Postprint: Study on Release-Migration-Inhibition Characteristics of Pollutants from Coal Gangue Subgrade Filler

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Abstract

This study investigates the release-migration-inhibition characteristics of heavy metal pollutants in coal gangue roadbed filler under natural rainfall. Laboratory tests were conducted to determine the basic properties of coal gangue filler, the types of heavy metal pollutants contained therein, and their release-migration characteristics under natural rainfall. Based on porous media solute transport theory, a numerical model for pollutant diffusion in coal gangue roadbed filler was established to predict the long-term impacts of pollutants on the water-soil environment under prolonged rainfall. The effectiveness of geopolymer chelation on heavy metal pollutants was investigated based on the solidification effects of geopolymer at different dosages (mass fractions) and curing ages, and compared with the solidification effects of conventional cement to comprehensively evaluate the inhibition characteristics of geopolymer on coal gangue roadbed filler. The leaching concentrations (mass concentrations) of Pb and As heavy metal elements in coal gangue exceeded the environmental limit values by 9.1 times and 9.8 times, respectively, compared to the Class III groundwater limit specified in the "Standard for Groundwater Quality". During the initial rainfall period, the release rates of various heavy metal pollutants in coal gangue filler were high with large leachate amounts; subsequently, the release rates gradually decreased until stabilization, while the cumulative release amounts continued to increase. Over time, heavy metal pollutants migrated toward the roadbed bottom. After incorporating geopolymer, the leaching concentrations of all heavy metals were below the environmental standard limits. The heavy metal pollutants in coal gangue roadbed filler exhibit persistent and long-term characteristics of environmental impact; as the geopolymer dosage and curing age increase, the heavy metal concentrations (mass concentrations) in the leachate decrease until they are far below the Class III water limit. The solidification effect of geopolymer is superior to that of cement, and the optimal chelation effect on pollutants is achieved at a geopolymer dosage of 8% and a curing age of 14 days.

Full Text

Study on the Release-Migration-Inhibition Characteristics of Pollutants from Coal Gangue Roadbed Fillers

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Abstract

This study investigates the release-migration-inhibition characteristics of heavy metal pollutants from coal gangue roadbed fillers under natural rainfall conditions. Through laboratory experiments, the fundamental properties of coal gangue fillers were determined, the types of heavy metal pollutants present were identified, and the release-migration behavior of these contaminants under simulated rainfall was characterized. Based on porous media solute transport theory, a numerical diffusion model for pollutants in coal gangue roadbed fillers was developed to predict the long-term impacts of sustained rainfall on soil and water environments. Additionally, the effectiveness of geopolymer chelation on heavy metal pollutants was evaluated by examining solidification performance across varying dosages (mass fractions) and curing ages, with results comprehensively compared against conventional cement stabilization to assess the inhibition characteristics of geopolymers for coal gangue roadbed applications.

The results reveal that the leaching concentrations (mass concentrations) of Pb and As in coal gangue exceed environmental limits by 9.1 and 9.8 times, respectively, compared to the Class III groundwater thresholds specified in the *Groundwater Quality Standard*. During the initial rainfall period, heavy metal pollutants from the coal gangue fillers exhibit high release rates and substantial leachate volumes, which gradually decrease and stabilize over time while cumulative release continues to increase. As time progresses, these heavy metal pollutants migrate downward toward the roadbed base. Following geopolymer incorporation, all heavy metal leaching concentrations fall below environmental standard limits.

The environmental impact of heavy metal pollutants from coal gangue roadbed fillers demonstrates persistent and long-term characteristics. As both geopolymer dosage and curing age increase, heavy metal concentrations in leachate decline significantly, eventually falling far below Class III water limits. Geopolymer demonstrates superior solidification effectiveness compared to cement, with optimal pollutant chelation achieved at a geopolymer dosage of 8% and a curing age of 14 days.

Keywords: roadbed engineering; coal gangue; solid waste; heavy metal leaching toxicity; dynamic leaching; geopolymer

Note: Figure translations are in progress. See original paper for figures.