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Assessing Ecological Impacts of Municipal Construction: A Comprehensive Modeling Framework with Indicator-Based Validation

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Abstract: ***This study investigates the ecological impacts of municipal public engineering construction on surrounding urban environments through a systematic modeling approach. It first analyzes the pollution mechanisms, categorized into three types: surface water and groundwater contamination, soil degradation, and tailings pond pollution. Based on these mechanisms, a hierarchical indicator system is developed, comprising primary indicators (geological, population, surface, water environment, and biodiversity pressures) and secondary indicators (including collapse, landslide, subsidence, per capita water resources, water quality, soil-water coordination, and land use). These indicators are further classified into three categories to construct sub-models for geological, biodiversity, and soil erosion impacts, which are then integrated into a comprehensive assessment model. Empirical results demonstrate high reliability and predictive accuracy of the proposed model. The findings suggest that strengthening environmental protection guidance and reducing tailings ponds are key strategies for mitigating the negative externalities of municipal engineering projects.***

Keywords: Municipal public engineering; Environmental impact assessment; Pollution mechanism; Indicator system; Comprehensive impact model.

1. Introduction

With the increasing development of China's industry, the demand for various metals is constantly increasing, and the pace of municipal public engineering construction is also accelerating. The resulting ecological environment problems of municipal public engineering have threatened the construction and development of mines. It can be seen that analyzing the ecological environment problems of municipal public engineering construction is imperative. The ecological environment of municipal public engineering construction is affected by many factors, making it complex to construct a model of the impact of municipal public engineering construction on the surrounding urban environment. At present, there are many methods and theories for environmental assessment of municipal public engineering construction, but the selected impact indicators have strong one-sidedness and limitations, which cannot fully reflect the detailed situation of the ecological environment of municipal public engineering construction, and the assessment accuracy is low. Therefore, constructing a model of the impact of municipal public engineering construction on the surrounding urban environment is of great significance. For the purpose of ensuring the correctness of the constructed model, the following research is carried out.

2. Mechanism of Environmental Pollution Caused by Municipal Public Engineering Construction on Surrounding Urban Areas

2.1 Pollution Mechanism of Surface Water and Groundwater Resources

Surface water and groundwater mainly spread pollution through dynamic forms. For such flow characteristics, analyzing their transfer properties and impact indicators is a basic condition. Usually, it is necessary to consider two hydrological conditions: groundwater being stationary and flowing at a constant speed. Pollutants caused by municipal utility engineering construction will first transfer downward under the influence of gravity, and after decomposition, they will spread horizontally due to capillary pressure 6. The effect under gravity is very obvious. As the transfer time continues to extend, the free phase of the pollution line reaches a relatively high boundary.

2.2 Mechanism of Soil Pollution

In nature, the stability of heavy metal elements is not strong and will change with the changes of their surrounding conditions. Heavy metals generated during the construction of municipal utility projects are mainly controlled by factors such as convection and adsorption during their transfer in soil, and they are very difficult to degrade. The compaction degree of soil has a great influence on the diffusion of heavy metal ions. The greater the soil compaction degree, the smaller the soil pores, which reduces the permeability of the soil. In summary, if the soil compaction degree increases, the diffusion efficiency of heavy metal ions will decrease and the range will also become smaller. The diffusion efficiency of heavy metal ions in unsaturated soil will change according to the characteristics of the soil, and the migration speed is faster in soil with lower clay content. The chemical environment in the soil has a great influence on the migration of pollutants generated by municipal utility engineering construction, and sometimes even greater than the influence caused by the soil's own compaction degree.

2.3 Mechanism of Tailings Pond Pollution

As complex accumulations, the acid drainage in tailings is related to the mineral properties in municipal utility engineering construction. Once temperature, humidity, and value change, they will cause minerals in tailings to undergo oxidation, adsorption, neutralization and other reactions, and also control the acid drainage and heavy metal release in municipal utility engineering construction. According to

massive experiments, whether tailings produce acid drainage and other phenomena is affected by the carbonate content. In fact, many minerals in tailings can neutralize acid drainage, thereby alleviating or even preventing tailings acid drainage. During the development of non-ferrous metal mines in municipal utility engineering construction, tailings are a key medium for heavy metal pollution of the ecological environment. Therefore, when analyzing the migration law of heavy metals during the development of mine resources in municipal utility engineering construction, it is necessary to strengthen tailings analysis. Based on the above analysis, the tailings pond can be judged as a key pollutant for the transfer of heavy metals from municipal utility engineering construction to the environment.

3. Model of the Impact of Municipal Utility Engineering Construction on the Surrounding Urban Environment

Currently, with the development needs of the situation, it is urgent to analyze the influencing factors and quantitative models of municipal public engineering construction on the surrounding urban environment. Using the screening of the above primary and secondary indicators, the above indicators are divided into major categories, and impact models are constructed respectively: the impact model of municipal public engineering construction on geology, the impact model of municipal public engineering construction on biodiversity, and the impact model of municipal public engineering construction on soil erosion. By integrating various models, the model of the impact of municipal public engineering construction on the surrounding urban environment is obtained. The relative change rate of geological restoration and compensation from previous municipal public engineering constructions is used as an indicator to determine the amount of geological changes caused by engineering construction, and based on this, the potential impact of municipal public engineering construction on the surrounding urban ecological environment system is analyzed. Currently, there are many assessment methods for soil erosion caused by municipal public engineering construction. Here, the assessment model for soil erosion in surrounding urban areas caused by municipal public engineering construction is completed using the commonly used Universal Soil Loss Equation (USLE), which is an empirical model derived from soil erosion concepts and massive actual observation data analysis, and is also widely used in China. Then, the expression for the impact of municipal public engineering construction on soil erosion in surrounding urban areas is R.K.LS.C.P. Among them, A represents the amount of urban soil loss, R represents the amount of rainfall erosion, K represents the erodibility factor of urban soil, LS represents the slope factor during the construction of municipal public engineering, C represents the vegetation coverage factor, and P represents the soil and water conservation factor.

4. Experimental Results and Analysis

In the experimental process, a municipal public engineering project at a certain mine was taken as the experimental object. The experimental object contains elements such as cadmium, mercury, and lead. The impact on the surrounding urban ecological environment is caused by long-term accumulation, and it directly pollutes groundwater. Urban people's domestic water, mine slag, and tailings directly become sewage through leaching, and the formation mechanism is relatively simple. The land pollution in the experimental area is relatively serious, with 80% of the land within the construction scope already abandoned, and the soil pollution channel is waterway. Observing the 3D modeling effect diagram, soil samples were taken at certain distances along affected by construction, with a sampling distance of and 15 sampling points. Water samples were taken from rivers on the edge of the urban area. During the model construction process, relatively representative indicators were selected as the basis for model construction, and in the construction of the comprehensive assessment model for the impact of municipal public engineering construction on the surrounding urban environment, the correction process was omitted when assessing a specific project, which not only improved the model construction accuracy but also reduced the model construction complexity. Regarding the impact of municipal public engineering construction on the surrounding urban environment, the following suggestion is put forward: strengthen environmental protection guidance.

Mud generated during construction, as well as industrial and domestic wastewater, should be properly treated to meet the discharge standards required by relevant national departments. In addition, during municipal engineering construction, measures such as separating clean water from sewage and rainwater from sewage should be implemented to increase the recycling of water resources. Industrial wastewater generated should be centrally stored and treated to prevent leakage. Hazardous substances produced during construction must be strictly treated to prevent them from mixing into groundwater through rainwater. Industrial and domestic waste involved in municipal engineering should be properly classified and uniformly disposed of, and burning garbage at the construction site is prohibited. For waste materials and other recyclable materials, specialized departments and personnel should conduct unified sorting, and after simple treatment, they can be re-circulated in the market, which not only avoids ecological pollution from industrial waste but also saves costs. Strengthening the guidance work on ecological pollution during the construction of municipal public works is the basis for the orderly progress of subsequent governance work. To alleviate issues such as tailings ponds in the construction of municipal public works, efforts should be made to strengthen engineering research, make full use of old tailings ponds and open pits, reduce land occupation, and minimize the construction costs of municipal public works.

5. Conclusion

In view of the impact of municipal public engineering construction on the surrounding urban environment, screening impact indicators lays the foundation for building an impact model. A comprehensive impact model is constructed by combining multi-faceted impact models, and experiments have proven the accuracy of the proposed model. Suggestions for future research: Municipal public engineering is relatively complex, with large topographic fluctuations, and the resulting pollution impacts involve many aspects. The next step is to design and build an early warning system to expand

the research scope.

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