

Comprehensive Utilization Analysis of Tailings

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Abstract

In the face of China's rapid economic development, China's mineral industry continues to improve, and the amount of tailings is also rising year by year. The economic and environmental problems caused by tailings are becoming more and more serious. According to the current tailings storage and utilization rate in China, this paper analyzes the types and comprehensive utilization direction of tailings in China, and takes Tangshan area as an example to carry out the investigation and comprehensive utilization research of tailings in this area. At present, there are more than 80 tailings reservoirs in Tangshan area, which are distributed in Qianxi, Qian'an, Zunhua and other areas. According to the characteristics of tailings in Tangshan area, an experimental analysis is conducted on the tailings of a certain tailings pond. According to the physical and chemical properties obtained from the experiment, the experimental results are analyzed, and the ways and methods of its reuse are considered, so as to provide technical support for promoting green economy and environmental protection industry, and realize the maximum utilization of resources on the premise of ensuring and protecting the environment.

Keywords

Tailings; Comprehensive Reuse; Tangshan Tailings Area; Tailings Characteristics.

1. Introduction

As a large energy country, with the rapid economic development, China's demand for minerals is also increasing. The development speed and scale of China's mining industry are irresistible. As a non renewable resource, minerals have shown a trend of increasing scarcity. Moreover, with the development of mining industry, the amount of tailings in China has also increased year by year. Under the current technical and economic conditions, there are certain difficulties in the treatment of tailings in China, In this paper, the relevant experimental research on tailings is carried out.

2. Classification and Harm of Tailings in China

Tailings are solid wastes discharged after ore crushing and smelting. Most of them are silicate minerals and carbonate minerals except for a small amount of valuable components. According to the type of ore, it can be divided into metal ore and non-metal ore. ferrous metal tailings, non-ferrous metal mine tailings and rare precious metal mine tailings are the main components of metal tailings; Limestone tailings, marble tailings and Kaolin Tailings are important components of non-metallic tailings [1]. Quartz, mica, dolomite, calcite and other minerals contained in some tailings have the value of further recycling. However, arsenic, lead, mercury, cadmium and other harmful elements in some tailings will have a great impact on the environmental pollution around the tailings. Therefore, the recovery of valuable components in

tailings can not only avoid the waste of resources, but also improve the utilization rate of tailings, and maximize the utilization of resources while protecting the environment [2].

In China, about 0.48t tailings will be produced per 1t iron ore mining, while about 0.92t tailings will be produced per 1t nonferrous metal ore mining [3], China's Tailings stock has exceeded 10 billion tons, but the comprehensive utilization rate of tailings is extremely low. In 2021, the comprehensive utilization rate of industrial enterprises' tailings is only 27.1%. The accumulation and storage of tailings materials brings many difficulties, which are specifically reflected in:

(1) The waste of mineral resources is serious. The final tailings that cannot be re-selected also contain a certain amount of metal ore and non-metal ore, and most of the useful components are directly shelved, resulting in a huge waste of resources.

(2) A large amount of tailings storage occupies a large amount of land, and the storage cost is huge. The metal or radioactive elements contained in the tailings will pollute the soil, damage the surrounding vegetation, and in serious cases, water and soil loss will occur.

(3) Tailings also have a great adverse impact on the natural ecological environment: first, in areas with frequent rainfall, the stacking of tailings is very easy to cause natural disasters such as collapse and landslide, and there is a great potential safety hazard. It is easy to cause casualties. Secondly, the components containing heavy metals in tailings and the acidification of sulfides will cause pollution to the water and air around the deposit, and cause serious damage to the ecological environment.

3. Production and Comprehensive Utilization of Tailings in China

3.1. Production and Utilization of Tailings in China

Table 1. Tailings production in China from 2011 to 2020 100 million t

Particular year	Amount of iron tailings	Copper tailings volume	Amount of gold tailings	Tailings volume of other metal mines	Non metallic ore tailings volume	Total amount of tailings
2011	8.06	3.07	2.01	1.40	1.27	15.81
2012	8.21	3.17	2.12	1.45	1.26	16.21
2013	8.39	3.19	2.14	1.49	1.28	16.49
2014	9.43	3.51	2.28	1.90	1.45	18.57
2015	8.60	3.55	2.35	1.86	1.32	17.68
2016	7.98	3.07	2.45	1.41	1.30	16.21
2017	7.65	3.31	2.29	1.44	1.28	15.97
2018	4.75	3.02	2.16	1.15	1.03	12.11
2019	5.20	3.26	1.98	1.19	1.10	12.73
2020	5.40	3.35	1.88	1.23	1.10	12.96
Total	73.67	32.50	21.66	14.52	12.39	154.74

It can be seen from the above chart that the utilization rate of tailings has increased in recent years, but the overall utilization rate is still at a low level. In the face of a huge amount of tailings, it is irresistible to solve the problem of tailings reuse [4-5].

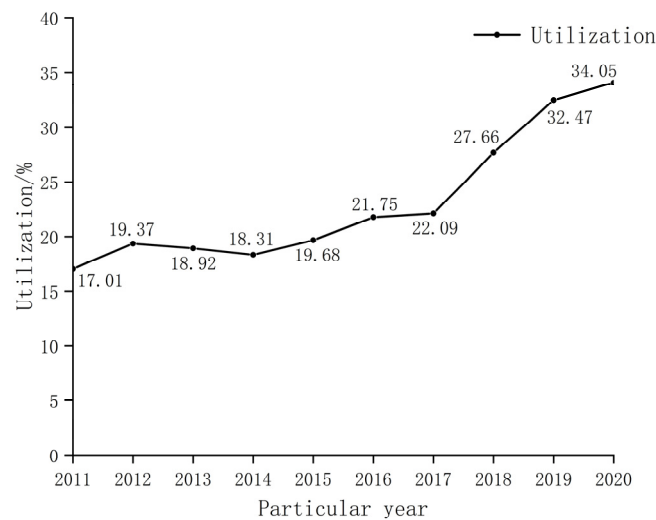


Figure 1. Utilization rate of tailings in China from 2011 to 2020

3.2. Comprehensive Utilization of Tailings

3.2.1. Direct Reselection as Secondary Resources

The main processes of tailings re concentration are divided into mineral re concentration and associated mineral re concentration. Among the tailings discharged from mines in China, the storage value of iron tailings is as high as 2.6 billion tons, the non-ferrous metal tailings is 2.1 billion tons, and the gold tailings is 270 million tons. These two processes have been applied in a concentrator in Shandong Province and a concentrator in Baotou Iron and Steel Co., Ltd. in this mine, 60% of the iron concentrate was obtained from the magnetite tailings with 20% iron element [6]; Rare earth concentrate and niobium are recovered from strong magnet tailings by multiple processes. Foreign countries use flotation technology to recover valuable elements such as cobalt, nickel and copper from tailings, and the recovery rate can reach 94.7%, 84.6% and 6.8% respectively [7].

3.2.2. As Building Materials

The silicon, aluminum, calcium, magnesium and other elements contained in the tailings are the required components of building materials. Under the effect of certain processes, the tailings can produce building materials that meet the national standards. At the same time of consuming tailings, the harmful substances in the tailings are also stabilized and solidified. At present, it is often used in building materials to make cement, glass, ceramics, tailings bricks and building sand. In the replacement of concrete materials, it can also be divided according to performance, and can replace coarse aggregate, fine aggregate and gel materials respectively [8-11].

3.2.3. As Filling Material

Due to the characteristics of fine particle size, uniform particle size distribution and easy cementation, tailings can be used for filling open-pit mines with closed pits and low-lying terrain. This method can reduce the land occupation of tailings, use local materials, eliminate many processes, reduce production costs and solve relevant safety and environmental problems [12-15].

3.2.4. Trace Element Fertilizer and Soil Improver

The tailings contain Fe, Zn, Cu, Mo, B and other trace elements required by plants, which can be made into "micro fertilizer" to promote the growth of crops. At the same time, some tailings contain magnetite, hematite, amphibole, pyroxene and other minerals to improve the physical

structure of soil such as water permeability and permeability, and prepare soil conditioner to improve the soil structure [16-19].

3.2.5. Land Reclamation

Reclamation and land reclamation is also an effective way to deal with tailings. Harmful substances can be eliminated by biochemical technology. After improvement by organic fertilizer and other mechanisms, the reclaimed land can grow normally and some crops on the ground can be harvested regularly. The dried ash can also be smelted to recover valuable metals [20-22].

4. Comprehensive Utilization of Tailings in Tangshan Mining Area

Tangshan is located in the east of Hebei Province and in the center of Bohai Bay, with a total area of 13472 km². It is rich in mineral resources, of which the iron content is as high as 6.2 billion tons. It is one of the three major iron ore areas in China. The long-term development of mineral resources has also caused a large amount of tailings discharge. At present, there are more than 80 tailings ponds in Tangshan area, with a tailings stockpile of 458 million m³. According to the characteristics of tailings in Tangshan area, this paper conducts experimental analysis on a certain tailings, considers the ways and methods of its reuse through data results, provides technical support for promoting green economy and environmental protection industry, and realizes the maximum utilization of resources on the premise of ensuring environmental protection [23-24].

4.1. Distribution and Characteristics of Tangshan Tailings

At present, there are more than 80 tailings ponds in Tangshan area, with a tailings stockpile of 458 million M³. The tailings in Tangshan area are mainly distributed in Qian'an City, Qianxi City, Zunhua City, Luanzhou City and Guye District. The main minerals are iron tailings. Tangshan area belongs to pre-Sinian Anshan type sedimentary metamorphic iron ore. The main metal minerals are magnetite, hematite and pseudo hematite. The main gangue minerals are quartz, chlorite, calcite and amphibole. The tailings pond is high silicon iron tailings.

4.2. Physical and Chemical Properties of Tailings

The tailings in a tailings pond in Qian'an city were selected as the experimental object to study.

4.2.1. Material Composition of Tailings

For the tailings composition in the tailings pond, the X-ray fluorescence spectrum test (XRF) is used to detect the element concentration and mineral composition in the tailings. The specific values are as follows:

Table 2. Chemical analysis results of tailings %

Element	Cu	SiO ₂	Zn	C	S	Fe	CaO	MgO	Al ₂ O ₃	other
Content(%)	0.0062	54.16	0.0046	2.34	0.09	1.95	3.35	2.16	7.54	0.00245

According to the above results, the content of SiO₂ and Al₂O₃ in the tailings is high, which indicates that it is a good inert material. CaO, MgO and other components are also conducive to cemented filling and can be used as a good filling material.

4.2.2. Particle Size and Gradation of Tailings

The filling material has certain requirements for the fine-grained materials of tailings, so the particle size test of tailings is very important. According to the particle size of materials and the different testing principles, the testing methods are divided into vibrating screening, hydraulic screening and laser screening. The vibration screening method and laser screening method are commonly used in the room. The former is used for coarse-grained screening and the latter is used for fine-grained material screening.

1) Vibrating screen method

Vibrating screening equipment mainly includes screen surface and vibrating screen machine. Under the action of the vibrator, the vibrating screen machine produces circular, elliptical or straight track vibration. Due to the vibration of the screen surface, the material layer on the screen surface is loose and thrown away from the screen surface, so that the fine-grained material can fall through the material layer and be discharged through the screen hole, and the particles stuck in the screen hole are vibrated out. In addition to screening, the material moves forward.

Since the tailings of the mine contains a small amount of coarse particles, the vibrating screening method is first used to screen the coarse particles. Firstly, the tailings sample shall be dried for 12h to constant weight, then naturally cooled to room temperature and dispersed to natural state. Take 50g sample and put it into 100 mesh and 200 target standard sieves for vibrating screening test. The vibrating screening results of tailings are shown in table 3.

Table 3. Particle size screening analysis results of tailings

Size fraction		productivity(%)		
mm	Mesh	number	Positive accumulation	Negative accumulation
+0.150	+100	21	21	100
-0.150~+0.100	-100~+150	12	33	79
-0.100~+0.074	-150~+200	4	37	67
-0.074	-200	63	100	63
Total		100.00	—	—

According to the vibration screening results of tailings, the proportion of particle size above 200 mesh of tailings is about 37%, the content of coarse particles is small, which is unfavorable to the strength of the filling body, and the particle size is too small. The filling body has good water retention, poor bleeding capacity, difficult dewatering in the stope, which affects the filling work.

2) Laser sieving method

The test instrument is a laser particle sizer. The measuring principle is that after the particles are uniformly dispersed in the dispersant, the circulating pump makes the dispersant pass through the laser beam at a certain speed. The diffraction angle is different with different particle sizes. The scattering angle of small particles to the laser is large, and the scattering angle of large particles to the laser is small. The particle size can be converted by measuring the scattering angle. The diffracted light is collected by the detector, and the received signal is converted into a particle size distribution curve to obtain relevant data.

Because the coarse particles in the tailings will lead to inaccurate analysis results of the laser particle sizer, first use a 200 mesh sieve to screen them, and conduct particle size analysis on the fine-grained tailings below 200 mesh. The analysis results are shown in Fig 2 and table 4.

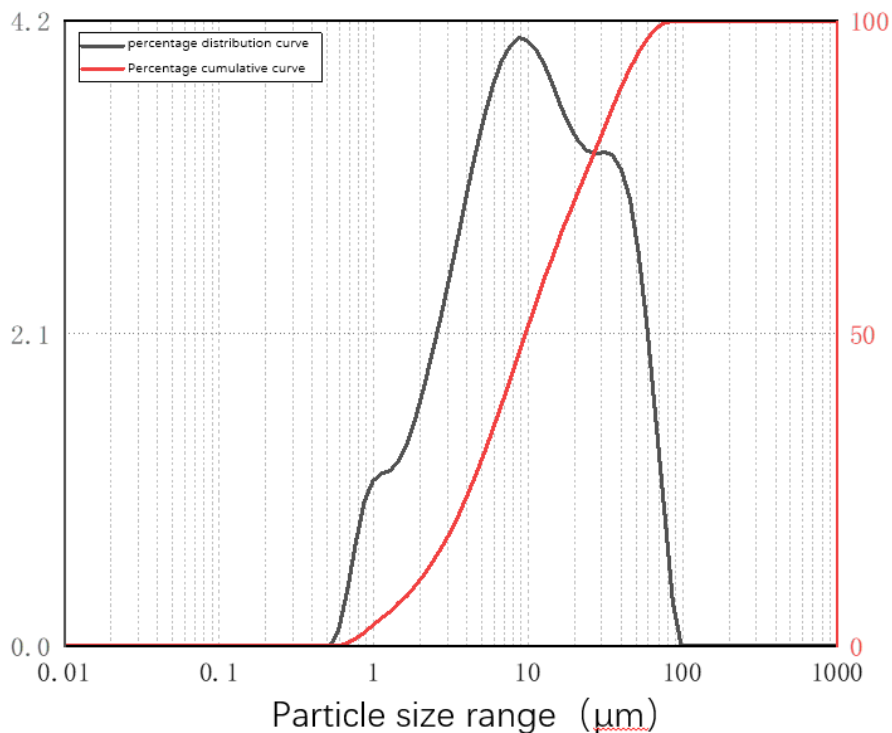


Figure 2. Cumulative distribution rate of tail sand particle size

Table 4. Particle size composition of fine-grained tail sand

Accumulate/%	d ₁₀	d ₂₀	d ₆₀	d ₈₀	d ₉₀	d ₁₀₀
Granularity/um	1.91	3.40	13.3	27.8	41.1	86.4

In production, non-uniformity coefficient is often used to express the uniformity of particle gradation:

$$\alpha_{90} = \frac{d_{90}}{d_{10}} \tag{1}$$

$$\alpha_{60} = \frac{d_{60}}{d_{10}} \tag{2}$$

The detection results of laser particle size analyzer show that the particles with the particle size of tailing less than 37um account for about 86% of the fine-grained tailing and 54.18% of the total tailing. For the non-uniformity coefficient, when α_{90} and α_{60} are less than 5, it indicates that the particle gradation is poor and relatively uniform; Greater than 10 indicates that the particle grading is good and uneven. For the tailing, $\alpha_{90} = 21.5$, $\alpha_{60} = 7$, indicating that the tailing particle size is relatively uniform, but the gradation is general. Although the density of the filling body formed by the tailing is high and the compressibility is good, the water permeability is small, which is unfavorable to the filling and dehydration.

4.2.3. Determination of Mud Content of Tailings

Weigh the sample with mass m_0 and put it into the container. Add water and wash the particles in the water by hand to separate the dust and clay from the coarse particles and suspend them in the water; Slowly pour the turbid liquid onto the 1.18mm and 0.075m sieves to filter out particles smaller than 0.075m. Add water to the container again and repeat the above steps until the washed water is clear. Wash the remaining fine particles on the screen with water, and put the 0.075mm screen in water (make the water surface slightly higher than the particles in the screen) to shake back and forth to fully wash the particles less than 0.075m. Then, put the remaining particles on the two sieves and the cleaned samples in the container into a shallow tray, put them in an oven with a temperature of $105^{\circ}\text{C} + 5^{\circ}\text{C}$ for drying to a constant weight, take them out and cool them to room temperature, and weigh the mass of the samples (m_1).

Calculation formula of mud content:

$$Q_n = \frac{m_0 - m_1}{m_0} \times 100$$

Where: Q_n —Silt content of crushed stone or gravel(%);

m_0 —Mass of dried sample before test(g);

m_1 —Mass of dried sample after test(g).

Test steps for clay content:

After passing the sample through 4.75m, weigh the mass (m_2) of the sample after sieving out particles less than 4.75mm, flatten the sample, add water to be higher than the surface of the sample, drain the water after 24h, twist and press the mud block by hand, and then place the sample on the 2.36m sieve and rinse with water until the washed water is clear. After taking out, place the test piece in an oven with a temperature of $105^{\circ}\text{C} + 5^{\circ}\text{C}$ to dry to constant weight, take out and cool to room temperature, and then weigh (m_3).

$$Q_k = \frac{m_2 - m_3}{m_2} \times 100$$

Where: Q_k —Clay content in crushed stone or gravel(%);

m_2 —4.75mm sieve balance(g);

m_3 —Mass of dried sample after test(g).

The measurement results are as follows:

Sediment percentage: I class $\leq 1.0\%$, II class $\leq 3.0\%$, III class $\leq 5.0\%$

Clay content: I class $\leq 0.2\%$, II class $\leq 1.0\%$, III class $\leq 2.0\%$

Based on the above analysis, in view of the quantity and performance of tailings in Tangshan area, the tailings in Tangshan area have great utilization value. At present, the comprehensive utilization of tailings in Tangshan area has made some achievements, but the overall comprehensive utilization level is low. For the tailings of different areas with different properties, the maximum utilization value should be specifically analyzed. Comprehensive utilization of tailings in Tangshan area has obvious economic, environmental and social benefits.

5. Epilogue

Driven by the green economy, we should actively carry out research on the recovery and reuse of tailings, put environmental protection in the first place, realize the production of less or no tailings in the mine, strive to study new technologies for tailings utilization and reduce the harm caused by tailings. Due to the complex types of tailings, we should analyze the physical and

chemical characteristics of tailings in Tangshan area, find out the characteristics of tailings in this area, find the corresponding utilization methods, and improve the utilization rate of tailings. Based on the principle of harmlessness, resources and reduction, realize the unification of environmental benefits, economic benefits and social benefits.

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