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Disposal methods on solid wastes from mines in transition from open-pit to underground mining

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Abstract

The important issues on disposal of solid wastes from metal mines are to choose the right varieties for the comprehensive utilization of mining waste and to control contamination from waste rocks and tailings. Environment-friendly disposal of solid wastes from mines is the key pathway. This paper summarizes and enumerates some comprehensive utilization methods and proposes new ideas on the disposal and comprehensive utilization of solid waste from mines, including reducing the discharge of solid waste by recovering sand from ore dressing flow for construction industry and a mine back filling approaches. The process flow of tailings separated for different purposes that could be carried out in iron mines is putting forward. The authors put forward certain guidance on disposing and utilizing of solid waste from mines.

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1. Introduction

Some of the extremely major problems and key challenges facing the contemporary world are shortage of resources, ever growing population and environmental pollution. With the development of mining industry, mining exploitation activities have produced more and more solid wastes and induced increasingly grievous destruction on eco-environment. Waste rock, tailings and other solid waste are the largest industrial solid waste generated in the process of exploitation of mineral resources. A comprehensive utilization of solid waste from mines to compensate resources shortage and environmental protection will have enormous economic and social benefits.
It is an effective way of solving the problem of waste discharge, land occupation and protecting environment if the mine solid wastes can be treated in new ways such as waste reuse, waste rock reduction and waste rock and tailings backfill. In order to protect and manage the mining environment, promote the recovery, most investigators at home and abroad [1-10] do their efforts to study on comprehensive utilization of solid waste to accomplish this purpose. And the authors of this paper, based on the investigation of the predecessors, summarized the methods on comprehensive utilization of solid waste and proposed some ideas on comprehensive utilization of solid waste in a mine in transiting from open-pit to underground mining.

2. Solid Waste from Mines

Waste rock and tailing, no matter which kind of development program was utilized in a mine, are the uppermost solid waste in the duration of exploitation of mineral resource. The discharging of waste rock and tailings has large portion of mine land use and higher safety requirements. Simultaneously, it also brings great destruction to the mine area environment.

2.1. Waste rock

Waste rock is one of the maximum solid wastes occurred in the mining industry. In order to extract ore, large amount of rock is stripped or excavated and transported to the waste-rock dump.

When the mineral resource was exploited by underground mining method, waste rocks are often rooted in the excavation of mine shaft and declines and other development areas. The production of waste rock are very different at different mines due to the geometry of the orebody, development program of ore exploitation, mining method and mining capacity of the underground mine.

If a deposit was exploited by open-pit mining method, waste rocks are produced in the process of stripping. The stripping ratio impacts on the amount of waste rock greatly. According to the geometry of the orebody, different mines have a different stripping ratio and yield of waste rock.

Generally, the amount of waste rock in an open-pit mine is more than that of underground mine. This requires more land to store waste rock.

2.2. Tailings

Tailings are the major solid wastes produced in the process of mineral beneficiation. In order to extract usable minerals, ore was crushed and milled to appropriate size, then, the usable minerals were separate from unusable minerals via different beneficiating methods. With the development and utilization of mineral resources, the production and disposal of tailings has become the important factor in the sustainable development of mining industry and endangering mining and surrounding area ecological environment. According to incomplete statistics, for example, China discharges more than 0.5 billion tons tailings every year, and the rate of comprehensive utilization of tailings is less than 7% at present.

The output of tailings in a mine depends on the grade of ore beneficiated in mineral processing plant. Generally, high grade of ore generated less tailings. The tailings should be disposed in time, otherwise, they would occupy land, pollute environment and even influence life of people.

Traditionally, the disposal method of tailing is to pump tailing slurry or transmit the dry tailing to tailings storage facility (TSF). And the construction of TSF costs money, especially land.
3. Reclamation of Solid Wastes

Comprehensive utilization of solid waste resources is an important disposal method of solid waste from mines. Facing the problem that more and more solid waste, many mines in China begin to utilize tailings and waste rock as resources in various ways to reduce the discharge of solid waste and to protect environment.

Generally, reclamation of solid wastes from mines could be categorized as following:

3.1. Producing construction materials

In order to give a real protection to the cultivated land to promote sustainable development of the socialist economy, the State imposes restrictions on mining of clay soil for producing construction material. Instead, more attentions are turned to the utilization of solid waste from mines. Nowadays, producing construction materials is the major reclamation of solid waste from mines.

3.1.1. Utilization of waste rock

Waste rock results from stripping in an open-pit or excavation of an underground mine. Usually, according to the difference utilities of waste rock, it could be used directly or dressed to various sizes for using. The following embodies utilization methods of waste rock:

a) A very good material for construction of roads. The coarser size waste rock can be used for subgrade building and the fine size for road surface paving;

b) A very good material for construction of dams;

c) A very good material for beneficiating coarse and fine aggregate of concrete;

d) It could be used for making construction bricks when beneficiated to suitable size; and

e) To backfill the mined out area, subsidence area and other area needed to be filled.

3.1.2. Utilization of tailings

As another kind of solid waste from mines, tailings have a wide range of utilization. Because of the diversity of grain fineness in different mineral processing plants, tailings can be classified to coarser size and the fine size. For most mines, the coarser tailings could be used as fine aggregate of concrete and the fine size tailings are good materials for making bricks. Using iron tailings, Das et al [10] succeeded in making floor tile and wall brick for construction. These kinds of bricks have a higher intensity and rigidity than those of conventional bricks and a lower cost. The usages of tailings as construction material are described as following:

a) Used for making wall bricks and floor tiles for construction;

b) Used for filling depressions, the mined out area or subsidence area;

c) Used for improving of the soil; and

d) Separating out coarser size for fine aggregate of concrete and building sand usage.

3.2. Recycling usable minerals

Because of the restricting of beneficiation of technological condition, processing recovery ratio was at a lower level in some old mines. These mines did not have comprehensive utilization of mineral resource and tailings deposited in tailing reservoirs or discharging now contains abundant usable mineral elements. For example, the iron grade in tailings of certain magnetic iron mines in Anshan area, located in the North-East of China, is approximately 20% [7]. With the development of mineral processing technology, it becomes possible that the usable minerals in tailings could be recycled.
Using floatation method, Sivas-Divrigi processing plant in America obtained[6] cobalt recovery ratio of 94.7%, nickel recovery ratio of 84.6% and copper recovery ratio of 76.8% at the best floatation condition in the process of recycling of iron tailings.

More and more Chinese metal mines have carried out or are to take action on recovering the usable mineral from tailings. For example, Waitoushan Iron Mine, with the tailings re-grinding and re-separating, got the iron concentrate production of 39.2kt with the grade of 65.76% via the magnetic separator [7].

3.3. Backfill mined out area

Waste rock and tailings could also be used in the backfill mined area of a mine in transition from open-pit to underground mining. Backfill the mined area is not only significant to the environmental restoring and improving the mining condition, but also a good idea of disposal method on solid waste from mines. Backfilling the mined out area could decrease the amount of land usage and reduce the impacts on environment and eco-environment. With the development of backfilling technology, more and more solid waste from industry, such as tailings, waste rock and smelter could be used as backfill materials.

For a mine transiting from open-pit to underground, it is very important that more attentions be paid to backfilling technology for the purpose of solid waste disposal. Traditionally, when backfilling method was utilized in a mine, waste rock could be used as material of dry backfilling and tailings of hydraulic backfilling.

Backfilling the mined-out area is another utilization approach of solid waste from mines in mining operation. When waste rock were transformed and deposited in the abandoned opencast, the land for storing solid waste temporarily was released and the backfilled area could be reformed to farming glebe or woodland. If the abandoned opencast is not far away from the residential area, it can also be used as a landfill site of municipal solid. In an underground mine, backfill the mined-out area could prevent the ground subsidence effectively and reduce the destroying of land. When filling method was used in underground mining, the discharge of solid waste could be reduced into a very low degree. For a mine in transition from open-pit to underground mining, backfill the opencast can improve the stress distribution of opencast side and prevent the rain water flow into the underground mine [11].

3.4. Regeneration of ground vegetation

The storing of solid waste induced increasingly grievous destruction on eco-environment and water and soil conservation. According to the Law of the People's Republic of China on Water and Soil Conservation, if the vegetation is damaged on account of the mining or construction, measures must be taken to rehabilitate the topsoil and vegetation, thereby preventing soil erosion. The investigation result [8] shows that vegetation planted on the surface of iron tailings was not only propitious to tranquilizing and reducing soil erosion but also enhancing growth of vegetation.

Facing the increasingly land decrement of mining and construction, land reclamation is very important to supplement land resource. When mine infrastructures, such as tailings reservoirs, were abandoned, land suitable for agricultural use should have the priority of developing into land for agricultural use. For example, Maojiawan tailings reservoir of Zhongtiaoshan Copper Mine was reclaimed to agricultural land and the yield of peanut reached 3300kg/hm2 and yield of broomcorn reached 8085kg/hm2. Furthermore, the quality of crop reaches food health standard of the state [9].

At the premise of protecting the eco-environment in an active way, it is a good idea on disposal of solid waste that waste rock and tailing could be utilized to carry out land treatment and rehabilitation.

3.5. Producing glass or fertilizer
According to the varieties of mineral composition in tailings of different mine, tailings could be used to produce glass or fertilizer.

For the purposes of comprehensive utilization of tailings and reducing environmental contamination, Xing Jun et al [13] successfully studied the preparation of glass ceramics by utilizing gold tailings as the main raw material. And Zhan Jinrui et al [4] carried out a research on producing glass ceramics by iron tailing in Tangshan Region.

Sino Steel Maanshan Institute of Mining Research [14] has carried out a series of studies successfully on producing soil conditioning agent or fertilizer by using magnetized iron-tailings.

4. New Ideas on Utilization of Solid Waste

The new idea on disposal of solid waste from mines is that the comprehensive disposal and utilization of solid waste could be actualized in various pathways in the process of solid waste generation.

4.1. Reducing the discharge of solid waste

Reducing the discharge of solid waste is an important pathway of comprehensive disposal and utilization of solid waste. For this purpose, it could be carried out via the following approaches:

a) *To control ore dilution ratio:* The best way of reducing the discharge of tailings is to minimize ore dilution and enhance quality of ore in the process of mining.

b) *To increase processing recovery ratio:* Another way of decreasing the discharge of tailings is to enhance the processing recovery ratio.

c) *To decrease stripping ratio:* This is the important and effective pathway to reduce the output of waste rock in an open-pit. But decreasing stripping ratio must be founded on the basis of safety reliability of mining and ensure the stability of opencast slope.

d) *To reduce the amount of excavation in rock:* On the premise of ensuring the without impairing its normal operation, the layout laneways of underground mine should be designed in ore bodies or via decreasing their sectional dimensions. By this method, the output of waste rock in an underground mine could be reduced.

4.2. Recovering sand from ore dressing flow for construction

Tailings are usually mined out and classified to different size from tailings reservoir for reutilization, and this needs a very strict procedure and measures according to the Safety and Monitoring Administrative Rule for Tailings Reservoir [12].

The new idea on utilization of tailings is that the tailings could be classified to different grain fineness in the process of mineral beneficiation. For example, building sands could be picked up in the ore dressing flow. If this approach was carried out in a mine, it could reduce the discharge of tailings and reduce the cost of comprehensive utilization of tailings.

Figure 1 shows the process flow of this approach carried out in an ore dressing plant of iron mine. In this flowsheet, there are four products excepting iron concentrate. They are waste rock, coarse tailings, fine tailings and muddy tailings. And the four products could be used for different purposes.
4.3. Combined filling approach

In order to improve the comprehensive utilization ratio of solid wastes, when waste rocks or tailings were utilized for land treatment and rehabilitation, it is a good idea that the admixture of waste rock and tailing was used in filling the mined out area, subsidence area and other area for this purpose. Tailings, as a kind of fine size material, could fill in the interstices of waste rocks effectively and increase the utilization amount of solid waste. Meanwhile, it could enhance the density degree and reduce the coefficient of permeability of backfill materials.

When the combined filling approach was used in construction of dam, such as tailings pond, it can meet the requirement of anti-liquefaction.

5. Conclusion

The important issues on disposal of solid waste from metal mines for further study are to choose the right varieties for the comprehensive utilization of and to control contamination from waste rock and tailings. The comprehensive utilization of solid wastes from mines is the necessary choice of mining industry, and it will bring tremendous economic and social benefits especially in environmental protection.

Therefore, waste management policies including reduction, recycle and safe treatment of mine waste, should be taken and waste management should be further tightened based on the principle of recycle economy. More attention must be paid to the proper disposal of solid waste from mines n land utilization.
management and reducing the discharge of solid waste by the comprehensive utilization of mining waste must be promoted in a more active way.

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