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Environmental Risk Analysis of Leachable Substances from Vitreous Residue of Solid Wastes Treated by High Temperature Melting

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Abstract. High temperature melting is a harmless treatment technology for solid wastes, which is applicable to hazardous wastes containing heavy metals and other harmful substances, obtaining amorphous glassy substances. Vitreous residue usually has high stability and low leaching toxicity. This paper simulates the leaching test of vitreous residue under natural conditions in ordinary rain and acid rain, systematically detects the concentration of leachable substances of typical residue, and analyses its environmental risks according to groundwater quality standards, indicating that harmful substances such as heavy metals may bring potential environmental risks when the vitreous residue enters the environment.

Keywords: vitreous residue; solid waste; leachable substance; environmental risk.

1. Introduction

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. [1]

Vitrification is a harmless treatment method for solid wastes at home and abroad at present, which is especially suitable for hazardous wastes containing heavy metals and other harmful substances. It uses high temperature means such as plasma to melt solid wastes at high temperature and then cool them to form amorphous glassy substances.

More than twenty enterprises in China have used high-temperature melting means such as plasma gasification, coal water slurry gasification or industrial furnace and kiln collaborative disposal to vitrify solid wastes, especially hazardous wastes [2][3]. They have achieved good economic, social and environmental benefits.

The vitrification treatment technology can be used to dispose various types and forms of hazardous wastes, including POPs. The residue generated after high-temperature melting is vitreous residue, which is regarded usually to have high stability and low leaching toxicity. In Europe, the United States, and Japan [1], vitreous residue is usually landfilled as general solid waste, or used as building and paving materials for comprehensive utilization. This is conducive to reducing the amount of hazardous waste landfills, and better realizing the reduction, harmless and recycling of hazardous waste [4].

In 2000, the European Commission issued the European Waste List, in which it clearly stipulates that the vitreous residue generated from the high temperature melting disposal of hazardous waste is a general solid waste (code: 19 04 01), not managed as a hazardous waste. According to the EU's Waste Landfill Technology Directive (1999/31/EC), the solid waste to be landfilled is divided into three grades: hazardous waste, non-hazardous waste and inert waste. The residue of hazardous

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waste after high temperature melting is a vitreous substance. Through leaching toxicity analysis, it is concluded that the concentration of the leached substance is lower than the identification standard of inert waste, and is usually landfilled as general solid waste. At present, more than half of the hazardous waste disposal facilities in EU countries have adopted high temperature melting treatment technology. Each member state has formulated relevant policies to encourage the application of vitrification disposal technology of hazardous wastes in combination with its own actual conditions, such as requiring high incineration removal rate and that incineration residues must reach the glassy state.

In Japan, due to the limitation of land, vitrification technology is widely used in order to effectively control the landfill volume of hazardous waste. Domestic waste incineration residues and ordinary waste incineration residues (including fly ash) are mainly vitrified by secondary melting in blast furnaces or melting incinerators to reduce landfill volume. More than 30 enterprises in Japan have adopted the technology of melting vitrification treatment of hazardous wastes.

Japan has established the most complete management system in the use of vitrified residue as building materials. In March 2005, the test standards for molten slag were formulated: JIS K 0058-1 Test Methods for Chemicals in Slag - Part 1: Leaching Test Method, and JIS K 0058-2 Test Methods for Chemicals in Slag - Part 2: Test Method for acid extractable contents of chemicals. In addition, in July 2006, JIS K 0058-1 and JIS K 0058-2 were cited as quality standards with "leaching standard" and "content standard", and JIS A 5031 "Melt-solidified slag aggregate for concrete derived from municipal solid waste and sewage sludge" and JIS A 5032 "Melt-solidified slag material for road construction derived from municipal solid waste and sewage sludge" were formulated.

In this study, the general exposure environment and extreme exposure environment of vitrification treatment residues, namely neutral rain soaking and acid rain soaking, were simulated by reference to the concept of "exposure environment that should be considered most" in the whole life cycle of building materials utilization in Japan and the risk assessment methods of building materials in different utilization scenarios in the European Union. We respectively used standard water leaching and acid leaching methods to treat 11 samples from typical Chinese vitrification enterprises. The vitrification residue was immersed in neutral and acid aqueous solutions to detect the concentration of the leached substances. By comparing with the standard limit of groundwater, the potential risks of dissolved substances to the environment are analyzed.

2. Experimental

2.1 Detection of water leaching content of harmful substances

The water extract solution of vitrification treatment product is prepared according to HJ 557 Solid waste — Extraction procedure for leaching toxicity — Horizontal vibration method. The specific experimental conditions are shown in Table 1. The detection of harmful substances in the water extract shall be carried out according to GB/T 14848 Standard for groundwater quality.

Table 1. The experimental conditions of vitreous residue of water leaching.

parameter	particle size	mass	leaching solution	liquid-solid ratio	vibration mode	leaching time	filtering method
requirement	<3mm	100g	pure water	10:1	horizontal vibration, 110 ±10 times/min, amplitude 40 mm	8h	microporous filtration with 0.45 μm

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2.2 Detection of acid leaching content of harmful substances

Take the vitrification treatment residue as the dried test body of GB/T 30810-2014, and prepare the acid leaching solution according to the methods specified in 6.2 and Chapter 7 of GB/T 30810-2014 Test methods for leachable ions of heavy metals in cement mortar. The specific experimental conditions are shown in Table 2. The content of harmful substances shall be determined according to GB/T 30810-2014.

Table 2. The experimental conditions of vitreous residue of acid leaching.

parameter	temperature	particle size	mass	leaching solution	liquid-solid ratio	leaching time	filtering method
requirement	20±2℃	0.125mm~0.25mm	10g	sulfuric acid nitric acid mixture	100:1	2h+7h	microporous filtration with 0.45 μm

3. Results and discussion

In this study, we collected 11 samples of vitrification residues from typical vitrification enterprises, and carried out water leaching and acid leaching tests respectively according to the above methods. The test data are shown in Table 3 and Table 4 respectively.

From the determination results in Table 3, we can see that nickel, arsenic, selenium and fluoride for some samples exceed the standard of GB/T 14848-2017 Standard for groundwater quality. The determination results in Table 4 show that zinc, chromium, nickel and manganese for some sample exceed the standard GB/T 30760-2014 Technical specification for co-processing of solid waste in cement kiln.

4. Conclusion

Vitrification treatment technology can solidify harmful substances such as heavy metals in a dense glassy three-dimensional structure, which is not easy to release harmful substances to the environment. Therefore, the environmental risk of vitreous residue is usually low. Due to the different raw materials and processes in the vitrification process, the content of heavy metals in the vitrification products is different. As the actual vitrification treatment process may have some fluctuations, the resulting residue may not be a perfect homogeneous glassy phase material, so when the vitrification treatment products are used as materials, heavy metals and other harmful substances may bring potential environmental risks [5][6]. In order to ensure that the environmental risks of vitrification residues in the preparation of building materials can be controlled, it is necessary to formulate standards for vitrification residues to reduce the subsequent environmental risks of high-temperature melting technology.

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Table 3. Water leaching test results of vitrification residue samples.

Sample No.	Concentration （mg/L）												
	Cu	Zn	Cd	Pb	Cr(VI)	Hg	Be	Ba	Ni	As	Se	Mn	F
1	ND	0.0341	0.000009	ND	ND	0.0001	0.0000644	0.000536	ND	0.00527	0.0012	0.0127	35.6
2	ND	0.0116	0.000018	ND	ND	ND	ND	ND	ND	0.000660	ND	0.0120	0.746
3	0.0010	0.1641	ND	0.0006	ND	0.0003	0.000261	0.00929	ND	0.0700	0.0036	0.0091	1.36
4	ND	0.0024	ND	ND	ND	ND	0.00000150	ND	ND	0.000565	ND	0.0082	0.080
5	0.0032	0.2317	0.000027	0.0001	ND	0.0002	0.0000588	ND	0.0256	0.133	0.0342	0.0171	51.8
6	0.0472	0.0922	0.000571	0.0000208	ND	ND	0.00000150	0.00461	0.0572	0.00828	ND	0.0133	0.535
7	0.0081	0.0201	ND	0.0001[illegible]	0.005	ND	0.00000010	ND	ND	0.000705	0.0001[illegible]	0.0091	0.302
8	0.4956	0.0917	ND	0.0002[illegible]	ND	ND	0.00000850	0.00226	0.0711	0.00703	0.0022[illegible]	0.0101	ND
9	ND	0.0336	ND	ND	0.005	ND	ND	0.00348	ND	0.00294	ND	0.0085	0.430
10	ND	0.0044	ND	0.0000368	ND	ND	0.00000150	0.00201	ND	ND	0.000555	0.0111	0.0583
11	ND	0.0062	ND	ND	ND	ND	ND	ND	ND	0.000275	0.000025	0.0107	1.497
limitation for	1.0	1.0	0.005	0.01	0.05	0.001	0.002	0.7	0.02	0.01	0.01	0.1	1.0
Number of	0	0	0	0	0	0	0	0	3	2	1	0	4

Note: ND means not detected.

Table 4. Acid leaching test results of vitrification residue samples.

Sample No.	Concentration （mg/L）							
	Cu	Zn	Cd	Pb	Cr	Ni	As	Mn
1	0.0210	0.226	0.0000167	ND	0.3676	ND	ND	0.194
2	0.0557	1.75	0.000518	ND	0.2703	0.0471	0.0246	0.529
3	0.2655	0.277	0.000197	ND	ND	ND	0.0189	0.139

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4	0.0581	ND	ND	ND	ND	ND	ND	0.0458
5	0.1369	0.422	0.000756	ND	ND	0.0650	ND	0.0666
6	0.4905	7.62	0.000944	ND	1.0525	0.6809	ND	1.27
7	0.0155	ND	ND	ND	ND	ND	ND	ND
8	0.9426	0.918	0.000277	0.0120	0.7025	0.9088	0.00504	1.80
9	0.0153	ND	0.0000124	ND	0.0167	ND	ND	0.303
10	0.0287	ND	ND	ND	0.0196	ND	ND	0.201
11	0.3308	3.52	0.000585	ND	0.1627	0.4028	ND	0.586
limitation value	1.0	1.0	0.03	0.3	0.2	0.2	0.1	1.0
Number of samples exceeding the limit	0	3	0	0	4	3	0	2

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