Feasibility of Isolation Remediation Technology for Heavy Metal Contaminated Soil

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Abstract This paper discussed current situations of researches about the isolation remediation technology "soil barrier and landfill technology" and "physical isolation remediation technology" for heavy metal contaminated soil in mining areas. In view of defects of current technologies, it introduced a new isolation remediation technology, of which the new isolation materials were mixed by slaked lime, soil, find sand, and clay mineral in certain proportion. The new isolation remediation technology is expected to realize isolation remediation of heavy metal combined pollution of soil through chemical passivation of slaked lime and physical adsorption function of clay minerals or activated carbons.

Key words Soil, Combined pollution, Heavy metal, Isolation remediation

1 Introduction

China is a large country with rich mineral resources. In recent 30 years, mineral resources have been developed and utilized on a large scale and made a great contribution to China's economic development. Due to mining, smelting, and slag piling during the development of mining area, especially, heavy metals in slag waste penetrates into the soil along with mine drainage and rainfall, and enters into animal and human body through the food chain, consequently harms the health[1-3]. The increasingly serious soil pollution has become a serious problem that should not be ignored.

2 Current situations of researches

The physical remediation technology is the technology most widely applied in the remediation of contaminated land in mining area. It mainly includes soil barrier and landfill technology and physical isolation remediation technology.

The soil barrier landfill technology, as a common technology used for remediation of contaminated land, is mainly suitable for remediation of heavy metals, organic matters, and heavy metal and organic matter combined pollution of soil. It includes *in situ* barrier covering and ex-situ barrier landfill.

At present, *in situ* soil barrier covering system mainly consists of soil barrier system, soil covering system and monitoring system. The soil barrier system mainly consists of impermeable barrier materials such as High Density Polyethylene (HDPE) film and slurry wall. Through building the barrier layer around the contaminated area, the pollution is limited to a specific area. By comparison, the soil covering system generally consists of one or many layers of clay, artificial synthetic material lining, sand, and cover, while the monitoring system is mainly made up of the upstream and downstream monitoring well in the barrier zone. The technical equipment has been widely applied in foreign countries and has become considerably mature. However, this technology needs establishing a soil barrier system, a soil covering system and monitoring system. When the treatment area of heavy metal contaminated soil is large and treatment works are increased, it will lead to increase of costs for remediation project. Yet, the *in situ* soil barrier covering technology costs 500 - 800 yuan/m^2, the cost is relatively low. In China, the soil barrier landfill technology for barrier treatment of contaminated site is close to the pollution control level of hazardous waste landfill sites. For most heavy metal contaminated sites, these barrier measures have the problems of excessive conservative requirements and excessive remediation[4-5].

The physical isolation remediation technology is to lay a certain thickness of the isolation layer, on which a certain thickness of clean soil layer, to realize isolation remediation of heavy metals in contaminated soil. In the clean soil layer, crops can be planted. The existing physical isolation remediation technology generally use soil, fine sand and slaked lime as the materials for the isolation of contaminated soils, and utilize the passivation and isolation of different heavy metals to prevent the migration of heavy metals to the upper soil. Studies have found that, through adding slaked lime to contaminated soil, it is able to significantly increase the soil pH, and the stability of Pb, Cu and Cd can reach 99.79%, 99.78% and 98.5%[6-7]. Practice indicates that the physical isolation remediation technology has simple, economical and efficient benefits in engineering application.

However, due to the influence of mining methods, mineral dressing process and characteristics of ore, the contaminated soil in mining area often contains a variety of heavy metal pollution elements. In the existing isolation layer, the passivated isolation of slaked lime for different heavy metals is selective. With the increase in the application amount and time of slaked lime, the ef-

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fective content of Pb and Cd are significantly reduced. However, no matter the treatment time, little slaked lime will not influence the available mercury content in the soil, while excessive slaked lime will increase the available mercury content in the soil[8]. Adding lime to mercury-containing soil is only effective in the range of pH 6 – 7, and the effect starts to decline at pH 7.72. It may even have counter action if pH continues to rise[9-10]. Therefore, it is still not sufficient to isolate main pollutants in the soil using the existing insulation layer, especially for heavy metal (containing Hg) contaminated soil.

3 New isolation remediation technology

In the physical isolation remediation technology, the isolation layer as the key layer can prevent high content heavy metal elements entering the clean soil layer. Thus, the physical and chemical properties, strength and stability of the isolation layer play a key role in this new isolation remediation technology. Because the inherent matrix of soil is complex and the pollution of heavy metal contaminated soil is mainly combined pollution through coexistence of many types of heavy metals, and there is complex interactions between heavy metals, and between heavy metals and soil interface, research and development of a barrier layer suitable for a variety of heavy metal contaminated soils is a key technology for the remediation of harmful heavy metals in contaminated soil.

Our survey found that the clay minerals have significant effect on adsorption isolation heavy metals. Especially, in recent years, extensive studies and applications have been carried out to remediate contaminated land with clay composite barrier materials[11-13]. The main principle is to utilize such features of clay minerals as large specific surface area, high polarity, and strong adsorption and ion exchange; through clay minerals absorbing heavy metals, and co-precipitation, it is able to reduce the mobility and bioavailability of heavy metals[14]. For example, achievements have been made in researches of using clay minerals such as palygorskite and zeolite to adsorb Hg^{2+} in soil and mercury-containing waste[15-16]. Jian Zhang *et al.*[17] used cheap and readily available activated carbon powder as pretreatment stabilizer of mercury-containing waste and obtained excellent effect in using activated carbon to absorb the mercury. Through study, Liu Jingjing[18] found that the application of slaked lime in the soil can increase the soil pH and strengthen the adsorption of clay to heavy metals.

Based on the existing isolation layer, we believed that through adding a certain amount of adsorptive substances (such as palygorskite or activated carbon), it is able to obtain a new isolation material, and realize the isolation remediation of combined pollution of many types of heavy metals. In the new isolation remediation technology, the soil, slaked lime, clay minerals, and fine sand are mixed in the ratio of 5∶2∶1∶2 (or 5∶1.5∶1.5∶2) to form the isolation layer (Fig. 1), and rolled and laid on the compacted contaminated soil. The laying thickness of isolation layer is 10 – 15 cm. On the isolation layer, a clean soil layer with the compaction coefficient of 0.86 and thickness of 40 cm is laid, then is the plow layer with the compaction coefficient of 0.83 and thickness of 30 cm as the plow and growth layer of plants, to realize the reclamation of contaminated land (Fig. 2).

Specifically, in the leveling and rolling of pollutants containing heavy metals in contaminated soil, the compaction coefficient should not be lower than 0.95; in the laying and rolling process of the isolation layer, water should be sprayed, to make the moisture content of the isolation layer reach 10% – 13%, and ensure the compaction coefficient not lower than 0.95, to prevent heavy metals penetrating the isolation layer and migrating to the overlying soil layer. Above the isolation layer, a clean soil layer is laid as the water and fertilizer retaining layer, and also the buffer layer between the isolation layer and the plow layer.

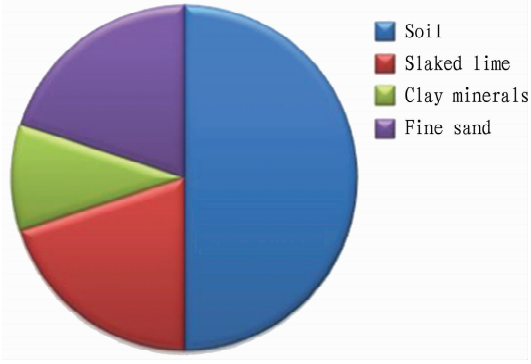

Fig. 1 The schematic diagram for isolation layer

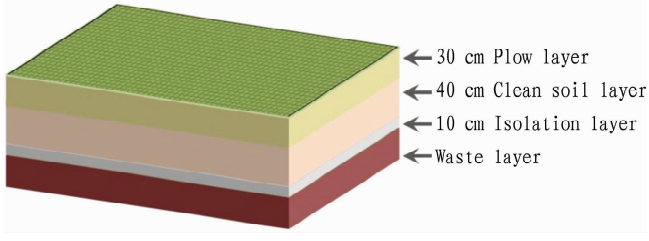

Fig. 2 The schematic diagram for soil structure

The isolation layer in this new isolation remediation technology can isolate and passivate heavy metals with the aid of chemical action of the slaked lime, and can further absorb heavy metals in the soil with the aid of physical adsorption of clay minerals. In particular, the slaked lime is not effective in passivation of heavy metals. However, the slaked lime and clay minerals can complement each other. Besides, the existence of slaked lime increases the soil pH, and it can promote the absorption of clay minerals. This will greatly strengthen the remediation effect of the new type of isolation layer on heavy metal contaminated soil, accordingly promote the development of isolation remediation technology for combined pollution of soil.

4 Conclusions and discussions

In the contaminated soil, especially many types of heavy metal contaminated soil, laying the new isolation layer can simultaneously isolate many types of harmful heavy metals in the soil. The new isolation remediation technology has benefits of low engineering

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It is assessed according to *Surface Water Quality Assessment Standard* (*GB*3828-2002). The total phosphorus content of Xinli River is higher than the threshold value of water quality standard Ⅴ(0.5 mg/L), and lower than the threshold value of heavy pollution (1 mg/L), indicating that the pollution is serious, the water is black near the drain outlet of Xinli River, and on the whole, the water eutrophication is serious in Xinli River.

5 Conclusions and discussions

5.1 Conclusions In this paper, we explore the pH, COD, ammonia nitrogen, total nitrogen, total phosphorus and other indices regarding Xinli River water in Binzhou City.

(i) The results show that the pH of Xinli River is 7.3 – 7.8, changing slightly, and there is a roughly rising trend from Yellow River 3 to Yellow River 8 in Xinli River, from 7.38 to 7.75, and the water is slightly alkaline.

(ii) The COD content of Xinli River is about 140 – 163 mg/L, it tends to first rise and then fall from Yellow River 3 to Yellow River 8 in Xinli River, and the COD pollution is serious in some water sections.

(iii) The ammonia nitrogen content of Xinli River is 0.2 – 2.17 mg/L, the total nitrogen content is about 0.799 – 1.3 mg/L, and the total nitrogen content of Yellow River 7 (0.799 mg/L) and Yellow River 3 (0.946 mg/L) is significantly lower than that of other river sections.

(iv) The total phosphorus content is about 0.54 – 0.92 mg/L, the highest concentration is 0.92 mg/L in Yellow River 6, and the lowest concentration is 0.54 mg/L in Yellow River 7, suggesting that the water eutrophication is very serious.

5.2 Discussions A large number of residential areas are on both sides of Xinli River from Yellow River 3 to Yellow River 8. Due to the large amount of domestic sewage discharged into Xinli River without treatment, slow circulation of river water and other factors, the eutrophication is serious in the urban watercourse.

It is recommended that the government should regulate the sewage discharge management on both sides of Xinli River, and strengthen the sewer network construction on both sides of the river. At the same time, it should carry out comprehensive improvement of the urban watercourse, in order to facilitate the transition of Xinli River to the ecological river.

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cost, rapid construction, high safety and reliability, so it is expected to be widely applied in many fields. However, for this new isolation remediation technology, it is necessary to make further theoretical researches and continuous experiments about the selection of different isolation materials, mixing ratio, and simultaneous isolation mechanism and effect of different isolation materials on different heavy metals, and adjust specific construction process and parameters, so as to suit the remediation of many types of heavy metal contaminated soil in different conditions.

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