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The influence of geological structure on the characteristics of groundwater pollution in the downstream of tailing pond

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Abstract. A large number of high-concentration pollutants in the tailings pond polluted the local groundwater. The contaminated groundwater moves to the Yellow River (YR) 12 kilometers south of the pond through natural flow and diffusion. However, how close the contaminated groundwater to the YR was difficult to determine by visual inspection. Therefore, the groundwater quality was analyzed through borehole sampling, and the results show that the Nemero index of groundwater pollutants presents a puzzling V-shaped distribution from the tailing pond to the YR. Soil permeability analysis shows that the concentration of groundwater pollutants in the vicinity of the Yellow River had risen again, which was caused by the blockage of the clay layer in the alluvial plain of the Yellow River. The results demonstrate that the pollutants leaked from the tailings pond have reached the bank of the Yellow River. This pollution has already threatened the water quality of the Yellow River; corresponding measures should be taken to ensure the ecological safety of the Yellow River. It provides a scientific basis for solving similar environmental problems in future.

1.Introduction

The mining of rare earth (lanthanide) mines has brought huge economic benefits to mankind, but it also has a huge impact on the ecological environment of the mining area and its surroundings [1]. A rare earth metal tailings pond in Baotou, Inner Mongolia is mainly used to store waste generated in the process of mineral processing and coking. This tailings pond has been in operation since 1965, coverring an area of about 11 square kilometers, and the surface is 35 meters above the ground [2]. The tailings pond mainly accepts wastewater and slag from a nearby concentrator, which has been in operation for more than 60 years since 1965. The processing plant has an annual capacity of 16 million tons of iron and rare earth ore. The iron and rare earth ore come from the Baiyun Obo Mine, 180 kilometers north of Baotou City. Since the mid-1990s, the tailings pond has also collected wastewater discharged from several rare-earth hydrometallurgical plants to provide rare earth supplies to the world. At present, it is estimated that about 180 million tons of tailings containing iron, rare earth elements, niobium, thorium and other trace element minerals have been accumulated in the pond.

Since the early site selection and construction of tailings ponds considered poor ecological safety, anti-leakage measures were not strong. For many years, a large amount of mineral processing wastewater is stored in the tailings pond. After natural evaporation and seepage filtration, the concentration of pollutants in the pond increases year by year. Wastewater penetrates the tailings dam body and the underlying soil, gradually enters the surrounding soil and groundwater, causing serious environmental pollution problems [3]. Leakage water not only pollutes groundwater, but also causes various environmental problems, such as soil salinization, surface water pollution, ecological degradation, and even affects other organisms and human health [4].

Baotou City is located at the western end of the Hu-Batou plane. The surrounding strata in this area is developed by the Quaternary, and the strata depth can reach 1000 meters. The strata experienced lacustrine deposition, aeolian deposition and proluvial deposition from bottom to top [5]. The tailings pond is located at the intersection of two alluvial fans in the western part of Baotou City—Wulashan alluvial fan and Kundulun alluvial fan. The local soil is mainly composed of coarse sand. The Yellow River flows from west to east 12 kilometers south of the tailings reservoir [5].

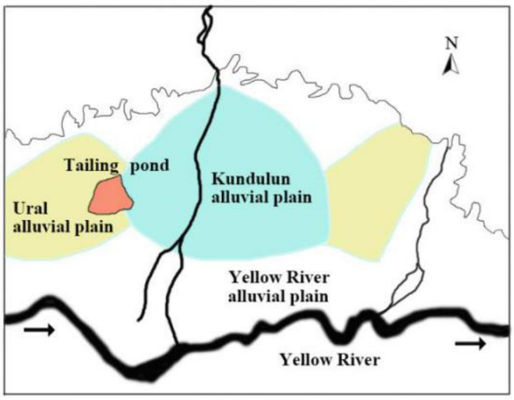

Fig. 1. The geological structure around the leaky tailing pond

The Yellow River originated from the Qinghai-Tibet Plateau and flows through the Loess Plateau. After entering the Hetao Plain, the flow rate slows down. A large amount of fine sand and mud carried by the river precipitated in the Baotou area of Inner Mongolia to form the Yellow River alluvial plain [1]. The soil of these alluvial plains is composed of fine sand and clay, and is characterized by low permeability. See Fig. 1 for the schematic diagram of the geological structure. However, the boundaries of alluvial plains and alluvial fans have not been accurately determined.

The groundwater level varies with location and season, in the depth range of 1-25 meters, and the hydraulic gradient is about 4‰[5]. After the leakage of the tailings pond enters the phreatic zone, it flows slowly with groundwater from northeast to southwest [2]. After more than 60 years of development, what is the degree of pollution of the surrounding groundwater caused by the leakage of the tailings reservoir? Has a large amount of pollutants in the seepage water entered the Yellow River along with groundwater? What are the migration characteristics and reduction degree of pollutants in groundwater? These are the main research goals of this article.

2. Materials and methods

2.1. Well drilling and sampling

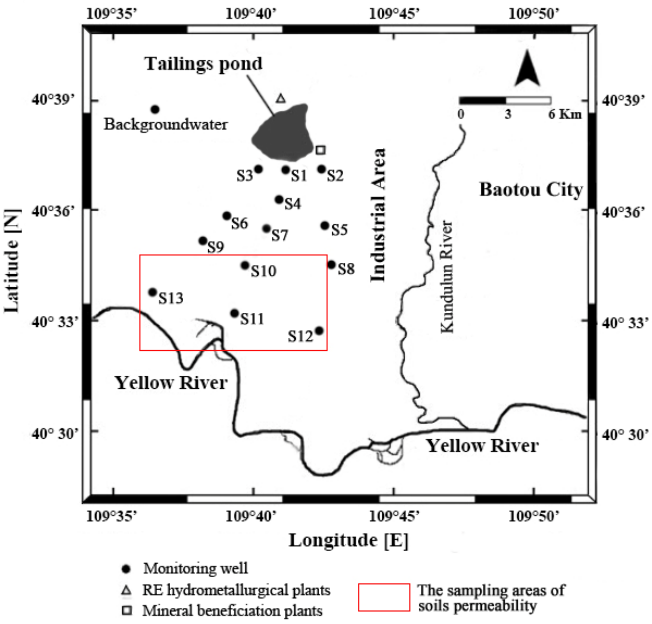

Fig. 2 Locations of the monitoring wells

In order to facilitate the sampling of groundwater, 13 monitoring wells were drilled on the south side of the tailings pond (Fig. 2). As groundwater flows from northeast to southwest, the pollution affected area should be located on the southwest side of the tailings reservoir. According to the initially predict of the groundwater flow direction, the drilling positions ($S_{\text{back groundwater}}$, and S1-S12) for monitoring groundwater quality are arranged on the southwest side of the tailings pond. The 105 geological team of Baotou City was hired to drill wells using professional tools. The depth of each well was between 3 m-30 m and the water can be discharged. The diameter of the well was 30 cm, and it is formed by PVC pipes.

The water sample extracted from the well is sent to the laboratory for analysis. The content of anion SO_4^{2-} and Cl^- were measured by ion chromatography (DZONEX ICS-900). After acid digestion of the water sample, the metal elements were measured by inductively coupled plasma emission spectrometer (ICP-OES, iCAP6000, Thermo Fisher Scientific, USA). In the case of our multi-factor pollution, in order to simplify the expression, the water quality is calculated and evaluated by the Nemerow composite index method [6], expressed as F. Water quality is divided into very clean (F≤0.80), clean (0.80≤F≤2.50), There are five pollution levels: light pollution (2.50≤F≤4.25), moderate high pollution (4.25≤F≤7.20), and heavy pollution (F > 7.20).

$$F = \sqrt{(F_{\max}^2 + \bar{F}^2)/2}, \quad \bar{F} = (\sum_{i=1}^{n} F_i)/n, \quad Fi = C_i/C_0.$$

Is the average value of a single pollutant index, Fmax is the maximum value of a single pollutant index, Ci is the concentration of a single pollutant, and C_0 is the standard value of a single pollutant.

The soil permeability coefficient is measured by TST-70 permeability meter. Use surfer11.0 software to make a rose chart of soil permeability coefficient.

3.Results and discussion

Measurements include Cl^-, SO_4^{2-}, Na^+, K^+, Mg^{2+}, Ca^{2+}, total hardness (TH), As, Se, total dissolved solids (TDS), Be, Mn, Co, Ni, Cu, Zn, Mo, Cd and Pb , A total of 19 water quality indicators. Use these 19 indicators to calculate the Nemerow Composite Index F (NCI) for each well point (Fig. 3).

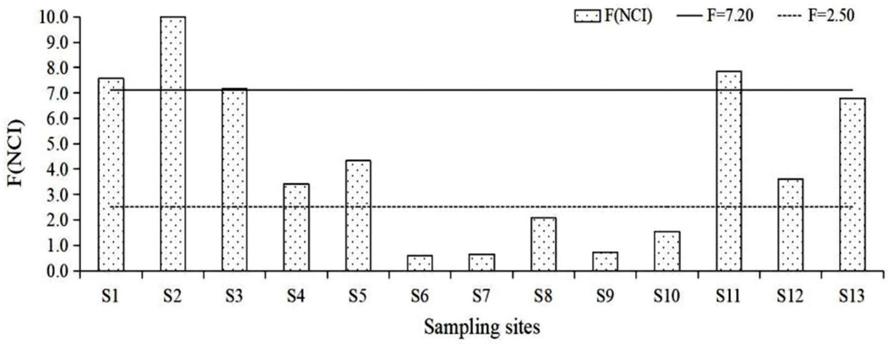

Fig. 3 Comprehensive analysis of groundwater quality by F (NCI) index

The results showed that the water pollution at S1, S2, S3, S4, S5, S11, and S13 were significant. The F values of S4, S5, S12, and S13 were between 2.50 and 7.20, indicating that the water body was slightly or moderately polluted. The groundwater collected at S6, S7, S8, S9 and S10 contained low levels of pollutants. After the groundwater was polluted by the tailings reservoir leakage wastewater, an unusual distribution pattern appeared, that is, the concentration of pollutants were higher near the tailings reservoir and on the banks of the Yellow River, while the concentration of pollutants in the middle were lower.

From the tailing pond to the Yellow River, the geological structure is undergoing a transition from an alluvial-proluvial type to a fluvial alluvial type. However, the exact transition zone is uncertain before. The soil near the tailings pond belongs to the Quaternary stratum and is composed of coarse sand with good water permeability, while the soil near the Yellow River is composed of fine sand and clay with poor water permeability [4]. Therefore, we speculate that when groundwater flows to the Yellow River and approaches the cross-section of the river's alluvial plain, the velocity of groundwater will decrease and the water quality indicators will change. By observing the changes in the value of F (NCI) in Fig. 3, we believe that the location of wells S11-S13 is likely to be located at the intersection of the alluvial fan and the alluvial plain, that is, on the transition zone. We assume that changes in soil permeability may cause resistance to pollutant transport. Therefore, we set up soil sampling points (#1-#20) at the location of wells S11-S13, collected soil at a depth of 100-200 cm, measured soil permeability, and drew a soil permeability rose diagram (Fig. 4).

For technical reasons, only the upper 2 m of soil was analyzed. The deep underground geological structure is more complicated, and the layers are interlaced with coarse sand and fine sand/clay. However, the overall trend of soil types transitioning from high to low permeability remains the same [2]. Therefore, our experimental results are reliable.

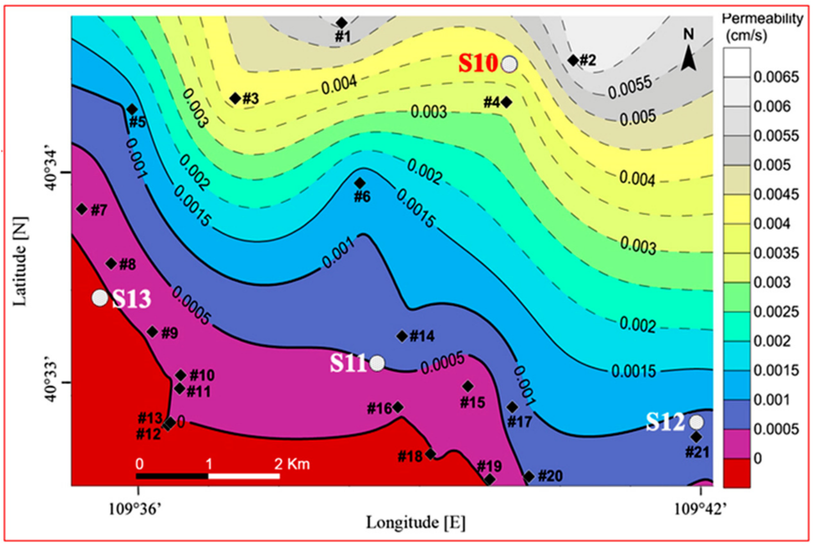

Fig. 4 The contour map of soils permeability

It can be seen from Fig. 4 that from the northeast to the southwest, the soil permeability coefficient gradually decreases, and the change direction is consistent with our prediction. Therefore, it is consistent with our idea of digging wells (Fig. 1). The data shows that the Yellow River alluvial plain The permeability of the clay (for example, #1 is 5.78×10^{-3} cm/s, #2 is 6.45×10^{-3} cm/s) and the permeability of gravel in the alluvial fan near the tailing pond (for example, #12 is 1.12×10^{-6} cm/s, #13 is 2.33×10^{-6} cm/s) up to 1000 times. Therefore, the pollutants leaking from the tailings pond are hindered as the groundwater flows to the vicinity of the Yellow River, and the pollutant concentration is enriched at the edge of the transition zone and increases year by year. This is also the main reason why the value of F(NCI) in Fig. 3 increases significantly at S11-S13.

4.Conclusion

The reason for the abnormal distribution of pollution is the drastic change of soil types near the Yellow River. Although the hydrodynamic relationship between the polluted groundwater and the Yellow River water body has not yet been determined, it is clear that the low-permeability soil on the riverbank prevents wastewater from flowing directly into the river. Therefore, in a sense, the alluvial plain formed by the river promotes its self-saving to a certain extent. Otherwise, the pollution will be worse.

Acknowledgments

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References

[1] Wang ZY, Wu B, Wang G (2007) Fluvial processes and morphological response in the Yellow and Weihe Rivers to closure and operation of Sanmenxia Dam. Geomorphology 91: 65-79.
[2] Huang X, Deng, H, Zheng C, Cao G (2016) Hydrogeochemical signatures and evolution of groundwater impacted by the Bayan Obo tailing pond in northwest China. Sci Total Environ 543: 357-72.
[3] Si WT, He XY, LI AL, Liu L Li JM, Gong DH, Liu J, Shen WS, Zhang XF (2016)

Application of an integrated biomarker response index to assess ground water contamination in the vicinity of a rare earth mine tailings site. Environ Sci Pollut Res Int 23: 17345-17356.
[4] He XY, Zheng CL, Sui X, Jing QG, Wu X, Wang JY, Si WT*, Zhang XF. Biological Damage to SD Rat by Excessive Anions Contaminated Groundwater from Rare Earth Metal Tailings Ponds Seepage. Journal of Cleaner Production. 2018. 185: 523-532.
[5] Wang Y, Tu X (1990) Percolating water's effect pm quality of underground water and Soil Salinization from tailiing pond of Baodo Steel and Iron Compony. Mining Geology 11, 44-49.
[6] Nemerow N (1991) Stream, lake, estuary, and ocean pollution, 2nd edn. , New York Shen S, Liu X (1957) New geotectonic movement and its effect on the geology and hydrogeology in Baotou area. Hydrogeol Eng Geol 8: 4-7.