Research Progress on Vegetation Ecological Restoration of Abandoned Land in Coal Mine Area

Shenglan Ye 1, 2, 3, 4, *

1 Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, China
2 Shaanxi Provincial Land Engineering Construction Group Co., Ltd, China
3 Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources, China
4 Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710075, China

*Corresponding author e-mail: yeshenglan@shaanxidijian.com

Abstract. The large-scale mining of coal mines produces a large amount of abandoned idle land, which seriously damages the ecological environment and causes severe environmental pollution. Among them, waste coal gangue takes up a lot of land. A large number of abandoned land remediation and restoration in coal mining areas have also been carried out at home and abroad. Among them, vegetation ecological restoration has special advantages in the restoration of coal gangue abandoned land. Therefore, this paper analyzes the characteristics of coal gangue wasteland and the feasibility of plant growth, discusses the methods and application progress of vegetation restoration, and proposes prospects for the future research work on the restoration and utilization of wasteland in coal mining areas.

Keywords: coal gangue; abandoned land; vegetation restoration.

1. Background

Mining wasteland refers to a type of land that is damaged and largely occupied during mining and cannot be used without remediation. It mainly refers to bare mining rock mouths, waste soil (stone, slag) piles, tailings ponds, coal gangue piles. Abandoned workshops and other construction land, as well as the collapsed land formed in the process of underground mining and the surrounding waste land with hidden dangers of collapse, etc. Among them, coal gangue is a kind of waste rock produced in the process of mining. Specifically, the waste rock is first stripped (open-pit mine) or opened up (underground mine) in the process of ore mining, thereby producing waste rock with no industrial value. my country's annual coal output has reached more than 1.3 billion tons, and hundreds of millions of tons of waste rock must be exploited or stripped. Together with the development of other metallic and non-metallic minerals, the mining of chemical raw materials and construction materials, the total amount of excavation from the inside of the earth can reach billions of tons every year [1]. The characteristic of this kind of waste land is that the particle size of the waste is often hundreds or even thousands of millimeters, and it is difficult to crush and weather by itself in a short time. The wasteland has poor water holding capacity.
and large gaps. The wasteland of mining pits often forms a deep pit, which accumulates water throughout the year or forms a wet wetland.

The mining wastelands in China are widely distributed, severely destroying the ecology and causing severe environmental pollution. At present, the reclamation rate of coal gangue mining wasteland in my country is still in the polar phenomenon, which will seriously affect the sustainable mining of mines and restrict the regional recycling development. Therefore, long-term practical development research on mining wasteland is urgently needed. However, the current remediation and reuse of mining wasteland needs to pay attention to the long-term effect and sustainable use of the land. Some scholars pointed out [2] that the main factor in the ecological restoration of mining wasteland lies in the reconstruction of vegetation, especially for the problems of land occupation and land pollution arising from the mining process. Shu Jianmin [3] pointed out that the essence of ecological restoration is to restore the important functions of the ecosystem itself and sustainably maintain it. The key to the ecological environment and reconstruction of the mining wasteland is to restore and reconstruct the vegetation based on the correct evaluation of the type and characteristics of the wasteland, so that the ecosystem can recover on its own and achieve a virtuous circle. The key to vegetation restoration and reconstruction is substrate improvement and plant species selection.

2. The basic characteristics of coal gangue mining wasteland
Coal-associated waste rock (coal gangue) is a type of mining solid waste, which is produced in the process of coal mining and coal washing. The main types include gangue in coal washing plants, hand-selected gangue in coal production, coal and rock discharged from the excavation of semi-coal and rock roadways, and a mixture of white gangue from coal measures stacked with coal gangue. It is a mixture of carbonaceous, argillaceous and sandy shale with low calorific value. It contains 20%–30% carbon, and some contain humic acid. China has accumulated about 1,000Mt of coal gangue over the years, and it continues to discharge about 100Mt every year, which not only accumulates land, but also spontaneously combusts to pollute the air or cause fires. Coal gangue is mainly used to produce gangue cement, lightweight aggregates of concrete, refractory bricks and other building materials. In addition, it can also be used to recover coal; coal and gangue are mixed for power generation, to produce crystalline aluminum chloride, water glass and other chemical products. It extracts precious and rare metals and can also be used as fertilizer.

Mining wasteland refers to the land destroyed by mining activities and cannot be used without treatment. According to its source, it can be divided into three types: one is the waste rock pile and waste land formed by the accumulation of stripped topsoil, mining waste rock and low-grade ore; the other is a large number of mined-out areas and subsidence areas formed with mineral mining. That is, mining pit waste land; the third is the tailings waste land formed by using various sorting methods to sort out the residue after the concentrate is discharged [4]. Waste rock pile waste land: mining ore must first strip the waste rock (open-pit mine) or open up (underground mine) to produce waste rock with no industrial value. Annual coal output has reached more than 1.3 billion tons in china, and hundreds of millions of tons of waste rock must be exploited or stripped. Together with the development of other metallic and non-metallic minerals, the mining of chemical raw materials and construction materials, the total amount of excavation from the inside of the earth can reach billions of tons every year [5]. The characteristic of this kind of waste land is that the particle size of the waste is often hundreds or even thousands of millimeters, and it is difficult to crush and weather it by itself in a short time. The wasteland has poor water holding capacity and large gaps. The wasteland of mining pits often forms a deep pit, which accumulates water throughout the year or forms a wet wetland. Tailings are solid waste discharged after sorting and recycling a certain element component or several element components in the ore during the development and utilization of mineral resources under the conditions of mining technology and equipment at that time. Due to the relatively low recovery rate of beneficiation, the tailings emissions are relatively large. According to preliminary statistics, the tailings discharged from mines in my country are about 200 million tons each year, and it is increasing at a rate of 10% per year [6]. After smashing during beneficiation, tailings particles are generally finer. The tailings often contain some valuable
components between 0.5 and 1mm, which are potential mineral resources, but they often contain toxic elements such as heavy metals and cyanide[7]. Generally speaking, the above three types generally exist in large mines, such as Guangxi Dachang and Chehe mining areas. Generally speaking, the mining wasteland is widely distributed and has particularity in the physical geography unit. It is the product of physical geography superimposed on human activities, and has special importance in the research and practice of regional sustainable development. On the one hand, as an environmental element, an environmental problem directly affects and threatens the sustainable development of regional economy and society; on the other hand, as a potential resource, it is an important support for regional sustainable development [8].

3. The harm of coal gangue wasteland to the ecological environment

Mining industry is the lowest ecological industry that destroys nature and excessively consumes limited resources. The mining wasteland along with the development of mineral resources has many impacts on the environment, from the destruction of the surface landscape, the occupation of land resources to the pollution of the environment and the impact on the habitat of animals and plants.

| Type of damage                           | Cause of damage                                                                 | Main hazard                                                                                                      |
|------------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Surface landscape destruction            | As the topsoil is removed after mining, it is usually new soil or slag, and the heavy pressure of large-scale mining equipment often makes the soil hard and compact, and lacks organic matter, nutrients and water. The ground collapse caused the groundwater level to drop and soil cracks. Nutrient elements in the soil also flow into the goaf or depression along with the cracks and surface runoff, resulting in a shortage of soil nutrients in many places and a decline in soil carrying capacity. | It leads to the destruction of regional ecology and natural landscape several times the scope of mining; and the damage to the surface landscape by open-pit mining is greater than that of underground mining, which can cause irreversible changes in mining areas, and even turn high mountains into artificial lakes. However, if the underground tunnel is not filled in time, there is a danger of ground subsidence. |
| Occupy land resources                   | The minerals and waste generated during the development of mineral resources will occupy a large amount of land; | As of 2018, the country's open-pit mines cover an area of more than 2 million hectares, of which coal gangue hills cover an area of about 124 hectares. |
| Environmental pollution                 | During the mining process, a large amount of pit water and waste rock leaching water are produced. The solid waste residues (coal gangue, etc.) in the mines are washed and leached by rain, causing the toxic and harmful components to leak out. | The acidic, alkaline, toxic or heavy metal components in mining wastes will pollute water, atmosphere, soil and biological environment through runoff and atmospheric diffusion, and their impact area far exceeds the scope of the mining area. |
| Ground collapse induced geological disasters | Underground mining, ground and side slope excavation affect the stability of mountains and slopes. Waste slag discharged from mines is piled up on hillsides or valleys, and the waste rock is mixed with soil to reduce the friction of the waste rock, and the water permeability becomes smaller and waterlogging occurs. | Mining will strongly disturb the geological structure, causing surface cracks, ground collapse, building damage, farmland destruction, river interruption, water accumulation in mine pits, earthquakes, collapses and landslides, etc. |
| Habitat destruction                     | Vegetation removal, soil degradation and pollution, and soil erosion are all fatal blows to the maintenance of biodiversity in mining areas and severely threaten the survival of animals and plants. | Water body and soil pollution caused the death of a large number of animals and plants, resulting in the reduction of biodiversity around the wasteland and the imbalance of ecological balance. |
4. The feasibility and restriction of coal gangue on plant growth

4.1. The feasibility of coal gangue for plant growth

In recent years, the research of coal gangue as a matrix filling material has been increasing [9-11]. Coal gangue filling can not only improve soil nutrients and increase plant production [12], but also realize the vegetation restoration of abandoned land through waste treatment. There are a large number of bare sites that are difficult to use. At present, the main measures adopted for its ecological management are to directly cover the soil for vegetation restoration and reconstruction. However, due to the high cost of soil covering, it is easy to cause secondary damage to the borrow area, so consider coal gangue application as a matrix filling material for bare sites can not only realize the resource utilization of waste, but also greatly reduce the cost of greening. However, the use of coal gangue alone as a greening matrix will result in poor matrix structure and because it contains a large amount of heavy metal harmful elements. It will lead to the accumulation of heavy metals in plants, and leaching will also pollute the surrounding water environment under rainfall and artificial watering [13]. Therefore, coal gangue can only be treated by mixing other improvement materials with soil improvement and heavy metal passivation. Use it wisely.

Shan Dan [14] studied the species composition of different vegetation configuration types in the dumps of typical grassland open-pit mines, and found that the plant species of the sample plots with artificial measures increased significantly, and the dumps adopted the configuration model of Caragana korshinskii + alfalfa. The effect is good. Hao Zhiyuan [15] studied the vegetation and soil of two coal gangue hills in the Lu'an mining area in Shanxi, and the results showed that in the initial stage of the gangue hill vegetation establishment, different vegetation restoration patterns and slope directions are the dominant factors affecting the distribution of vegetation. In the early stage of ecological restoration of coal gangue hills in Zaoquan 3, the arbor and woodland configuration mode is more suitable for planting configuration types, and the main soil chemical factor affecting plant species diversity is soil alkaline nitrogen [16].

4.2. The restriction of coal gangue on plant growth

Coal gangue hills are formed by long-term stacking of large boulders or boulders discarded during coal mining. For plants, the eco-environmental conditions of gangue hills are extremely harsh, similar to the original bare land. Analysis of the main problems restricting plant survival lies in the following aspects:

First, there is a large gap between the coal gangue block and its weathering material, and there is no normal soil structure. The gangue block cannot effectively maintain water and fertilizer. The proportion of solid, liquid and gas is out of balance. The gangue as a substrate for plant growth provides nutrients and moisture. Extremely barren, making it difficult for plants to survive and grow.

Second, the pyrite contained in the coal gangue is oxidized by contact with oxygen to generate sulfates and release heat, which causes the coal remaining in the gangue to ignite spontaneously, leading to an increase in the temperature of the gangue matrix, a decrease in pH, and an increase in salt content, etc. The problem arises. The action of acid-loving microorganisms can increase the oxidation rate of pyrite, thereby further reducing the pH value of the waste rock. The leaching effect of rainfall can also cause similar problems. Related studies have found that after weathering and rain leaching, the salt content of coal gangue increases, and the pH can drop to 3.5. The content of aluminum ion, sulfate and nitrate are all large increased. These factors are very unfavorable for plant growth and can even cause plant death.

Third, coal gangue contains heavy metal components, including Cu, Pb, Cd, Zn, Hg, As, etc. These heavy metals are more soluble under acidic conditions. As precipitation flows into the surrounding water and soil, it brings environmental risks. It has a more direct toxic effect on the plants on the gangue hill.

To sum up, coal gangue mines have many objective factors that are not conducive to the settlement and growth of plants. If natural recovery is relied on, it may take decades or even hundreds of years for coal gangue mines to appear relatively stable communities, so human intervention Rapid construction of plant communities is necessary for ecological restoration of mines. Due to the existence of the above-
mentioned unfavorable factors, it is generally necessary to cover coal gangue mines with soil to reduce the degree of acidification and salinization before planting plants. Even so, the types of plants that can successfully survive in such an environment are very limited, so the suitable plants Screening and applied research has important scientific significance and practical application value.

5. Vegetation ecological restoration method of coal gangue wasteland

5.1. Principles of Vegetation Screening

The environmental conditions of coal gangue mines are harsh, so the selection of plants should follow the principle of rapid greening first and economic benefits second. Therefore, the selected plants should have the characteristics of pioneer plants, that is, rapid growth, strong anti-interference ability, high survival rate, and fast covering the ground surface, so as to quickly improve the ecological environment of coal gangue mines; it must have stress tolerance, that is, drought resistance, cold resistance, heat resistance, barrenness, heavy metal resistance, etc.; it has the characteristics of lateral root development. It can produce adventitious roots and has strong sprouting ability, which can effectively adapt to the environment of the shallow soil layer and harsh substrate conditions of the coal gangue ore hill; in addition, the principle of mainly local native plants should be considered to make it harmonious with the original local biological community structure, Choose carefully the alien species that may cause biological invasion. After pioneer plants improve the environmental conditions, they can rely on natural succession or artificial selection of other plants to further optimize and transform the community. According to the climate and soil conditions of the mining area, vegetation screening should focus on the recent performance of vegetation varieties, taking into account their long-term advantages. The selection of plant varieties should first be based on biological characteristics and consider the principle of suitable trees for the site, especially the choice of well-developed roots and soil consolidation Native plant with good slope stabilization effect, high survival rate and fast growth.

5.2. Vegetation types

In the initial stage of vegetation restoration and reconstruction of mining wasteland, the selection of plant species is very important, and the selection of appropriate plant species depends on time and place. According to the extreme environmental conditions of the mining wasteland, the following principles should be followed when selecting plant species [17]: 1) Choose plants with fast growth, strong adaptability, good stress resistance, and high survival rate; 2) Preferentially select plants with the ability to improve soil 3) Try to choose local excellent native and pioneer tree species as much as possible, and also introduce foreign fast-growing tree species; 4) When selecting tree species, not only should consider the high economic value, but also the multi-functional benefits of the tree species, including drought resistance, moisture tolerance, Anti-pollution, anti-wind and sand, resistance to barrenness, resistance to pests and diseases, and has high economic value. Especially those plants that settle naturally on mining wastelands can adapt to extreme conditions, have strong tolerance and plasticity, and should be considered as priority plants [18].

5.3. Vegetation restoration methods

After selecting the plant species and improving the wasteland substrate, how can we save costs and achieve the purpose of restoring and rebuilding the ecological environment? We believe that there are two ways to choose. One is to plant plants on abandoned land. Undoubtedly, with sufficient funds, this is a good way to quickly restore vegetation, but the problem is that it requires more labor and expense. The second is to divide the abandoned land into several small blocks and plant plants alternately. Of course, the reasonable area of small blocks needs to be studied continuously. This approach saves labor and funds, and provides space for natural restoration of plants. Since each small piece of space is surrounded by surrounding vegetation, its adverse impact on the environment is relatively small before the vegetation is restored [19].
6. Application of phytoremediation of coal gangue wasteland

The goal of coal gangue hill reclamation is to establish a stable ecosystem with significant ecological benefits. To achieve this goal, in the initial stage of ecological restoration, attention should be paid to the construction of artificial communities with a certain level of biological diversity, and the comprehensive configuration of three levels of trees, shrubs and grass should be emphasized, and a variety of plants should be used in each level to avoid planting a single species. The increase of plant diversity plays an important role in stabilizing community structure and enhancing system functions. Herbs grow fast, easily cover the ground, and effectively reduce soil erosion; shrubs often have strong sprouting ability, planting shrubs can significantly improve the environmental conditions of coal gangue mines, such as maintaining moisture, increasing total nitrogen, available phosphorus, available potassium, etc. [20]; Woody plants can play a relatively powerful ecological role, for example, locust tree can prevent soil acidification and increase organic matter content. Herbs, shrubs, and trees cooperate with each other to maximize the use of horizontal and vertical space, so that the built community presents the above-ground stratification and horizontal mosaic similar to natural communities. Studies have shown that mixed forest and grass can effectively improve site conditions, reduce the large pore size of the gangue mine soil, increase capillary tubes, and reduce the rate of water infiltration, thereby improving water and fertilizer retention [21]. In addition, when constructing the gangue hill community structure, some vines can also be appropriately selected to form a more complex and stable community structure, improve the environment, and thereby facilitate the successful migration and settlement of other local animal and plant species. It is worth noting that the construction of landscape is also an important part of ecological restoration and reconstruction [22]. When selecting plant species for ecological restoration of coal gangue mines, attention should be paid to the landscape effect after greening [23], while achieving the purpose of quickly covering the surface. Should combine relevant theories and successful practical experience of landscaping, landscape gardening, etc., try to consider the landscape effect of ecological restoration of mines, combine the topography for landscaping and consider the selection and application of garden flowers and shrubs and other plants, and carry out coal gangue mining ecology At the same time of restoration, it can beautify and enhance the viewing effect.

7. Prospects

The ecological restoration of coal gangue mines is a complex project, involving ecology, environmental science, geography, mining, soil science, botany, forestry, garden landscape, aesthetics, etc., so when choosing suitable plants In order to ensure the success of ecological restoration, we must fully consider various factors, draw on the results of related research, select local suitable native species, fully study the habitat characteristics of the ore mountains, and try to improve the physical and chemical properties of the soil. Different mining areas should choose plant species reasonably according to their own site conditions and characteristics. The laws of natural succession of communities should be respected, and the characteristics of natural restoration of degraded ecosystems should be fully understood to construct artificial communities. Vegetation restoration and reconstruction of coal gangue hills is a difficult and long process. One cannot rush for success. It is unrealistic to hope that the expected results will be achieved within one to two years. At present, there are many shortcomings in the selection of plant species for restoration of coal gangue mines, the research and application of restoration mechanisms. In the future, we should continue to carry out relevant research on the suitability of plants in different gangue mine sites, and continue to screen suitable plant species to meet the needs of mine ecological restoration practices. The ecological restoration evaluation mechanism of waste rock should be established, and the physiological and ecological characteristics, growth and survival of selected plants under the action of various stress factors should be evaluated at the molecular level, tissue and organ level, individual level, etc., to study the accumulation of heavy metals And resistance, reveal its adaptation mechanism; from the macro-scale, plant population dynamics, inter-species relationships, plant-microbe interactions, community succession, dynamic changes in ecosystem structure and functions, landscape patterns and their ecological functions should be developed. Perform dynamic and
long-term evaluation from the perspective of effectiveness, so as to provide a more comprehensive basis for the selection of subsequent mine restoration plants.

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References
[1] Chen Changji. Research on the Recycling Utilization of Mining Wasteland-Comment on "Surface Space Ecological Development and Key Technology of Mining Wasteland" [J]. Mining Research and Development, 2020, 40(11): 193.
[2] Truman P. Young. Restoration ecology and conservation biology. [J]. J. Biogical conservation, 2000, 92:73-83.
[3] Shu Jianmin, Liu Xiaochun. Theoretical basis, key technologies and application prospects of restoration ecology [J]. China Environmental Science, 1998, 18(6):540-543.
[4] Wang Zhencheng. Utilization and treatment of solid waste [C]. Xi'an Jiaotong University Press,1987, 116-127.
[5] Liu Baochen. A way out to reduce the impact of mineral resource development on the global environment [J]. World Science and Technology Research and Development, 2000, 21(1).
[6] Mao Qirui.Comprehensive recovery and utilization of mine tailings [J]. China Resources Comprehensive Utilization, 2000.
[7] Sun Wei.Comprehensive recovery and utilization of non-ferrous metal mine tailings [J]. Non-ferrous metals (mineral processing part), 1999, (3).
[8] Song Shuqiao, Zhou Yongzhang. Abandoned mining land and its ecological restoration and reconstruction [J]. Conservation and Utilization of Mineral Resources,2001,(05):43-49.
[9] Liu HB, Hu ZQ. Discussion on characteristics and weathering mechanism of gangue [J]. Coal Mine Environ Prot, 1995, 9 (6):43-45.
[10] Li SZ. Present status and outlook on land damage and reclamation technology of mining subsidence area in China [J]. Coal Sci Technol, 2014, 42 (1): 93-97.
[11] Qi JZ, Hu ZQ, Zhou JH. Effect of coal gangue filling and reclamation on environment in higher water level mining area [J]. China Coal, 2002 (10): 39-41.
[12] Hu ZQ, Kang JT, Wei XJ, Ji JJ, Wang WJ. Experimental research on improvement of reclaimed soil properties and plant production based on different ratios of coal-based mixed materials [J]. Trans Chin Soc Agric Eng., 2007, 23 (11): 120-123.
[13] Zhang Ruchong, Wang Dongmei, Zhang Yin, et al. Effects of green substrates composed of coal gangue on the growth of Trifolium repens L. and its resistance to heavy metal pollution[J]. Chin J Appl Environ Biol, 2018, 24 (4): 0908-0914.
[14] Shan Dan, Xing Ende, Rong Hao, et al. Ecological restoration of different vegetation collocations of coal mine dump in typical steppe [J]. Chinese Journal of Ecology, 2019,38(2):336-342.
[15] Hao Zhiyuan. Research on the Interaction Relationship between Vegetation and Soil System of Coal Gangue Mountain Reclaimed Land in Lu'an Mining Area [D]. Taiyuan: Shanxi University, 2019.
[16] Xu Li, Feng Fei, Liu Ying, et al. Relationship between plant species diversity and soil chemical properties in coal gangue dump: early stage of ecological restoration in Lingwu Mining Area [J]. Coal Science and Technology, 2020, 48(4):97-104.
[17] Bao Zhiyi, Chen Bo. Vegetation reconstruction technology in the ecological restoration of industrial wasteland [J]. Journal of Soil and Water Conservation,2004 (3): 160-163.
[18] Yang Xiu, Gao Lin. Research on Vegetation Restoration and Reconstruction of Dexing Copper Mine Abandoned Land [J]. Acta Ecologica Sinica, 2001 (11): 1933-1940.
[19] Song Shuqiao,Zhou Yongzhang. Mining Wasteland and its Ecological Restoration and Reconstruction [J]. Conservation and utilization of mineral resources,2001, (05): 43-49.
[20] Wei Zhongyi, Hu Zhenqi, Zhang Guangcan, et al. Influence of vegetation greening measures on coal gangue hills on the physical and chemical characteristics of coal gangue weathering [J]. Anhui Agricultural Sciences, 2007, 36: 11929-11930+12033.

[21] Wang Wenying, Li Jinchuan, Lu Chongen, et al. Vegetation reconstruction technology in abandoned mining area [J]. Shanxi Agricultural Sciences, 2002, 30 (3): 82-86.

[22] Wang Yuan, Che Dai. Analysis on the Plant Landscape Construction of Coal Gangue Wasteland in Northeast China-Taking Hegangling North Coal Gangue Wasteland as an Example [J]. Modern Gardens, 2012 (4): 39-44.

[23] Li Nan, Guo Jinping, Mi Wenjing, etc. Research on Plant Diversity of Vegetation Restoration of Coal Gangue Pile of Lu'an Group [J]. Journal of Shanxi Agricultural University (Natural Science Edition), 2013, 33 (5):408-412.