Heavy Metal Pollution Status and Environmental Quality Assessment of Roadside Soils in Yining City (Postprint)

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Abstract

Taking the surface soil layer along main urban roads in Yining City as the research object, a total of 52 soil samples were collected, and a spectrophotometer was used to determine the contents of 6 heavy metal elements (Hg, Cr, Ni, Pb, Cu and Zn). Based on geostatistical methods, the single pollution index (CF) and pollution load index (PLI) were applied to investigate the current status of heavy metal pollution along roads and interpret environmental quality issues. The results showed that: The mean values of Hg, Ni, Pb and Cu in the surface soil layer exceeded the Xinjiang soil background values by 2.75, 1.48, 2.60 and 1.52 times, respectively, while Cr and Zn did not exceed their background values. Except for Pb, the contents of other elements did not exceed the National Soil Environmental Quality Grade I standard (mg·kg-1). The six elements in roadside surface soil all exhibited point and planar distribution patterns, with high values for each element present in the study area, indicating that anthropogenic activities such as economic production, industrial development, and road traffic have negative impacts on roadside soil habitats. Hg and Pb showed regionally severe pollution, Ni and Cu exhibited slight pollution levels of varying degrees, while the proportions of slight pollution and non-pollution levels for Cr and Zn were 17.31%, 82.69% and 23.08%, 59.62%, respectively. The mean CF values of each element in the study area decreased in the following order: Pb, Hg, Ni, Cu, Zn, Cr. The average PLI value for heavy metals was 1.20, indicating slight pollution. Pb pollution in soil was more severe than other heavy metals.

Full Text

Heavy Metal Pollution Assessment in Urban Soil of Yining City Based on Geostatistics

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Abstract

A total of 52 soil samples were collected from the topsoil beside the main roads in the downtown area of Yining, and the contents of six heavy metals (Hg, Cr, Ni, Pb, Cu, and Zn) were determined by spectrophotometer. The environmental quality related to heavy metal pollution in urban soil was studied using the Contamination Factor (CF) and Pollution Load Index (PLI) based on geostatistics. The results showed that: (1) The mean values of Hg, Ni, Pb, and Cu in topsoil were 2.75, 1.48, 2.60, and 1.52 times higher than the background values of soil in Xinjiang, respectively, while neither Cr nor Zn exceeded their background values. In addition to Pb, the contents of other elements did not exceed the Level I threshold of national soil environmental quality ($mg \cdot kg^{1}$). (2) The six elements in urban soil were distributed in both point and planar patterns, with high values occurring throughout the study area, indicating that human activities such as economic production, industrial development, and road traffic had negative effects on soil habitats. (3) Hg and Pb pollution was serious, while Ni and Cu pollution was slight. Cr and Zn accounted for 17.31% and 82.69% at slight pollution level, and 23.08% and 59.62% at non-pollution level, respectively. (4) The mean CF values of the elements in urban soil followed the order: Pb > Hg > Ni > Cu > Zn > Cr. The mean value of heavy metal PLI was 1.20, indicating that the urban soil was slightly polluted. Pb pollution was more serious than other heavy metals.

Keywords: soil heavy metal; soil pollution; environment quality; spatial distribution; Yining

1 Introduction

Heavy metal pollution in urban soils has become an increasingly critical environmental issue, particularly in rapidly developing regions. Urbanization and industrialization processes introduce various anthropogenic sources of heavy metals, including vehicle emissions, industrial discharge, and construction activities. These pollutants accumulate in surface soils and pose significant risks to ecosystem health and human well-being. Yining City, located in the Xinjiang Uygur Autonomous Region, has experienced rapid economic growth and urban expansion in recent years, particularly under the framework of the "Belt and Road" initiative. However, systematic assessment of heavy metal contamination in Yining' s urban environment remains limited. This study investigates the spatial distribution and ecological risk of six heavy metals (Hg, Cr, Ni, Pb, Cu, and Zn) in roadside soils of downtown Yining using geostatistical methods and pollution indices.

2 Materials and Methods

2.1 Sample Collection and Analysis

A total of 52 topsoil samples (0–20 cm depth) were collected from sites adjacent to main roads in downtown Yining. Sampling locations were recorded using GPS coordinates. The soil samples were air-dried, ground, and sieved for laboratory analysis.

For heavy metal determination, samples were digested using appropriate methods: Cr, Ni, and Pb were analyzed using the alkaline fusion method; Cu was processed using the aqua regia digestion method; Zn was extracted using the hydrochloric acid method. Mercury (Hg) was measured using a specialized mercury analyzer with a detection limit of 2.58 ng · g ^{1}. Quality control was ensured using certified reference materials and replicate analyses. The background values for soil in Xinjiang were used as reference standards, with measured concentrations of Hg, Cr, Ni, Pb, Cu, and Zn at 0.11, 32.91, 34.68, 61.30, 31.35, and 61.29 mg · kg ^{1}, respectively. For quality assurance, the relative standard deviations for Hg, Ni, Pb, Cu, and Zn were controlled below 0.5, while Cr measurements maintained appropriate precision standards.

The Contamination Factor (CF) and Pollution Load Index (PLI) were calculated based on the measured concentrations and background values. The spatial distribution patterns were analyzed using geostatistical methods to identify pollution hotspots and potential sources.

3 Results and Discussion

3.1 Heavy Metal Concentrations

The statistical summary of heavy metal concentrations in the study area is presented in Table 1. The results indicate significant variation in heavy metal content across the sampling sites, with some elements showing clear anthropogenic enrichment.

The mean concentrations of Hg, Ni, Pb, and Cu substantially exceeded the Xinjiang soil background values, with enrichment factors of 2.75, 1.48, 2.60, and 1.52, respectively. In contrast, Cr and Zn remained near background levels. Notably, Pb content exceeded the Level I national soil environmental quality standard (35 mg · kg ^{1}) in several sampling locations, while other elements generally remained within acceptable limits.

3.2 Spatial Distribution Patterns

Geostatistical analysis revealed that all six heavy metals exhibited both point-source and diffuse planar distribution patterns throughout the study area. Elevated concentrations were particularly concentrated in areas with intensive traffic, industrial facilities, and commercial districts. This spatial pattern strongly suggests that human activities, including economic production, industrial development, and vehicular traffic, serve as primary sources of soil heavy metal contamination in Yining' s urban environment.

3.3 Pollution Assessment

Based on the CF evaluation, the pollution severity ranking was Pb > Hg > Ni > Cu > Zn > Cr. The PLI value of 1.20 indicates slight overall pollution in the urban soil. Specifically, Hg and Pb were identified as the primary pollutants of concern, with serious contamination levels observed at multiple sites. Nickel and Cu exhibited slight pollution, while Cr and Zn were predominantly at non-pollution or slight pollution levels, accounting for 17.31% and 82.69% in the slight pollution category, and 23.08% and 59.62% in the non-pollution category, respectively.

4 Conclusions

This study demonstrates that urban soils in Yining are experiencing slight heavy metal pollution, with Pb and Hg being the most significant contributors. The spatial distribution patterns clearly link contamination sources to anthropogenic activities, particularly traffic and industrial operations. Continuous monitoring and targeted remediation strategies are recommended to prevent further soil degradation and protect urban ecosystem health.

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