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Risk Assessment of Groundwater Pollution in a Mining Area Based on Physical Processes

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Abstract. At present, the study of groundwater pollution risk assessment is generally based on the study of groundwater vulnerability. The impact of the pollutants themselves has not been paid more attention. The assessment of the risk of groundwater pollution should include two aspects: one is the contaminated nature of the aquifer itself and the other is spatial distribution of the pollutant. The vulnerability of the aquifer is only the natural susceptibility of the aquifer to the contaminant. Therefore, the risk assessment of groundwater pollution should also reflect the distribution and transport of pollutants in an aquifer. This study takes a tailings area as an example, and puts forward the risk assessment method of groundwater pollution based on physical processes. Before aquifer contamination occurs, the experts determine spatial distribution of each risk level according to the surrounding economic and social sensitivity conditions and hydrogeological conditions; and then use the numerical model to invert the intensity of the pollution source corresponding to each risk level. The results show that this method can express the distribution in space and time of risk level. For a single point source of contamination, this method is better than the previous based on aquifer vulnerability risk assessment method.

1 Introduction

Groundwater pollution risk assessment is an important method of groundwater management and pollution prevention and control as a basic work of rational development, utilization and protection of groundwater [1]. The concept of groundwater pollution risk is an extension of the concept of groundwater vulnerability [2, 3], which has evolved on the basis of deepening groundwater vulnerability research. So far, the concept of groundwater pollution risk has not yet formed a unified understanding. Finizio et al. [4] consider that the risk of groundwater pollution is a potential for pollution incidents in the groundwater environment; Morris et al. [5] argue that the risk of groundwater pollution is the result of the

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interaction between the vulnerability of the aquifer and the pollution load caused by human activities; Zhou and Li[6] note that the risk of groundwater pollution is defined as the probability of groundwater pollution and the consequences of pollution products. As can be seen from the above studies, the risk of groundwater pollution is caused by the pollution capacity of the aquifer itself and the pollutant load generated by human activities.

2 Method

2.1 Numerical model

The numerical simulation is carried out by constructing a physical model, and the risk evaluation is carried out according to the spatiotemporal effect of pollutant advection and diffusion. According to the analysis of the hydrogeological conditions of the study area, the conceptual model of hydrogeology is used to formulate the mathematical model. Then, the mathematical model uses the actual observed data to identify and validate the model. In this way the migration of pollutants released from contaminated sites is simulated.

2.2 Inverting the intensity of the pollution source

Considering the environmental sensitivity and capacity in the study area, the source intensity of pollutants of each risk level (C_1, C_2, C_3, C_4, C_5) entering the groundwater from the contaminated site is inverted by the model trial according to the spatial distribution of each risk level delineated in advance. This source intensity forms the groundwater pollution risk assessment criteria.

3 Study Area

The study area is in an uninhabited portion of the Gobi desert. The tailings area is located in the piedmont alluvial slope. The terrain is high in the west and low in the east, and the south, west and north is surrounded by mountains. The climate is arid; the annual average rainfall is about 140 mm. The hydrological network has not been developed previously. The main industry in this area is a large-scale nonferrous metallurgy and chemical enterprise; the main production is arsenic and other rare chemical products. The total discharge of wastewater is about 6200 m^3d^{-1}. Waste water contains arsenic (mainly arsenate) and other heavy metal ions, and its salt is SO_4^{2-} based.

4 Results and Discussion

4.1 Spatial distribution of each risk level

The distribution range of 5 risk levels is marked off according to the economic and social sensitive factors and hydrogeological conditions of the area.

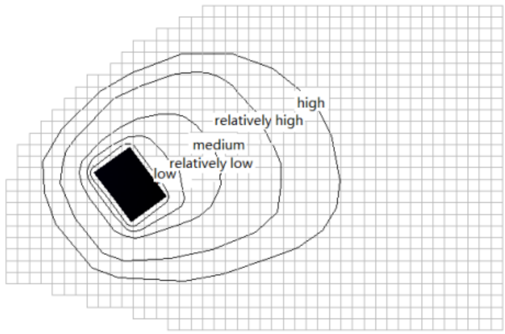

Fig. 1. Relationships between contaminant and risk levels.

4.2 Numerical model of vadose zone and aquifer

Total arsenic (as arsenite or arsenate) is regarded as the main pollutant. The main parameters are obtained from the actual measurement as well as from the literature. The results of field sampling and laboratory tests show that the adsorption of total arsenic in the unsaturated zone is in accordance with the Langmuir isothermal adsorption equation. According to the results of laboratory experiments and literature reports, there is competitive adsorption of a variety of heavy metal ions on the porous media.

MODFLOW models were used to simulate the migration of total arsenic in groundwater. The total arsenic concentration in this range is higher than the groundwater Class III standard and the drinking water standard (0.05 mgL^{-1}). The concentration of total arsenic in the vicinity of the pollution source is 0.10 mgL^{-1}, and the groundwater in the study area had varying degrees of pollution. The total results show that the tailings will continue to be a source pollution on the groundwater for at least 30 years.

4.3 Determine the risk level

According to the distribution of each risk level (low, Relatively low, medium, Relatively high, high) in Table 1, the corresponding pollution sources intensity was inverted by numerical trial. The result are shown in Table 1. The source intensity of arsenic entering groundwater from the previous step is about 0.11 mg, indicating that the groundwater pollution risk level in the tailings area is medium.

Table 1. Relationships between sources intensity and pollution risk level.

Pollution risk level	Low	Relatively low	Medium	Relatively high	High
Pollution sources intensity C/mg·L^{-1}	0.05	0.07	0.10	0.35	0.60

4.4 Discussion

Before the occurrence of pollution, the spatial distribution of each risk level is determined according to the economic and social conditions of the sensitivity, then the intensity of pollution source can be inverted by numerical trial. This source intensity forms the groundwater pollution risk assessment level criterion. This evaluation standard is dynamic, varying with the hydrogeological conditions of the site, socioeconomic conditions and the type of pollutants.

The aquifer is mainly sand and gravel, and the aquifer is strongly permeable. Because the hydraulic gradient is relatively large, and the water velocity is fast, so the transportation of the pollutants in the aquifer is fast. Therefore, contaminants in the aquifer are effectively diluted and the contaminant plume tends to be stable. To ensure that the tailings area of groundwater pollution risk level is low, the source concentration should not be greater than 0.10 mgL^{-1}, and the daily emissions shall not exceed 6200 m^3d^{-1}. Therefore, effective technical means and engineering facilities should be employed, such as increasing the thickness of the surface clay layer, laying high density polyethylene impermeable membrane (HDPE) and other measures to prevent a large number of pollutants into the groundwater. The tailing is located at sparsely populated area, and the economic and social condition is relatively simple, so the environmental sensitive factors are relatively less in this case. If environmental sensitive factors are more complicated, the spatial distribution range of different risk levels should be adjusted flexibly.

5 Conclusions

In this study, we evaluated physical processes that control contaminant migration from a mining area to predict contaminant migration and evaluate risk of aquifer contamination. The risk assessment based on the physical processes determines spatial distribution of each risk level in advance, and then inverts the pollution source intensity of each risk level. This intensity is the assessment standard. This method can reflect the dynamics of groundwater flow and the transportation of pollutants. It is a flexible method that can determine the risk with the socio-economic and hydrogeological conditions of the site. For point sources of contamination, it is a detailed risk characterization method, and represents a possible improvement over methods based on aquifer vulnerability risk assessment methods. This method is applicable to the risk assessment of existing contaminated sites, and optimization of site selection, and may help to provide design parameters for site construction.

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