Construction of Testing Standards System for Comprehensive Utilization of Bulk Industrial Solid Waste

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Abstract. According to the general steps of comprehensive utilization of each type of bulk industrial solid waste, including fly ash, coal gangue, tailings, smelting slag, industrial by-product gypsum, and red mud, we construct the testing standards system for comprehensive utilization of bulk industrial solid waste in China. The standards system, according to the lifecycle stage of "raw materials - pre-treatment - processing - forming products - using products", can be divided into 5 standard subsystems, namely a subsystem of physical property testing standards for raw materials, a subsystem of chemical property testing standards, a subsystem of process testing standards, a subsystem of the product quality performance testing standards and a subsystem of the environmental impact testing standards. The standards system provide top-level guidance for the implementation and development of comprehensive utilization testing methods for bulk industrial solid waste.

Keywords: bulk industrial solid waste; comprehensive utilization; testing standards system.

1. Introduction

According to the general definition of China's industrial regulatory authorities, bulk industrial solid waste refers to solid waste generated by various industrial sectors in China during production activities, with a volume of over 10 million tons and a significant impact on the environment and safety. Currently, bulk industrial solid waste in China mainly includes six categories: fly ash, coal gangue, tailings, smelting slag, industrial by-product gypsum, and red mud. [1] At present, the annual production of bulk industrial solid waste in China is about 4.038 billion tons, which has exceeded the historical peak and reached its peak. In 2020, the comprehensive utilization of bulk industrial solid waste such as metallurgical slag and tailings in China was approximately 2 billion tons. [2] Solid waste is one of the focus issues of environmental protection in China, which has a high environmental risk and may cause potential pollution to groundwater, surface water, soil and air. At the same time, solid waste may also cause geological hazards and occupy a large amount of land. The treatment, disposal and utilization of solid waste, especially hazardous waste, has always been the key to restricting the construction of ecological civilization in China, and has become a key issue of great concern to the society, the public and government departments. [3]

The increase in storage capacity will increase environmental pollution and safety hazards. [4] The chemicals and various metal elements such as copper, lead, zinc, chromium, cadmium, arsenic, mercury, etc. contained in bulk industrial solid waste will flow into nearby rivers or infiltrate underground with water, seriously polluting water sources. [5] Dried tailings, fly ash, and other materials form dust when exposed to strong winds, and sulfur dioxide generated by coal gangue spontaneous combustion can form acid rain, posing a threat to the environment. Overdue or overloaded use of tailings ponds, red mud ponds, and even illegal operations can bring great safety hazards, posing a serious threat to the property and life safety of people in surrounding areas. In addition, the exploitation of a large number of non-metallic natural mineral resources has also caused serious environmental and ecological damage.

The comprehensive utilization of bulk industrial solid waste is an important component of the strategic emerging industry of energy conservation and environmental protection. It is a fundamental solution to the environmental pollution and safety hazards caused by improper disposal and storage of bulk industrial solid waste. It is also an important measure to achieve industrial transformation and upgrading, and a long-term strategic policy to ensure the sustainable development of China's industry.[6]

The storage volume of bulk industrial solid waste is huge, and environmental risks are prominent. Its resource utilization is the fundamental solution to the environmental pollution and safety hazards caused by improper disposal and storage, and is also an important measure to achieve industrial transformation and upgrading. It is urgent to conduct research on standards and policies related to the comprehensive utilization of technological processes, risk control, product quality and safety.

The comprehensive utilization and testing standard system for bulk industrial solid waste is based on the development and research of a series of utilization technologies, which has important technical and practical guidance significance for the utilization of bulk industrial solid waste. Establishing a comprehensive utilization and testing standard system for bulk industrial solid waste is in line with the national policy requirements for resource conservation and comprehensive utilization. It is an objective need for the development of coal, mining, mining, environmental protection and other related industries, and is conducive to achieving standardized and standardized management of the comprehensive utilization of bulk industrial solid waste, ensuring the sustainable development of China's national economy. It also helps to standardize the standardized production and management of enterprises, and promotes the market promotion of comprehensive utilization products for bulk industrial solid waste.

2. The necessity of establishing a comprehensive utilization and testing standard system for bulk industrial solid waste

The resource-based products of bulk industrial solid waste, due to their differences in raw materials and processes, are significantly different from products typically prepared from traditional raw materials and processes. In terms of raw material selection, monitoring of the processing process, and safe use of products, specialized environmental risk and quality safety testing are required to ensure that there is no secondary pollution generated during the resource-based process, ensuring the quality and environmental safety of resource-based products.

The utilization of bulk industrial solid waste differs from the usual meaning of products as follows:

Firstly, the sources of industrial solid waste raw materials are complex and often contain toxic components such as heavy metals, requiring source detection and screening. For example, unlike ordinary clay, limestone, and other raw materials, the main components of coal gangue are oxides of aluminum and silicon, as well as metal elements [5] such as Ga, Be, Co, Cu, Mn, Mo, Ni, Pb, In, Bi, and some also contain radioactive elements.[7] When using coal gangue to prepare building materials and other products, it is necessary to detect its radioactive intensity, heavy metal components, and content to avoid these environmental risks from migrating to products such as cement, coal gangue bricks, and ceramic particles along the industrial chain, causing surface diffusion of environmental pollution.

Secondly, the process of industrial solid waste recycling is different from the usual process of products, and its complex components require detection and monitoring of environmental emissions during the process. For example, the organic components and volatile non organic components in solid waste raw materials such as coal gangue, fly ash, tailings, and red mud are prone to release multi-component exhaust gas during activation, calcination, and other processes. There are also a large amount of solid residues at the end of the process, which are potential factors of

environmental pollution. Specialized testing techniques and methods need to be adopted for detection based on the utilization process of industrial solid waste.

Thirdly, the environmental and safety attributes of bulk industrial solid waste recycling products themselves also need to be closely monitored to ensure their safe use and promote the promotion of safety standards for industrial solid waste recycling products. The complexity of the composition of industrial solid waste raw materials will also lead to significant environmental and safety risks for products. For example, building materials prepared from raw materials such as coal gangue, fly ash, and tailings pose one of the important environmental risks. There have been multiple cases in China where building materials prepared from solid waste products have exceeded the standard in terms of radioactivity, leading to health hazards for residents. [8]

In order to comprehensively promote the comprehensive utilization of bulk industrial solid waste in China and improve the level of comprehensive utilization, there is an urgent need for strong support from the supporting technical service industry. It is also necessary to establish a public testing platform for the comprehensive utilization of bulk industrial solid waste, to test the pollution control of industrial solid waste raw materials, resource utilization processes, and the performance of resource utilization products, and to promote the healthy and rapid development of the resource utilization of bulk industrial solid waste.

In recent years, with the rapid development of China's national economy, the production of large amounts of industrial solid waste such as coal gangue, tailings, red mud, fly ash, industrial by-product gypsum, and white mud has rapidly increased. In addition, various solid waste stored in history cannot be fully consumed in the short term, and the pressure on comprehensive utilization has further increased. In order to promote the comprehensive utilization of bulk industrial solid waste and solve many problems in the industry as soon as possible, China has formulated a series of policies and regulations for solid waste management. These policies and regulations aim to control pollution and comprehensively utilize resources, regulate various links in the process of industrial solid waste disposal and comprehensive utilization, and clarify the principles of encouraging and supporting the industry of industrial solid waste comprehensive utilization. Various ministries and commissions of the State Council have also issued many policies aimed at accelerating the construction of industrial solid waste comprehensive utilization bases, strengthening the research and development of common key technologies, gradually establishing and improving the resource comprehensive utilization testing standard system, and establishing an industrial resource comprehensive utilization information monitoring platform. The introduction of these policies and regulations will play an important role in improving the comprehensive utilization level of industrial solid waste resources in China.

3. Framework of the Testing Standards System for Comprehensive Utilization of Bulk Industrial Solid Waste

The process of resource utilization of bulk industrial solid waste cannot be separated from the control of the chemical composition, physical properties, mineral composition of its raw materials, as well as the material form and operating conditions during the utilization process, as well as the detection of the composition, structure, performance and other attributes of the resource products. These detection methods are the means to analyze and monitor important parameters in the process of bulk industrial solid waste utilization, and are also necessary measures to control product quality and safety. Due to the universality of the detection of physical, chemical, and mechanical properties of bulk industrial solid waste and its utilization process products, many parameter detection methods are consistent with the detection of other substances or materials, and are not unique to the detection of bulk industrial solid waste. Some of these standards are testing method standards for the basic properties of substances or materials.

3.1 General framework of testing standard system

The bulk industrial solid waste testing standard system is mainly expressed through the framework diagram of the standard system and the standard system table. The comprehensive utilization testing standard system for bulk industrial solid waste is a comprehensive standard system with multiple objects, stages, and indicators, which should include at least the following three dimensions (see Fig. 1):

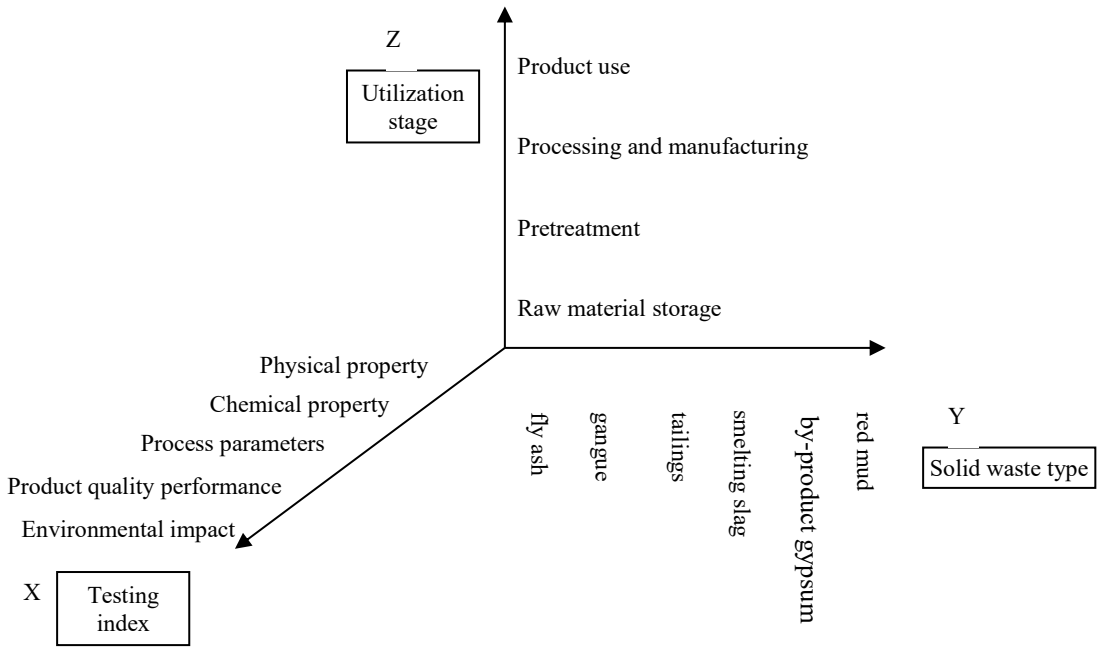

Fig. 1. Dimensional Analysis of the Testing Standard System for Comprehensive Utilization of Solid Waste in Bulk Industry

(1) Different objects

China's bulk industrial solid waste mainly includes six categories: fly ash, coal gangue, tailings, smelting slag, industrial by-product gypsum, and red mud. The bulk industrial solid waste testing standard system should first be classified according to different types of solid waste.

(2) Different stages

The comprehensive utilization of any type of bulk industrial solid waste will involve the collection, testing, transportation, pre-treatment, processing, product transportation, product use, and environmental impact assessment of raw materials. For a certain type of bulk industrial solid waste, its testing standard system should be refined according to different stages.

(3) Different indicators

In the process of industrial solid waste utilization, the detection indicators that may be involved can be divided into physical properties such as basic properties, mechanics, phase, opto magnetic and thermal properties, chemical properties such as composition, element detection, reactivity, etc. based on the different categories of indicator parameters. The product properties such as product properties, mechanical properties, usage performance, opto magnetic and thermal properties can be tested using processes such as pre-treatment, processing parameters, and intermediate products during the process, and environmental impact testing on soil, water, gas, etc.

Based on the above analysis, according to the current classification method for bulk industrial solid waste by the competent government departments in China, the testing standard system can be divided into six parts: fly ash, coal gangue, tailings, smelting slag, industrial by-product gypsum and red mud. According to the lifecycle stage of "raw materials pre-treatment processing forming products using products", each part can be divided into 5 standard subsystems: a subsystem of physical property testing for raw materials, a subsystem of chemical property testing, a subsystem

of process testing, a subsystem of product quality performance and a subsystem of environmental impact. The overall framework structure of testing standard system for bulk industrial solid waste is shown in Fig. 2.

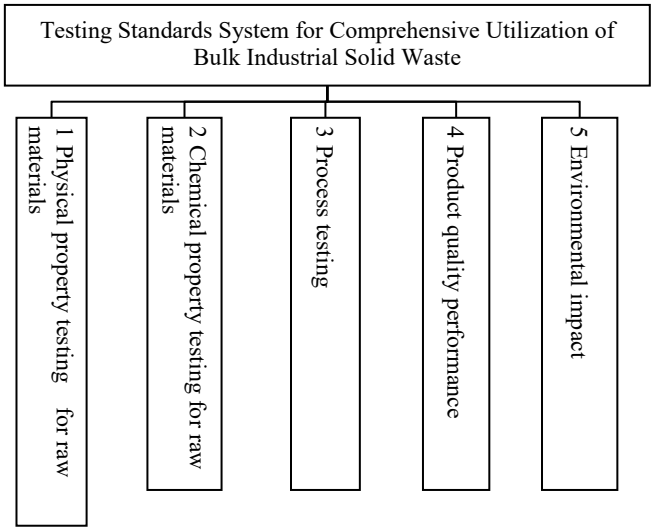

Figure 2. General Framework of the Testing Standards System for Comprehensive Utilization of Bulk Industrial Solid Waste

3.2 Composition of the testing standard system framework

Due to the similarity in physical, chemical, environmental, and product performance testing indicators for each type of bulk industrial solid waste, each standard subsystem for different types of industrial solid waste can be divided into the same series.

Based on the different corresponding indicators and parameters in terms of physical properties, chemical properties, process testing, product performance, environmental protection, etc. for each type of bulk industrial solid waste comprehensive utilization, the 5 subsystems can be decomposed into 42 series, thus forming a three-level framework for the comprehensive utilization testing method standard system of bulk industrial solid waste. As shown in Figures 3-7.

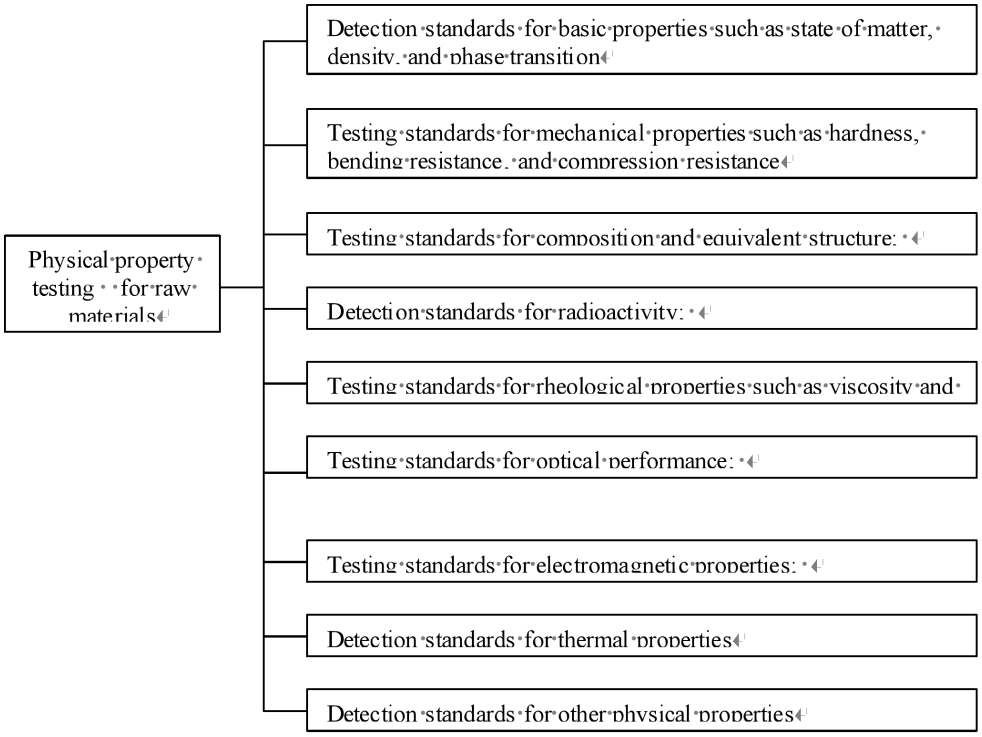

Figure 3. Physical Property Testing Standard Subsystem for Bulk Industrial Solid Waste Raw Materials.

3.2.1 Physical Property Testing Standard Subsystem for Bulk Industrial Solid Waste Raw Materials.

This standard subsystem is decomposed into 9 series of standards, namely detection standards for basic properties such as state of matter, density, and phase transition; Testing standards for mechanical properties such as hardness, bending resistance, and compression resistance; Testing standards for composition and equivalent structure; Detection standards for radioactivity; Testing standards for rheological properties such as viscosity and ductility; Testing standards for optical performance; Testing standards for electromagnetic properties; The detection standards for thermal properties and other physical properties are shown in Figure 3.

3.2.2 Chemical Property Testing Standard Subsystem for Bulk Industrial Solid Waste Raw Materials.

The standard subsystem is decomposed into 8 series of standards, namely the detection standards for chemical composition; Testing standards for acidity and alkalinity; Testing standards for metal elements; Testing standards for flammability, calcination, and other aspects; Detection standards for redox properties; Detection standards for chemical reaction activity; Detection standards for changes in material migration; Other relevant chemical property testing standards are shown in Figure 4.

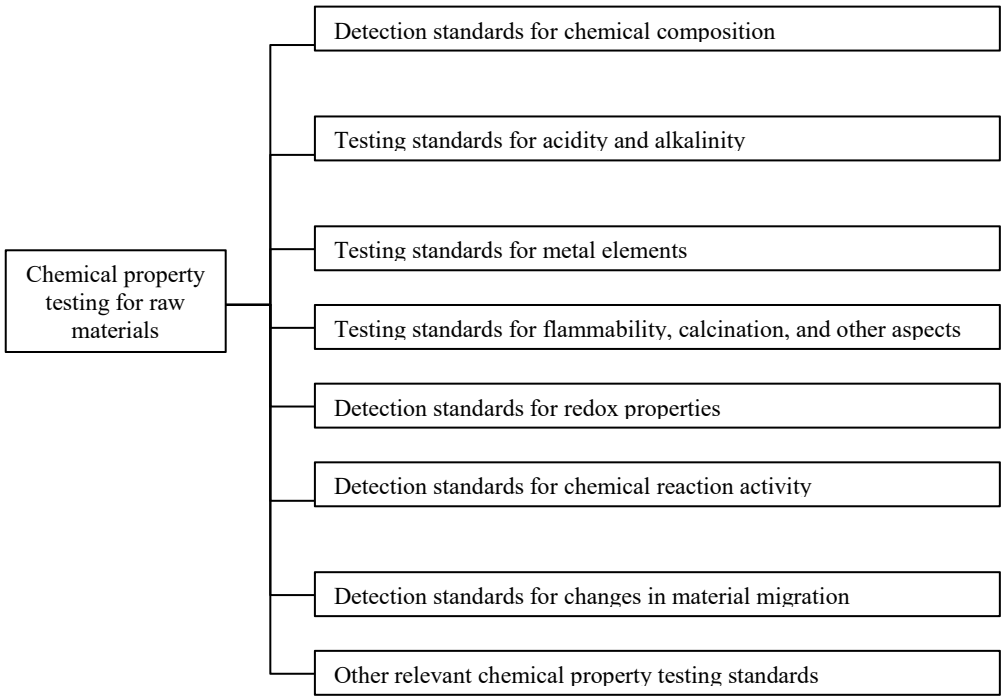

Figure 4. Chemical Property Testing Standard Subsystem for Bulk Industrial Solid Waste Raw Materials.

3.2.3 Subsystem of relevant testing standards for the utilization process of bulk industrial solid waste.

The standard subsystem is decomposed into 5 series of standards, namely the detection standards for the physicochemical properties of raw material pretreatment processes; Testing standards for the activation performance of solid waste processing; Testing standards for process parameters such as temperature, pressure, and atmosphere; Testing standards for the physicochemical properties of intermediate products; and other relevant testing standards are shown in Figure 5.

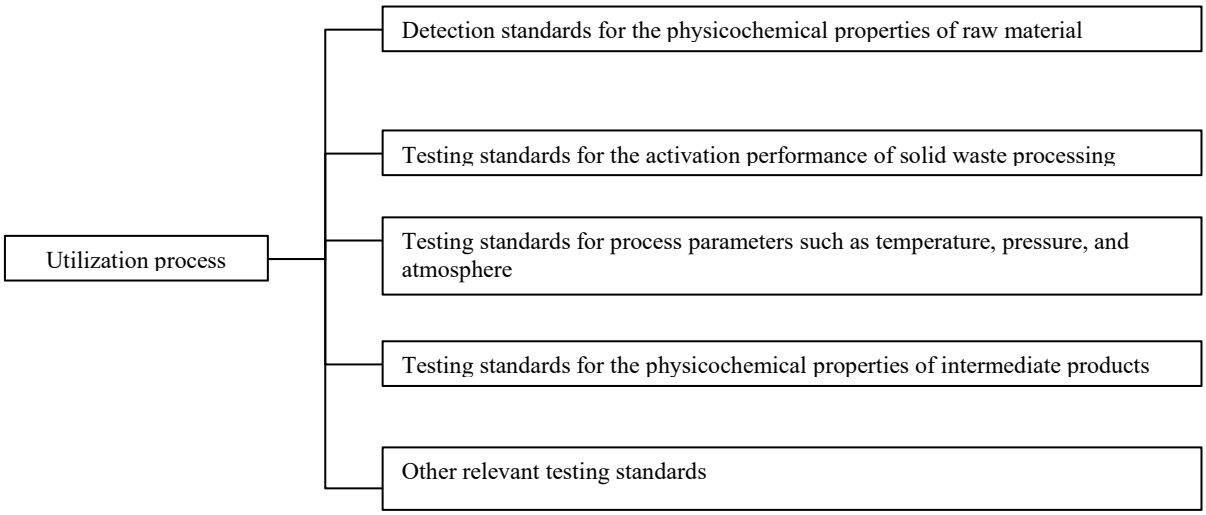

Figure 5. Subsystem of relevant testing standards for the utilization process of bulk industrial solid waste.

3.2.4 Quality performance testing standard subsystem for bulk industrial solid waste products.

This standard subsystem is decomposed into 9 series of standards, namely the detection standards for basic attributes such as product composition and density; Testing standards for mechanical properties such as hardness, bending resistance, and compression resistance; Testing standards for product particle size, phase, porosity and other structural aspects; Testing standards

for product radioactivity; Testing standards for product durability and other aspects; Environmental testing standards for heavy metal leaching and volatile matter release of products; Testing standards for thermal properties such as combustion and thermal conductivity; Testing standards for electromagnetic properties; The detection standards for other physical and chemical properties are shown in Figure 6.

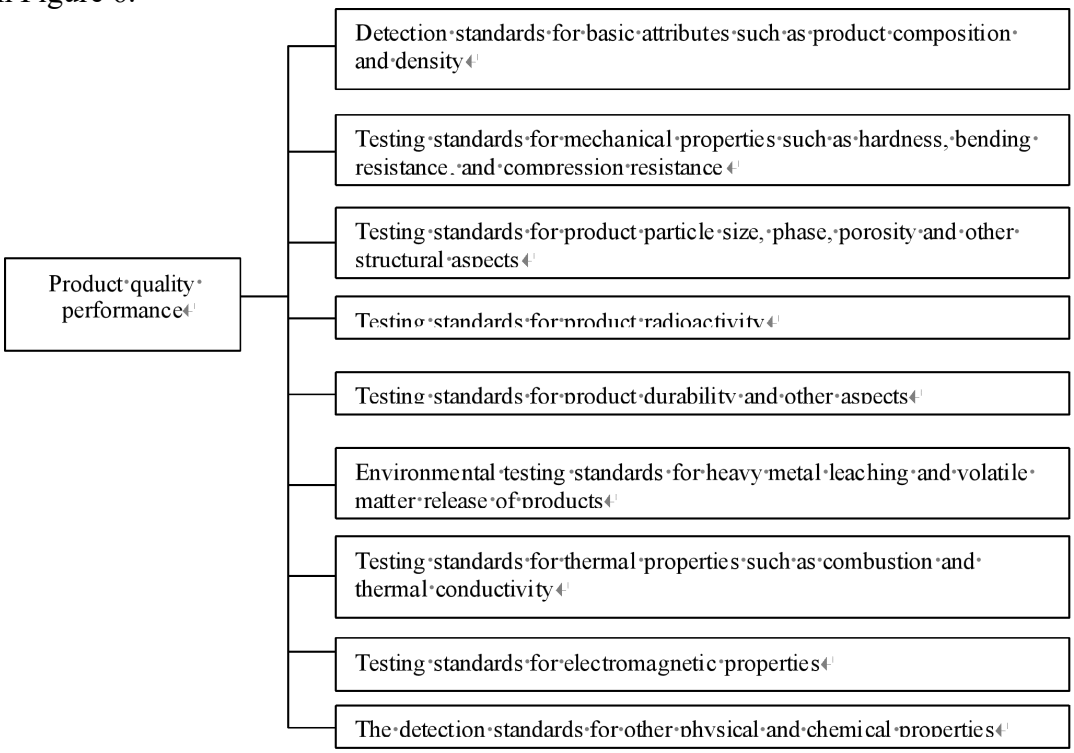

Figure 6. Quality performance testing standard subsystem for bulk industrial solid waste products.

3.2.5 Standard subsystem for environmental impact assessment of bulk industrial solid waste.

This standard subsystem is decomposed into 7 series of standards, namely the detection standards for the impact of bulk industrial solid waste on soil; Wastewater detection standards for the utilization of bulk industrial solid waste; Waste gas detection standards for the utilization of bulk industrial solid waste; Utilize noise detection standards during the process; Radioactivity detection standards during storage and utilization processes; Testing standards for volatile substances in bulk industrial solid waste; and the detection standards for other environmental pollution are shown in Figure 7.

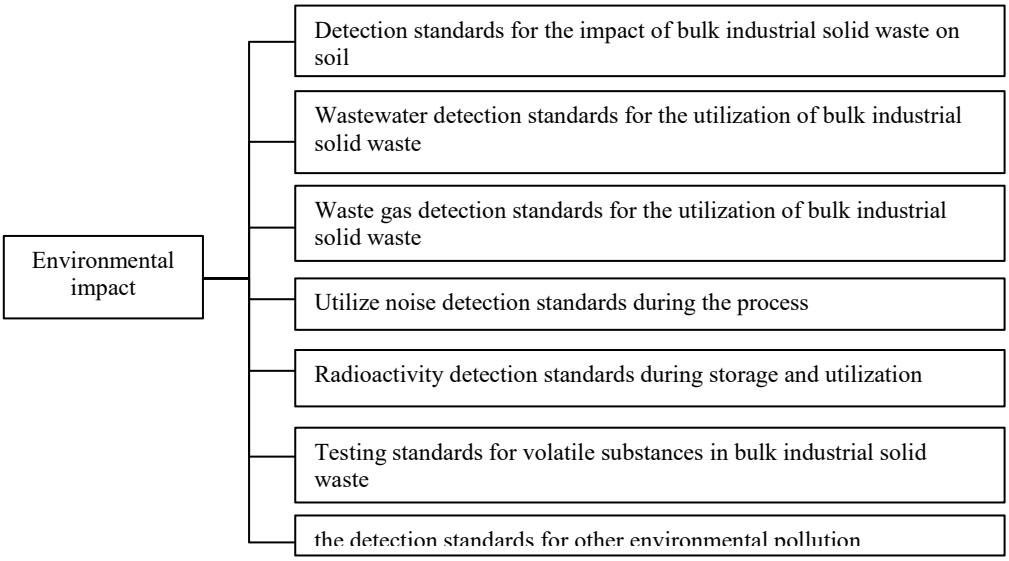

Figure 7. Quality performance testing standard subsystem for bulk industrial solid waste products.

4. Table of Testing Standards System for Comprehensive Utilization of Bulk Industrial Solid Waste

Based on the testing requirements for various performance indicators in the comprehensive utilization process of large industrial solid waste such as fly ash, coal gangue, tailings, smelting slag, industrial by-product gypsum, and red mud, a comprehensive utilization standard system table for bulk industrial solid waste is formed by integrating existing standards, upcoming standards, and future standards.

After thorough research and analysis, based on the existing technological processes and industry development level, the establishment of a relatively comprehensive testing standard system for the comprehensive utilization of bulk industrial solid waste should include at least 332 standards, of which 205 are issued standards, 4 are currently being developed standards, and 123 are standards that should be considered for future development (including planned and pending status standard projects).

Due to the different technological levels and industry scales of comprehensive utilization of industrial solid waste, the requirements for corresponding testing technology standards are also different. Among them, fly ash and coal gangue, due to their early technological development, have a relatively large number of detection technology standards, with 67 and 139 items respectively, while industrial by-products such as gypsum and red mud have relatively fewer standards, with only 16 and 11 items respectively.

With the progress of various technologies for the comprehensive utilization of bulk industrial solid waste, new technologies and processes are constantly emerging, and new products will also be developed. The demand for testing standards for the comprehensive utilization of bulk industrial solid waste is also increasing, and more testing standards will be proposed and developed one after another. Therefore, the comprehensive utilization and testing standard system for bulk industrial solid waste will be a dynamically developing standard system, with its quantity, scale, and completeness continuously increasing.

Acknowledgments

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