Prevention of Metal Tailings Based on Ecological Safety

Zuohua Miao\(^1,2\), Cheng Yan\(^1,\ast\), Likun Liu\(^1\), Lei Ren\(^1\) and Yong Chen\(^1,2\)

\(^1\)School of Resources and Environmental Engineering, Wuhan University of Science and Technology, Wuhan, China
\(^2\)Hubei Key Laboratory for Efficient Utilization and Agglomeration of Metallurgic Mineral Resources, Wuhan, China

\*Corresponding author e-mail: ycwust123@163.com

Abstract. The tailings pond is a place for storing industrial solid wastes in mines. Due to insufficient mining, the tailings contain a variety of heavy metals. The heavy metals discharged into the tailings pond will pollute the soil and groundwater and affect the ecological environment. The comprehensive utilization of tailings is inappropriate. Will cause pollution transfer. This article analyzes the environmental pollution and ecological damage of the tailings pond, and puts forward the comprehensive utilization of tailings, the anti-seepage of the tailings pond and the environmental supervision during the construction period, follow-up inspection, tailings treatment and ecological environmental protection and restoration treatment, which effectively alleviates the tailings pile. Environmental pollution and safety hazards caused by after the tailings mining is completed, effective ecological reconstruction measures are taken to reduce pollution and protect the surrounding environment.

1. Introduction

Mineral resources are an indispensable and important element of human life and production, and provide a lot of raw materials and energy for industrial production. China's annual production of non-ferrous metals ranks in the forefront of the world. After the mining resources are extracted, it will inevitably produce many tailings that are difficult to handle. However, due to the limitations of production technology and management methods, non-ferrous metals cannot be fully recovered, which greatly wastes resources, and the heavy metals remaining in the soil also destroy the ecological environment. Therefore, fully integrating the actual situation of domestic non-ferrous metal tailings, improving the comprehensive utilization rate of metal tailings has far-reaching significance for ecological security.

In the field of mining and metallurgy, industrially developed countries in the world have regarded waste-free mines as the development goals of mines, and the comprehensive utilization of tailings as a sign of measuring a country’s technological level and economic development. The purpose of its utilization is not only to pursue the maximum economic effect, but also to comprehensively consider the comprehensive recovery of resources and the protection of the ecological environment.

At present, the comprehensive recovery of tailings from developed countries such as the United States, Russia, and Canada has done a good job. For example, the United States International Mining and Chemical Company comprehensively recycles lead in copper and nickel tailings, and can obtain 600,000 tons of lead metal annually. Canada's largest barite-siderite is magnetically separated by a
strong magnetic separator, and it can obtain siderite concentrate with a recovery rate of 70%; and a recovery rate of 65%-70% barite concentrate. With the development of science and technology and the interpenetration of disciplines, the ways of using tailings are getting wider and wider. Some small European countries have developed towards waste-free mines, and the utilization rate of tailings can reach more than 60%. Russia uses tailings as a building material accounted for about 60%, and can now use iron ore tailings to manufacture glass-ceramics, chemical-resistant glass products and chemical pipes; Bulgaria uses quartz recovered from tailings as cement inert Mixtures and copper smelting fluxes; some mines in the Czech Republic added flotation tailings mortar, finely ground lime and barite to the pigment and pressed them into colored lime sand bricks [1].

At present, the recovery rate of the vast majority of metal tailings mineral resources is generally low, and the processing equipment and processing technology are relatively backward. Compared with the recovery rate of 75% abroad, the recovery rate in my country is only about 38%. This low utilization rate of mineral resources not only causes a lot of waste in my country’s mining resources, but also produces a huge number of tailings every year. There is currently no good method for the disposal of tailings. Except for a few tailings that can be recovered as concentrate or used as building materials, fertilizers, etc., most of the tailings are piled up in the open air or directly discharged into the tailings pond. At present, the comprehensive utilization rate of tailings piled in my country is only about 8.2%. A large number of tailings piled up have caused huge direct and potential harm to the ecological environment: tailings piled up occupy a lot of land resources; heavy metals released by tailings have a serious impact on the surrounding ecosystem and threaten human health; metal sulfide tailings are in Under the combined action of air, water and microorganisms, oxidation produces a large amount of acidic mine wastewater, releasing a large amount of toxic and harmful heavy metal ions and sulfate ions, which has a serious impact on the surrounding and downstream environment of the mining area, and poses a threat to human health through the food chain [2]. How to reduce or eliminate the environmental pollution caused by metal tailings is one of the major problems facing the current environmental protection.

2. Impact of heavy metal tailings ponds on the ecological environment

2.1. Impact on the air
The main impact of metal tailings ponds on air is wind erosion and dust, mainly from the tailings sediment beach. During the operation of the tailings pond, the tailing slurry is evenly dispersed and discharged from the dam. Under the action of gravity, the tailings slurry will form a water accumulation area at the tail of the reservoir and a dry shoal surface in front of the dam. Due to the fine particles of tailings deposited on the shoal, the tailings sand accumulated during discharge overflow will cause capillary rise, which will increase the water content of the surface tailings sand, which can partially suppress the generation of wind erosion dust [3]. According to the process requirements, the particle size of the tailings sand is generally less than 0.075mm and accounts for more than 70% of the total tailings. The specific particle size distribution is shown in Table 1:

| Composition of particulate matter | dp | d_{10} | d_{50} | d_{60} | η  |
|----------------------------------|----|--------|--------|--------|----|
| 0.075mm                          | 0.038mm | 0.020mm | 0.010mm |
| 6.0%                             | 28.2%  | 27.6%  | 24%    | 0.033mm | 0.026mm | 0.035mm | 0.01mm | 3.5  |

Where \( d_p \) is the weighted average particle size; \( d_{10} \), \( d_{50} \), and \( d_{60} \) represent the masses less than 10%, 50%, and 60% of the particle size; \( η \) is the unevenness coefficient.

\[ η = \frac{d_{60}}{d_{10}} \]
When the tailing mud deposits and the water evaporates, the fine dust on the surface of the deposited dry beach condenses and crusts, as long as the dry beach surface is not damaged, regardless of the moisture content of the tailings dust, the maximum experimental wind speed \( U=1.048 \text{m/s} \) will not make it dusty [4]. After a long period of wind and sun, the dry beach surface will be destroyed, and the bottom dust will gradually dry out, and dust may occur under the action of wind force. Once the dust is generated, the impact range is large, so measures such as regular watering of the tailings shoal surface and covering a certain thickness of gravel blocks are needed to reduce the impact of the tailings pond particulate pollutants and other harmful substances on the surrounding area environment pollution.

2.2. Impact on soil

The influence of the tailings pond on the surrounding soil is mainly through two ways: dust and infiltration. The main ways for the heavy metals in the tailings pond to enter the soil near people are: tailings are accumulated in the tailings pond for a long time, and the wastewater enters the nearby soil through infiltration; the surface runoff enters the downstream hydrological system or infiltrates into the groundwater, Runoff also carries heavy metals into the soil flowing through; rainwater scours into the soil [5], for example, Figure 1:

![Figure 1. Metal seeping into the soil.](image)

2.3. Impact on ecology

Heavy metal-bearing tailings damage the ecological environment very seriously. The sulfide in them produces acidic water to further leach heavy metals. The loss will cause harm to the entire ecological environment, while the chloride, cyanide and sulfide residues in the tailings, Flocculants, surfactants and other toxic and harmful agents, when the tailings are stored for a long time, they will be affected by air, moisture, sunlight and self-interaction to produce harmful gases or acidic water, which will aggravate the loss of heavy metals in the tailings and flow into the arable land. Destroying crop growth or polluting crops will increase the heavy metal content in crops by a factor of ten or more; the flow into the water system will also contaminate surface water bodies or groundwater sources, poisoning aquatic organisms [6]. As the storage capacity of the tailings reservoir increases, it will inevitably lead to the gradual coverage of the mountain slopes upstream of the dam. As the coverage area increases, it will affect the surrounding wild animals and plants and their habitats. The destruction of the habitats directly leads to the instability of the regional ecosystem has caused a certain degree of damage to the ecological environment and connectivity within the region. At the same time, the construction of the tailings dam will destroy local mountain surface vegetation in the reservoir area, and at the same time cause a larger space exposed surface, affect the mountain surface vegetation, local continuity and connectivity of the rock and soil mountain, produce bad visual impact, and produce landscape impact.

3. Prevention measures of tailings pond

3.1. Damming process

At present, the mine uses a more mature damming process as tailings pool filling damming process. The dam-building process of pool filling method can make full use of the natural deposit law of
tailings coarse sand, improve the beach top elevation, solve the problems of slow sedimentary beach slope and slow tailing sand soil consolidation speed, and can meet the requirements of safe operation of tailings ponds in flood season.

The specific method is as follows: firstly divide several small pools on a dam construction section, nearly square, the side of the pool is 20m long, then use artificial or mechanical construction to enclose the ridge, the ridge is 0.5m high, the top width is 0.5m, and the slope is about 1:1 Then, install an overflow pipe, the overflow pipe adopts DN50 steel pipe, the distance is 5m, a total of 10 pieces, the top of the overflow pipe is 0.1m lower than the top of the field, and the water inlet of the overflow port is located at a distance of 2m near the inner side of the field. The outlet is set at 2m outside the dam, which is convenient for recovery. After the construction of the enclosure, scattered ore is used to flush and fill the pool, coarse particles are deposited in the pool, and fine particles are discharged into the reservoir along with water from the overflow pipe. When the alluvial deposit reaches the top of the ridge, stop the ore mining, dry for a period of time, and then build the surrounding ridge, repeat the above operations until the required sub-dam height is reached [7]. The advantages of tailings dam construction technology are simple process, low dam construction cost, no need of large mechanical equipment, high density of dam body, not easy to permeate, and high utilization factor of storage capacity; the disadvantage is that someone needs full care during the dam construction process, which is difficult. It takes a long time to form a dam and is greatly affected by the quality of the tailings.

3.2. Vegetation greening

Due to the low grade of ore, the beneficiation requires fine grinding ore particles, and the tailing particles of the dam are also fine, and the higher the height of the dam, the greater the wind speed at the top of the dam, thereby increasing the occurrence of dust in the tailings reservoir. After the heightening of the dam is completed, the fine sand on the surface of the dam is likely to form dust after drying, which will adversely affect the surrounding environment. After the heightened dam is covered with green, it can effectively avoid the impact of dust, and can greatly reduce the impact of rain on the scouring of the dam, prevent the surrounding water pollution, and ensure the safety of the tailings pond.

The greening method is to plant grass soil on the slope of the dam covered with grass bags, covering a thickness of 25cm, and no seams can be left between the grass bags. The crest of the dam is covered with 20cm thick planting soil. The thickness of the overlying soil must be uniform and compacted. The crest of the dam forms a slope toward the drainage outlet to facilitate drainage of the crest [8].

3.3. Drainage facilities

The purpose of the construction drainage facilities is to drain the precipitation during the rainy season and seepage from the seepage pipes in time to prevent the dam area from immersing in the dam body and causing the dam body to become unstable.

The longitudinal drainage ditch shall be built on the surface of the outer slope of each sub-dam, which shall be consistent with the vertical drainage ditch of the sub-dam of the next level. A horizontal drainage ditch is built at the foot of the dam with a drainage pipe. The horizontal drainage ditch is designed with a slope of 1% from the middle point of the connection of two adjacent longitudinal drainage open ditch to both sides [9].

The construction method of the longitudinal drainage ditch adopts the brick bottom and the two retaining walls are bricked. The ground between the two-stage sub-dam drainage chute is covered with concrete, and a slope of 1% is formed towards the outside of the dam. The horizontal drainage ditch adopts brickwork structure, and uses cement mortar to wipe the surface.
4. Ecological reconstruction of tailings pond

4.1. Soil improvement and surface covering technology of tailings pond

The improvement of the tailings pond soil should adopt different methods according to different tailings properties. For acidic tailings sand, lime admixture can be used; for alkaline, calcium chloride, gypsum, etc. can be used as modifiers. Tailings sand generally contains toxic heavy metal elements, which is not good for plant growth, and the method of laying isolation layer is generally adopted. The isolation layer is covered with a layer of substances that can react with heavy metals to precipitate them, such as lime, calcium silicate, furnace ash, steel slag, fly ash and other sulfur-containing substances, which can react with heavy metals to form sulfide precipitates and reduce diffusion of heavy metals. After the isolation layer is covered, the soil shall be covered, and the thickness can be determined according to the direction of the tailings pond. The cover soil layer with agriculture as the direction of use should be relatively thick. Generally, it is 0.5~1.0m; it can be thinner in the direction of planting trees and grass, 0.05~0.3m is enough [10]. Some tailings ponds do not require rapid restoration of vegetation, and can be planted directly without covering the soil. However, due to the relatively poor tailings sand, appropriate improvements can be made by mixing soil, organic fertilizer, domestic waste and sawdust. In areas with soil sources, after the tailings pond is covered with a soil layer, agriculture and forestry can be reconstructed; if there is a relative shortage of soil sources, the stripped topsoil can be stored elsewhere at the beginning of the tailings pond construction and wait for the tailings When the library is closed, it is used as a covered soil source.

4.2. Screening and planting of plants planted in tailings ponds

Plant heavy metal-tolerant plants and legume nitrogen-fixing plants on the tailings, use plant roots to accumulate heavy metals or change heavy metal forms, reduce the toxicity of tailings heavy metals, reduce the transfer of heavy metals to the surrounding environment, increase the content of organic matter in the soil, and improve the living space of animals and plants, To provide an environment for the survival and reproduction of microorganisms in the soil, which can effectively reduce the degree of pollution to the surrounding environment [11]. Plants for ecological reconstruction of tailings ponds should be combined with the recovery direction of tailings, and plants with strong resistance, infertility, absorption or fixation of harmful elements should be selected. Especially in the early stage of reconstruction, local plants should be considered as pioneer plants. Studies have found that legumes and gramineous plants can be used as preferred pioneer plants, such as alfalfa, clover and other gramineous plants have a strong nitrogen fixation ability, can effectively increase the nitrogen content in the soil, effectively improve the tailings environment, these green manure plants replacement after that, it can increase the content of organic matter in the soil and increase the porosity of the soil [12]. There are also some plants with strong vitality, large biomass, strong resistance to heavy metals, and certain absorption and fixation effects, such as sea buckthorn, purple locust, black locust, ryegrass, oleander, etc. In addition, the plant screening process should pay attention to species diversity, use mixed species, establish a multi-layer configuration of arbor, shrub, grass, and vine, and gradually form an independent and balanced ecosystem.

5. Conclusion

Judging from the operation of the tailings pond in recent years, the comprehensive management of the tailings pond has played a huge role in the production process, ensuring that the tailings pond serves the purpose of production and maximizes its effectiveness. At the same time, the safety and environmental protection requirements of the tailings pond are guaranteed, so that the tailings pond can get along with the local ecological environment, making a big step for the mine to build an ecological mine. The ecological reconstruction design can effectively control the late pollution of the tailings reservoir and greatly improve the ecological environment such as waters, soil, and atmosphere. Relevant designers should raise awareness of environmental protection, combine the different properties of tailings and local geological environmental conditions, and adopt targeted design
schemes to truly achieve local conditions, fortify against hazards, and give priority to prevention and benefit first.

Acknowledgments

This work was financially supported by the National Natural Science Foundation of China (41071242 and 41701624 and 41271449) and Educational Commission of Hubei Province of China (D20131104).

References

[1] Zhixue J, Zhiguo L, and Xin W. Research on the beneficiation process of a rare earth mine abroad [J]. Modern Mining, 2019, 35 (11): 168-171.
[2] Xuhui Z. Problems and improvement measures in the development of mineral processing technology in my country [J]. World Nonferrous Metals, 2020 (03): 61-62.
[3] Ronghai L, Miao Y et al. Research on comprehensive treatment measures of dust in tailings pond [J]. Metal Materials and Metallurgy Engineering, 2012, (40): 135-139.
[4] Jingang H, Yaxian Z, Fei Y, and Zhenshi G. Difference analysis of physical and mechanical properties of tailings of high-stack tailings dam [J]. China Luye, 2016, 40 (01): 24-28.
[5] Jingmeng Z. Analysis of the environmental protection and anti-seepage design of the tailings pond [J]. China New Technology and New Products, 2019 (22): 84-85.
[6] Yingzi Z. On the anti-seepage measures and ecological reconstruction of tailings ponds [J]. Mining Engineering, 2017, 5 (3): 55-57.
[7] Luofa F, Qiang S. The dam construction by pool filling method improves the height of tailings flooding [J]. Mining Express, 2018, (12): 101-102.
[8] Chunfeng Z, Wenjia Z. Afforestation technology of abandoned land in mine [J]. Hebei Forestry Science and Technology, 2015 (06): 91-92.
[9] Xingxing G, Chunjuan L. Effects of rain intensity and slope on runoff and sediment production before and after reclamation of iron tailings sand slopes [J]. Soil and Water Conservation Research, 2019, 26 (01): 8-13.
[10] Chaojun W, Zhe H, and Mingjie C. Research on the effect of phytoremediation on the microstructure of tailings matrix [J]. Environmental Protection and Circular Economy, 2019, 39 (12): 42-47.
[11] Tao L. Research on anaerobic resource treatment and soil remediation of rare earth mining area [D]. Lanzhou University of Technology, 2019.
[12] Peng Y, Xiuyu S, and Shugang H. The status and technology of mine restoration and management [J]. World Environment, 2018 (03): 30-32.