolated space for underground storage and personnel protection An underground data center has been set up in Pennsylvania to store paper documents, film, photos, etc Due to the low temperature and dry air in the underground space, the storage time can reach 2000 years, and the security level is second only to the secret database of the White House Hangzhou City, Zhejiang Province, China has built an in barrel parking garage using abandoned mines. Compared with traditional parking garages, it can accommodate more vehicles and improve the efficiency of urban land use In addition, many countries around the world have built underground gas storage, oil storage, underground cold storage, shelters for personnel and strategic materials by using abandoned mines Low carbon cycle mode is to develop low carbon cycle industry by using space resources, land resources, light and heat resources in the region where the mine is located Germany, the United States and other countries use abandoned or closed mines to develop compressed air storage power plants, pumped storage power plants, etc. for power generation Dingyuan County, Anhui Province, China has built the largest photovoltaic power station for abandoned mines in the province in abandoned rock mines; Xunwu County, Ganzhou City, Jiangxi Province and Huzhou City, Zhejiang Province respectively built abandoned mines into industrial parks and green intelligent manufacturing industrial parks using green technologies.

4.6.2 Main path to realize the value of ecological products based on mine ecological restoration

Element integration

According to the requirements of the Opinions on Establishing and Improving the Value Realization Mechanism of Ecological Products, we should "accelerate the improvement of the path of realizing the value of ecological products led by the government, participated by enterprises and all sectors of society, market-oriented operation, and sustainable, and strive to build a policy system that transforms" green water and green mountains "into" golden mountain and silver mountain " The institutional and institutional barriers that constrain the improvement of the quality of ecological products, value transformation and market transactions will be gradually removed through institutional adjustment, reconstruction, new construction and other forms, and eventually achieve market-oriented transactions with agricultural products and industrial products Factor integration is the most commonly used means for national and local governments to promote the ecological restoration of mines and the development of continuous industries in a market-oriented way, which is mainly reflected in resources, funds, property rights, policies, etc For example, the long-term rare earth mining in Xunwu County, Ganzhou City, Jiangxi Province has caused a large area of ecological damage. In the process of restoration and development, we adhere to the integrated governance of various resource elements such as "mountains, water, forests, fields, lakes, grasses, mines, roads, landscapes and villages", which has achieved the goal of "working together to tackle difficulties" in project promotion; Through the integration of "mountains, rivers, forests, fields, lakes and grasses" ecological protection and restoration funds, transfer payment funds for national key ecological functional areas, horizontal ecological compensation funds for the upstream and downstream of Dongjiang River, low quality and low efficiency forest transformation funds, joint financing with banks, and active introduction of social capital contributions, a resultant force of funds has been formed to ensure the acceleration of various projects Caojiafang Mining Area, Shijiaying Township, Fangshan District, Beijing, has transferred more than 4700 mu of collective forest land in the area where the mining area is located to the development company with a 70 year contract period, and implemented the integration of multiple rights such as the right to construction, development, operation and income of the restoration project, which fully mobilized the enthusiasm and initiative of the market players The policies of Zoucheng City, Shandong Province, such as land circulation subsidies for comprehensive utilization of coal mining subsidence land, and awards and subsidies for afforestation and greening, encourage the centralized afforestation of barren mountains and ditches, and achieve "online" multi-level greening and "surface" diversified greening Policies such as comprehensive utilization of land reclamation in Pan'anhu coal mining subsidence area, Xuzhou City, Jiangsu Province, and linking the increase and decrease of urban and rural construction land, such as expropriation of collapsed land, acquisition of idle land, relocation of residents in the subsidence area, and transfer of property rights such as land contracting rights and redistribution of business rights of the vacated land provide development space for the industrial development and transformation of the mining area, and safeguard the rights and interests of land owners

Regional coordination

The integration of mine ecological restoration and industrial development with regional development is conducive to broadening the energy carrier for realizing the value of mine ecological products and accelerating the process of industrial development Regional integration mainly includes the integration of mine and mine, mine and city, mine and village For example, Huzhou City, Zhejiang Province has built a green intelligent manufacturing industrial park by planning, designing and managing many closed mines in South Taihu Lake Jiaozuo City, Henan Province, was once prosperous and trapped by coal. In recent years, in order to promote the transformation and upgrading of the industrial structure, establish a new industrial system of sustainable development, comprehensively promote the ecological restoration of mines and the improvement of urban functions, and through the integrated development of mountains, water and cities, it has built a set of leisure tourism, fitness and entertainment, and popular science education, covering mine parks, mountain parks, wetland parks, forest parks The multi-level and multi-functional ecotourism system, such as the green corridor and fast track, has realized the transformation from "black impression" to "green theme" Tangshan, Hebei Province, once faced the same dilemma. The mining activities of more than 140 years have formed a large area of coal mining subsidence area in the city, and the area of Nanhu Lake alone is up to 30 km^2. In order to solve the problem of serious ecological damage, Tangshan City, through systematic investigation and analysis, integrated the treatment of coal mining subsidence area into the construction planning of Nanhu Ecological City, and planned the overall layout of land space after ecological restoration, We also vigorously developed industries such as "ecology+culture", "ecology+sports" and "ecology+tourism", built a national 5A South Lake tourist attraction, a cultural square, a grand theater, a catering culture museum, an intelligent sports post, a new sports center, and a botanical museum, and successfully held the World Horticultural Expo, the TBA Tangshan Basketball League, and the Tangshan International Marathon The South Lake coal mining subsidence area has transformed from the "industrial scar" to the "urban central ecological park", and has successively won the "China Habitat Environment Example Award", "Dubai International Best Example Award for Improving the Residential Environment" and other titles, becoming a new growth point of regional development The treatment of coal mining subsidence land in Zoucheng City, Shandong Province has provided more than 1200 jobs for local villagers through the construction of the "Green Heart" project, which has driven 5000 villagers to develop aquaculture, facility agriculture and other industries, with an increase in per capita income of more than 2000 yuan. At the same time, through the construction of supporting facilities and the development of community greening, the living environment of more than 50000 people has been significantly improved [19].

Industry integration

With the strong support of the government department, the development subject usually adopts the form of aggregation development and multi-point development to promote the transformation of the value of ecological products for the restoration of mines Among them, the aggregation development mainly focuses on the core industry and develops by extending the industrial chain or expanding the relevant industrial types For example, Ruhr District of Germany has built the world's largest mining museum of the same type by using mining machinery equipment and production system of coal mines, built exhibition rooms by using hundreds of meters deep pipes and other machines to transport miners underground, built concert halls, sanatoriums, hotels, etc. by using tens of kilometers of layers of mine tunnels, and displayed Ruhr's century old industrial heritage together with other cultural and tourism industries built by relying on coal mines, steel relics, etc; And because of its rich experience in coal mine ventilation system, wastewater collection and recycling, it has driven the development of environmental protection industry in Ruhr and its state, making it a famous gathering place of environmental protection talents in Germany and providing services for the world Laixi City, Qingdao, Shandong Province, China has built a grape planting base by taking advantage of the geographical advantage of the abandoned mine being located in a suitable place for grape planting, and has built an industrial complex integrating wine cellar castles, manor hotels, international wine trade, business leisure, and healthy outdoor vacations by taking advantage of the abandoned mine pits left by mining [20]. Its products are exported to Europe, America, Japan and other countries and regions The multi-point development mainly relies on various resources left over after mining or develops corresponding industries according to relevant planning and design, and the connection between industries is relatively small For example, the Lianhuashan Mine in Danzhou City, Hainan Province uses the mine resources in the area to develop characteristic tourism, build a mine theater, use the geothermal resources in the surrounding areas to develop health tourism, use the local cultural resources to develop cultural tourism, and introduce fossil resources from other provinces to develop creative entertainment. It has built a national 4A level scenic spot and "the second batch of national forest health demonstration bases" Xunwu County, Ganzhou City, Jiangxi Province has built industrial parks and photovoltaic power stations on the treated industrial and mining wastelands, planted characteristic cash crops, developed tourism, science popularization, sports fitness and other industries, and realized the two-way integration of ecological industrialization and industrial ecology.

5 ECONOMIC EFFECTIVENESS OF ENVIRONMENTAL MEASURES

5.1 Economics and environmental protection

Economic effectiveness is a means of measuring the efficacy and purposefulness of a given business activity given by the comparison (ratio) of the value of the obtained effects to the factors invested in order to achieve them [20].

Economics explains how people survive. It concerns the ways in which individuals and groups act to attain what they want in terms of income, subsistence and other goods and services which they feel will provide them with an adequate quality of life. Economics basically addresses the problem of scarcity – how to fulfil people's unlimited needs and aspirations from a scarce resource base in a way which is both equitable and efficient.

Incorporating environmental concerns into economics involves introducing concepts of sustainability into scarcity. It deals with the issue of how to meet people's current needs in a way which is both equitable and efficient and does not diminish the supply or quality of environmental goods and services available for future generations.

If the environmental resource base is conserved it will continue to provide these economic benefits and support human production and consumption in the future. If it is destroyed or environmental quality declines, such goods and services will decrease and human economies will suffer as a result, at global, national and local levels [21].

Economics is also linked to the environment because economic forces contribute to environmental degradation. While environmental resources support economic production and consumption opportunities, the same economic activities impact back on the environment through using up non-renewable environmental goods and services, by converting environmental resources to other uses and by adding waste and effluent to the environment. A decline in environmental quality and resources impacts on economic activities by diminishing the amount of goods and services available for future production and consumption, and by progressively precluding economic activities. Economic opportunities spiral downwards as the environment becomes more and more degraded.

This downward spiral has implications for both economic efficiency – the sound use and management of scarce resources to generate output, and equity – the access of different groups and individuals to secure livelihoods and economic opportunities. The people who bear the costs of environmental degradation are not necessarily those who are causing degradation, spatially or temporally. For example, many of the indirect or knock-on effects of environmental degradation such as bad health, loss of productive opportunities and ecological disaster are felt by poorer people who lack the resources to cope with these costs, or will be felt by future generations as a result of activities carried out today. Environmental degradation also incurs substantial costs to governments, who bear the overall responsibility for maintaining the basic quality of life in a country.

It is clear that production and consumption activities can lead to a downward spiral of environmental degradation, economic costs and loss of productive opportunities. Conversely, environmental conservation can lead to an upward spiral of economic growth and benefits. A major challenge is to ensure that sound environmental management systems are set in place which will enhance current opportunities for production and consumption at the same time as sustaining economic growth in the future.

A range of policy factors, as well as broader socio-economic conditions such as poverty and land pressure, put people in a situation where it makes more economic sense to them to degrade the environment in the course of their day-to-day economic activities than to conserve it. There is often little immediate or tangible economic gain to conserving the environment, and many gains and profits from mining, depleting, polluting or converting it. People are often unwilling − or economically unable − to conserve the environment, because there is no personal benefit to them in doing so.

Economic analysis provides a useful set of tools understanding the forces which lead to environmental degradation. Economic measures can encourage people to conserve the environment by setting in place the conditions which result in their being economically better off by doing so. They aim to make sure that producers and consumers take into account the real value of the environment and the real cost of environmental damage when they make decisions.

Basic tools for the use of economics for environmental planning and management are as follows [22]:

Identifying environmental economic benefits and costs: ensures that the economic impacts of environmental activities, and the environmental impact of economic actvities, are understood and made explicit in both conservation and development planning and management.

Valuing environmental economic benefits and costs: provides important information which can be integrated into both development and conservation planning and management. Making monetary estimates of environmental values means that they can be considered, and given equal weight, alongside other sectors of the economy, benefits and costs.

Analysing the profitability of economic activities in terms of their environmental effects: provides a framework within which to use information about environmental costs and benefits and their values for decision-making. It provides basic measures of whether a policy, programme or activity can be judged desirable in environmental and economic terms.

Highlighting the economic causes of environmental degradation and the need for economic measures for environmental conservation: points to areas and groups where there is a need for the use of economic measures to provide incentives and finance for environmental conservation. It forms the basis of identifying and planning conservation activities.

Setting in place economic incentives for environmental conservation: forms a cross-cutting component of environmental planning and management. Unless people are provided with positive incentives to conserve the environment in the course of their economic activities, and the perverse incentives which encourage environmental degradation are overcome, environmental programmes and projects are unlikely to succeed.

Financing mechanisms for environmental conservation: form an important part of environmental planning and management because they provide the basic funding which enables environmental projects, programmes and activities to be carried out.

Ensuring that economic measures for conservation are appropriate and sustainable: means that they are practically implementable in different social, cultural, institutional and ecological situations.

5.2 Calculation of the financial profit of resource saving

Net financial result due to the implementation of resource-saving measures in company is calculated by the equation:

$$FP = t \cdot (C_f + p_e + p_h) - I_t \quad (5.1)$$

where:

t is time of implementation of resource saving measures, years;

C_f is the cost of fuel saved, USD/year;

p_e is the payment for emissions of pollutants into the environment, USD/year;

p_h is the payment for damage to public health, USD/year. We accept equal to 0 USD;

I_t is the investment in resource-saving measures, USD.

Cost of fuel saved:

$$C_f = Pr \cdot N_f \quad (5.2)$$

where:

Pr is the price for fuel (1 m^3 of natural gas - 0.38 USD, 1 ton of coal – 125 USD);

N_f is the amount of fuel saved or the amount of fuel that would need to be burned to obtain energy produced by alternative sources. In fact, N_f is the total amount of fuel used by company (then we suggest that we completely replace it with alternative energy).

Payment for emissions of pollutants into the environment:

$$p_e = (M_1 \cdot r_1) + (M_2 \cdot r_2) + ... + (M_n \cdot r_n) \tag{5.3}$$

where *M* is the amount of pollutant emission, ton:

$$M = q \cdot N_f \tag{5.4}$$

where *q* is specific emission of pollutant:

for coal: SO_2 – 30 kg/t, NO_x – 9 kg/t, CO – 55 kg/t

for natural gas: SO_2 – 0.0037 kg/m^3, NO_x – 0.0031 kg/m^3, CO – 0.0051 kg/m^3.

r is fee rate per ton of pollutant, USD/t (see Table 5.1).

Table 5.1. Fee rate for pollutants [23]

Pollutant	**rate, USD/t**
Nitrogen oxides	75
Ammonia	15
Sulfur dioxide	75
Carbon monoxide	3
Hydrocarbons	5

Investments (e.g., in wind or solar energy) are calculated as follows:

$$I_t = k \cdot N_f \cdot T / 8760 \tag{5.5}$$

where:

k is the specific investment in the production of 1 kWh of energy (for wind turbines k = 500 USD/kWh, for solar panels k = 900 USD/kWh);

T is the heat capacity of the fuel to be replaced (7.5 kW/t for coal and 8.8 kW/m^3 for natural gas).

Calculate the net tresult from the implementation of resource saving measures in coal mining company. The company mines 16000 ton of coal per year and is going to replace it with wind turbines). The project implementation period is 5 years.

1. Time of implementation: t = 5 years
2. Amount of fuel used (= amount of fuel saved): Nf = 16000 t/year
3. Cost of fuel saved: Cf = Pr · Nf (Eq. 5.2).

The price for coal Pr = 125 USD/t.

Then, Cf = 125 USD/t · 16000 t/year = 2000000 USD/year

4. To calculate the payment for emissions of pollutants (p_e), we need to know amount of pollutant emission (M) for each pollutant (see Eq. 5.4):

Pollutant 1. Nitrogen oxides. q1 = 9 kg/t (see specific emission of NOx for coal). Then, M1 = q1 · Nf = 9 kg/t · 16000 t/year = 144000 kg/year = 144 t/year.

Pollutant 2. Sulfur dioxide. q_2 = 30 kg/t (see specific emission of SO_2 for coal). Then, $M_2 = q_2 \cdot Nf$ = 30 kg/t · 16000 t/year = 480000 kg/year = 480 t/year.

Pollutant 3. Carbon monoxide. q_3 = 55 kg/t (see specific emission of CO for coal). Then, M3 = q3 · Nf = 55 kg/t · 16000 t/year = 880000 kg/year = 880 t/year.

5. From Table 5.1:

for NOx r_1 = 75 USD/t

for SO_2 r_2 = 75 USD/t

for CO r_3 = 3 USD/t

According to Eq. 5.3:

$p_e = (M_1 \cdot r_1) + (M_2 \cdot r_2) + (M_3 \cdot r_3)$ = (144 t/y·75 USD/t) + (480 t/y·75 USD/t) + (880 t/y ·3USD/t) = 46440 USD/year

6. Specific investments for wind turbines k = 500 USD/kWh, heat capacity for coal T = 7.5 kW/t.

Then investments:

It = k·Nf·T / 8760 = 500 USD/kWh · 16000 t/year · 7.5 kW/t / 8760 h/year = 6848 USD

7. Financial result (Eq. 5.1):

FP = t (Cf +p_e +p_h) – It = 5 y · (2000000 USD/y + 46440 USD/y + 0) – 6848 USD = 10240000 USD.

Therefore, implementation of resource-saving measures in company (use of wind turbines for energy production) would lead to income 10.24 million USD during 10 years.

CONCLUSIONS

Strengthen the overall planning and systematic thinking of mine ecological restoration. Ecological restoration of abandoned mines involves not only environmental issues, but also industrial development, rural revitalization, cultural tourism and other aspects, so it is necessary to strengthen planning and systematic thinking. First, the ecological restoration and management of mines should be integrated into the land space planning and ecological restoration planning, adapt to regional major strategies, major ecological restoration projects, focus on key areas, and formulate restoration goals according to the functional orientation of ecology, agriculture, and urban space. Second, it is necessary to break through the limitation that traditional mine environmental governance only focuses on the mining area, strengthen the organic coordination with the surrounding overall ecosystem in the design of governance scheme, highlight the overall restoration of mountains, rivers, forests, fields, lakes, grass and sand, and transform to improve the comprehensive efficiency of the social economic natural composite ecosystem. Third, in terms of work promotion, it is necessary to strengthen the coordination of natural resources, ecological environment, agriculture and rural areas, and integrate mine ecological restoration with rural revitalization, pollution prevention and control, industrial transformation, public infrastructure construction, especially with rural characteristic towns, pastoral complexes, and other organic integration to achieve space, ecology, and industry reconstruction.

The selection of restoration mode should be based on local conditions, with one mine and one policy. The transformation direction of mine ecological restoration and management is to put more emphasis on the use of diversified and market-oriented mechanisms to promote the transformation, upgrading and comprehensive utilization of mines on the basis of disaster elimination, greening and ecological restoration. The exploration of various new models has been successful in Beijing and other regions. In addition to the above three models, some regions have also explored the reuse of sand and gravel, garbage treatment plants, storage and other models. Each model has its own advantages and disadvantages. Therefore, the selection of mine ecological restoration governance mode should be based on the comprehensive analysis of the regional geology, local customs, economic development level, advantageous industries, etc. of the mining area, adhere to the principle of ecological priority, achieve the organic combination and cross use of different modes, adhere to the local conditions, one mine, one policy, design personalized and diversified restoration plans, avoid cutting across the board, and avoid blindly copying. Among them, we should pay special attention to soliciting opinions and suggestions from local people, actively accept public supervision, enhance the transparency of ecological restoration of mines left over by history and the public's right to know, and effectively protect the legitimate rights and interests of the people.

Improve policies and measures to stimulate market vitality. The ecological restoration of mines mainly depends on the government. The lack of market vitality is a common problem in most areas of China. It is the current policy requirement to take multiple measures to stimulate market vitality, and it is also an inevitable path to accelerate the ecological restoration of mines in the future. In order to stimulate the market-oriented operation mode of third-party governance enterprises, relevant policies, measures and rights protection still need to be further improved. First, we should clarify the subject of property rights. For mines with clear subject, we should adhere to government guidance and enterprise governance. For mines that have been lost for many years and whose subject is unknown, we should first clarify the property rights, solve the problems left over by history, and lay the foundation for introducing market subjects. Second, we should break through the policy barriers in land use, such as defining the types of ecological restoration projects for abandoned mines, and refining the rules for the transfer of indicators of land for construction. At the same time, we will formulate financial support policies to promote the development of the mine ecological restoration industry and attract market players. The third is to establish a mechanism for market selection of projects. The government departments should make targeted use of mine restoration, create a new ecological industrial chain, cultivate new local economic growth points, and explore the realization mechanism of ecological value of mine restoration.

Promote integrated innovation and application of remediation technology. First, we should give play to the leading role of state-owned enterprises in the industry. Local governments should actively introduce competent enterprises to undertake mine ecological restoration projects, create a government industry university research cooperation model for mine ecological restoration, build an innovation cooperation platform, give play to the advantages of all parties, and accelerate technology integration innovation and application. The second is to further guide the standardization of mine ecological restoration technology. Relying on the theory and technical strength of industry associations, summarize and sort out the technical application practice of current typical mine ecological restoration, study and formulate technical framework systems under different restoration modes, form relevant industry standards and technical specifications, and deeply explore the establishment of a technical support system for resource reuse and ecological value realization. Third, all regions should strengthen the construction of geological environment monitoring platforms in mining areas. We can fully rely on the existing technical advantages of geological exploration units, continue to set up geological environment monitoring points in the treated mining areas, use information technology to dynamically track and analyze the treatment effect, timely feed back new problems and new situations, and actively take countermeasures.

The ecological restoration and management of mines will still be an important environmental governance issue in the future. Respecting history, fearing nature, adapting measures to local conditions, and implementing policies based on mines, and gradually promoting the construction of a long-term mechanism led by the government and participated in by multiple factors are the inevitable choice to promote the ecological restoration and management of mines in China. In general, the realization of the value of ecological products relying on the ecological restoration of mines in China is still at the initial stage. In further practice, the government departments, mining enterprises and other market entities need to work together to strengthen the top-level design on the basis of fully considering the characteristics of natural resources in the mine and the region where the mine is located, social and economic development conditions, and constantly improve the evaluation system and institutional system for the achievement of the value of mine ecological products.

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APPENDIX A

Technical task

Ministry of education and science of Ukraine
Vinnytsia National Technical University
Faculty of Construction, Civil and Environmental Engineering

APPROVED
Head of the Department
ECEPT
Prof. V. Petruk
____
27.09 2022

TECHNICAL TASK

for master thesis

"Environmental safety of mine wasteland remediation"
specialty 183 – Environmental protection technologies

08-12.МКР.104.01.01 ТЗ

Supervisor: PhD, Dr.
____________________ R. Petruk
(signature)
«27.09» 2022

Student: group 2ТЗД-21м
Haiyan Wang Haiyan
(signature)
«27.09» 2022

Vinnytsia VNTU 2022

1. Basis.

The basis for master thesis preparing is the order of VNTU No. 203 on "14" 09 2022, and individual task approved by protocol of Department ECEPT No. 3 on "21" 09 2022.

2. Goal.

The goal is to assess environmental impact of mining industry in China and to analyze the methods of mine wasteland restoration.

3. Input data.

Iron ore reserves of China as of 2021ares 16.124 billion tons.

4. Research methods

Analysis, mathematical modelling, environmental impact assessment, statistical methods.

5. Stages and deadlines

No	Stages of master thesis	Deadline
1.	Technical task	
2.	Literature review	
3.	Overview of China's mineral resources	
4.	Adverse impact of mining on the environment	
5.	Smart mine safety management model and system	
6.	Mine reutilization for environment restoration	
7.	Conclusions, literature list	

6. Area of use

The government can use these results to reduce the impact of mines on the environment.

7. Requirements

Main part and illustrative part.

8. Procedures

Public defense «27» 06 2024
Beginning of writing «27» 06 2024

Finish due to «27» 06 2024

Student Haiyan Wang Haiyan

APPENDIX B

PROTOCOL
OF CHECK FOR PLAGIARISM

Title of work: Environmental safety of mine wasteland remediation

Type of work: master thesis

Department Ecology, Chemistry and Environmental Protection Technologies

Similarity report by Unicheck

Originality 90,8% Similarity 9,2%

Analysis of similarity report (mark the relevant)
1. Similarities found in the work are correctly formatted and may not be considered as plagiarism.
2. Similarities found in the work may not be considered as plagiarism, but their large amount results in doubts about the value of the work and the lack of independence of the author during writing. The work has to be assessed by expert committee of the Department.
3. Similarities found in the work may be considered as plagiarism.

Person responsible for the check M. Matusiak

Acquainted with the similarity reportgenerated by Unicheck:

Author Haiyan Wang Haiyan
Supervisor R. Petruk

APPENDIX C

ILLUSTRATIVE PART

ASSESSMENT OF ENVIRONMENTAL POLLUTION BY CHEMICAL INDUSTRY

Table C.1 – Evaluation index system of mine ecological environment protection and restoration

Target layer O	Criteria layer A	Sub criteria layer B	Indicator layer C
mine ecology environment protect And recovery government	Ecological environment protection A1	Mine wastewater treatment B1	Domestic wastewater treatment rate C1
			Domestic wastewater treatment rate C2
		Solid waste treatment B2	Comprehensive disposal rate of production solid wastes C3
			Boiler slag safety disposal rate C4
			domestic waste disposal rate C5
		Treatment of flue gas and dust in mining area B3	Boiler flue gas desulfurization and dust removal compliance rate C6
			Compliance rate of production dust control C7
			dust control rate of transportation C8
		Water resource protection in mining area B4	Compliance rate of surface water protection C9
			Compliance rate of environmental groundwater protection C10
	Ecological restoration and management A2	Greening measures in mining area B5	Greening rate of industrial square C11
			Greening rate of dedicated road C12
		Ecological restoration and control of subsidence crack area B6	greening rate of suitable forest land C13
			Ecological restoration and control rate of historical subsidence crack area C14
		Ecological restoration and rehabilitation of abandoned wasteland B7	Recovery and control rate C15
			Recovery and treatment rate of village relocation site C16
		Ecological restoration and control of gangue yard B8	Ecological restoration and control rate of slope protection and top of gangue yard C17
		Ecological restoration of borrow pit Ecological restoration control rate of borrow pit B9	Ecological restoration of borrow pit Ecological restoration control rate of borrow pit C18
	Capacity building of ecological monitoring A3	Monitoring facilities equipped with B10	Allocation rate of monitoring facilities C19
			online monitoring rate of wastewater discharge after treatment C20
		On line monitoring rate of pollutant emission B11	On line monitoring rate of pollutant emission B11 boiler desulfurization and dedusting C21
		Surface deformation and subsidence monitoring Surface deformation in B12	Monitoring rate of surface deformation and subsidence in mining area C22

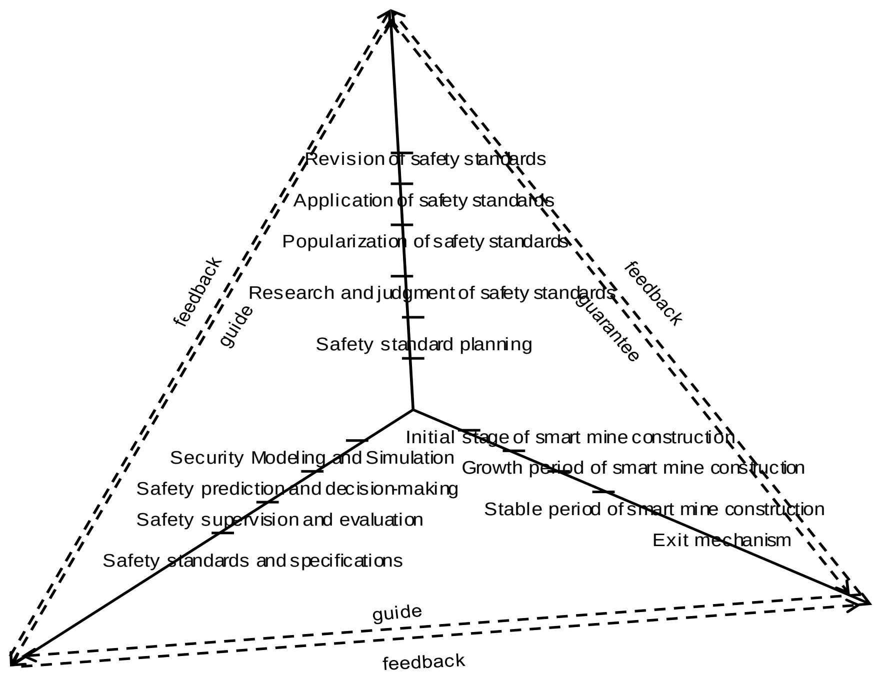

Figure C.1 – Standard 3D framework structure of smart mine

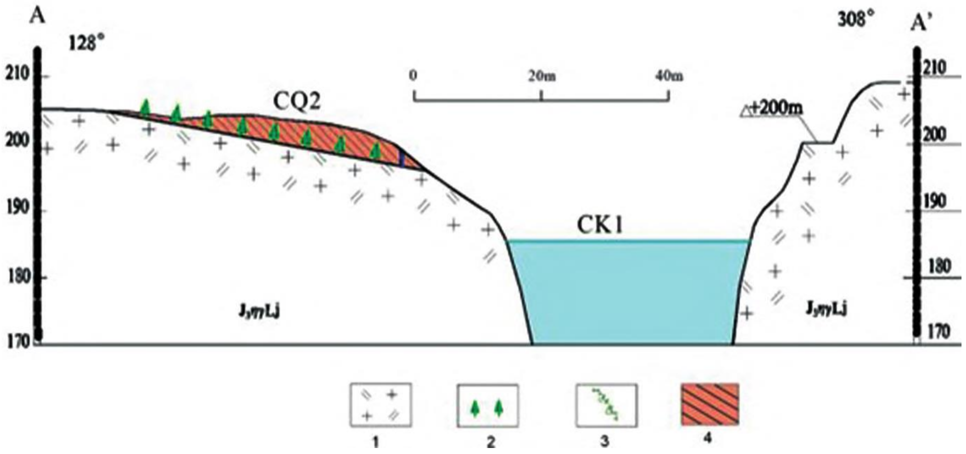

Figure C.2 – Schematic diagram for blasting leveling of residual hillock:
1 – monzogranite; 2 – planting black pine; 3 – planting parthenocissus tricuspidata;
4 – blasting leveling part of monadnock

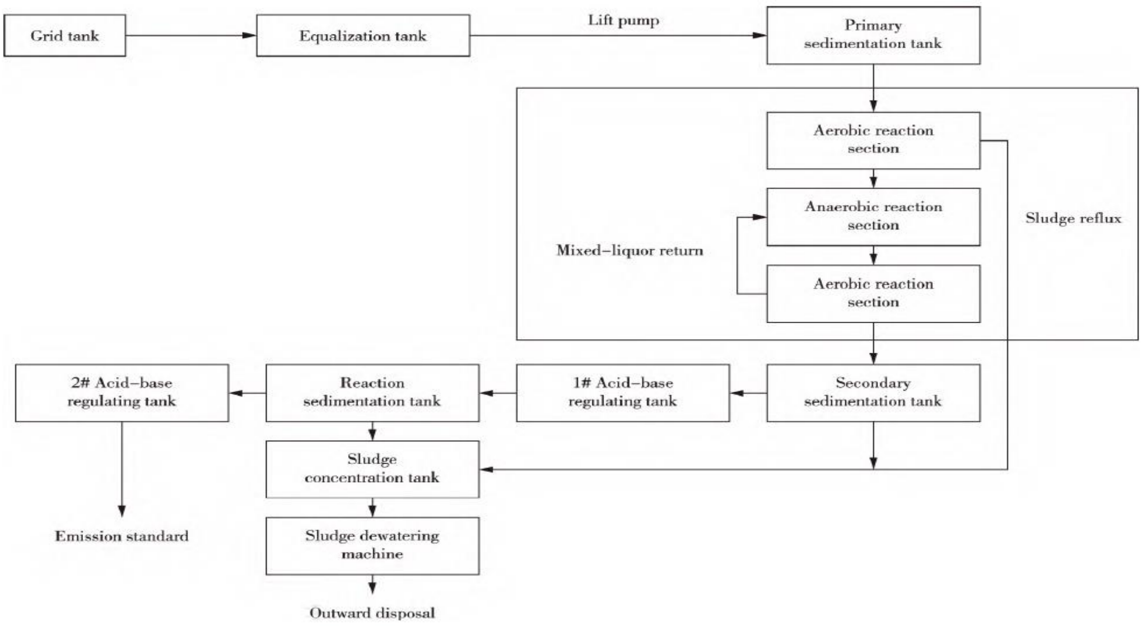

Figure C.3 – The process diagram of tailwater collection and utilization treatment plant