EFFECTS OF TAILINGS ON GROUNDWATER ALONG BOR AND BELA RIVERS IN THE BOR MINING AREA, EASTERN SERBIA

Dragana Adamović[1,2], Daizo Ishiyama[1], Hiroshi Kawaraya[1], Ogawa Yasumasa[1]

[1]Gaduate School of International Resource Sciences, Akita University, Tegatagakuen-machi 1-1, Akita Pref. 010-8502, Japan

[2]Mining and Metallurgy Institute Bor, ZeleniBulevar 35, 19210 Bor, Serbia

Abstract

Contamination of water bodies is a large problem in many mining areas in the world. Groundwater in mining areas can be polluted by different mechanisms and the pollution can often be severe. Mixing calculations are useful to clarify the mechanism of pollution as well as to define the source of pollution. Based on the mixing calculation between interstitial water in tailings along strongly polluted rivers and unpolluted groundwater, it is thought that interstitial water in tailings along Bor River and Bela River located in the Bor mining area is causing pollution of groundwater in the vicinity of those rivers.

***Keywords**: groundwater pollution, calcium, sulfate, interstitial water, mixing calculation.*

1. INTRODUCTION

Mining development in the Bor mining area started in 1903. Mining activity has been the main economic activity in Eastern Serbia in the last 120 years. The long history of mining in the Bor mining area leads to serious environmental problems, which are most pronounced on air, soil and surface water pollution around the mining sites [1,2,3,4,5]. Adamović, 2021[6] defined the earlystage of groundwater pollution based on Ca^{2+} and SO_4^{2-} concentrations at Slatina Village, Rgotina Village and Vražogrnac Village along strongly polluted Bor River and Bela River. The early-stage groundwater pollution was detected by using a combination of geochemical maps and threshold values. However, the mechanism of groundwater pollution is not clear. Given this reason, the aim of this study was to clarify the mechanism of groundwater pollution and to define the source that affects groundwater quality in the study area by using mixing analysis considering geochemical reactions.

2. MATERIALS AND METHODS

A field survey was carried out for field observation and sample collection in August 2019. Thirty-seven groundwater samples were collected at Slatina Village, Rgotina Village and Vražogrnac Village, while 3 groundwater samples were collected outside the mining area as background samples. In addition, 3 polluted river water samples were collected. In this study, interstitial water in tailings that have been collected in 2017 was also considered.

In the field, pH, Eh, water temperature and bicarbonate concentrations were measured at each sampling site. All samples were filtrated using cellulose acetate hydrophilic filters with a pore size of 0.20 μm. Finally, two kinds of samples were collected, one non-acidified sample for determination of major cations and anions by ion chromatography (IC), and one acidified sample for determination of trace elements by inductively coupled plasma mass spectrometry(ICP-MS). After the field survey, all of the samples were transported to Japan where chemical analyses were done (Akita Industrial Technology Center in Akita City, Japan).

3. RESULTS AND DISCUSSION

3.1 General features of water samples

Polluted river water had an acidic pH ranged from 2.9 to 3.7. All of the river water samples were classified as Ca-Mg-SO_4-dominant type water (Figure 1) having high SO_4^{2-} concentrations as well as high concentrations of Cu, As, Fe and Mn.

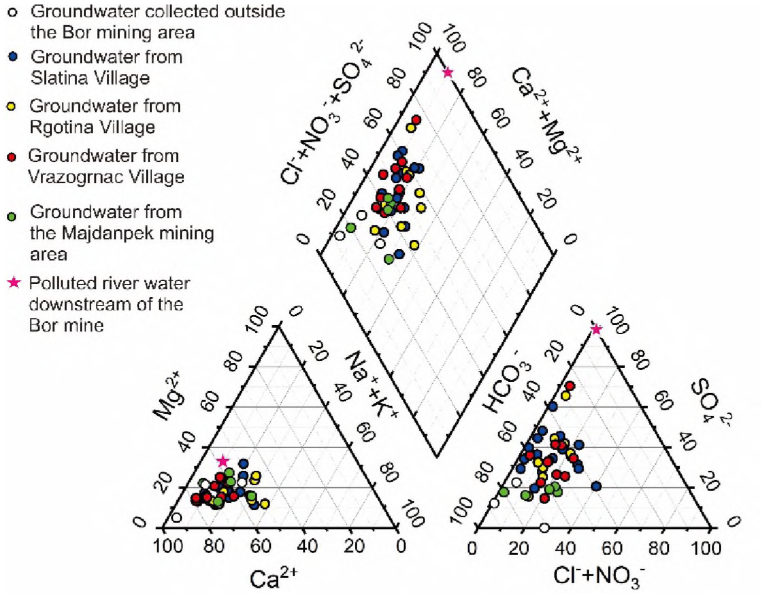

Figure 1 Piper diagram showing the chemical composition of groundwater and polluted river water in the study area.

All of the groundwater samples considered in this study had a near-neutral character. Groundwater samples that were collected outside the mining area at Luka, Donja Bela Reka and Zlot Villages are classified as Ca-Mg-HCO_3-dominant type water (Figure 1). Ca-Mg-HCO_3-dominant type water is typical in areas where carbonate bedrocks are present, which is the case with Eastern Serbia[7]. On the other hand, groundwater samples that were collected at Slatina Village, Rgotina Village and Vražogrnac Village are classified either as Ca-Mg-HCO_3-dominant type water or Ca-Mg-SO_4-dominant type water. These groundwater samples are plotted in the Piper diagram between polluted river water samples and groundwater samples collected outside the mining area, indicating the presence of groundwater pollution in the Bor mining area (Figure 1). Content of heavy metals and arsenic in all groundwater samples resulted to be low, which is to be expected for water having a near-neutral character.

3.2 Mechanism of groundwater pollution

Early-stage groundwater pollution was defined based on Ca^{2+} and SO_4^{2-} concentrations along polluted rivers downstream of the Bor mine. However, not all of the collected groundwater samples at Slatina, Rgotina and Vražogrnac Villages showed pollution. Higher concentrations of Ca^{2+} and SO_4^{2-} were found along Bela River at Rgotina and Vražogrnac Villages which are located farther from the Bor mine compared with Slatina Village. To know the mechanism of groundwater pollution along polluted rivers, mixing analyses were performed. Mixing diagrams are shown in Figures 2, 3 and 4.

For the creation of mixing diagrams, two polluted end-members and one unpolluted end-member were considered. The polluted end-membersconsistedofconcentrations of Ca^{2+} and SO_4^{2-} obtained for polluted river water and interstitial water in tailings along the banks of polluted rivers, while an unpolluted end-member consisted of concentrations of Ca^{2+} and SO_4^{2-} obtained for groundwater samples that were collected outside the mining areas.In the mixing diagrams, groundwater samples collected near polluted rivers, intermediate part and far from the riversare marked by circles in red, orange and yellow, respectively. End-members in the mixing diagrams are shown in different colors (Figures 2, 3 and 4).

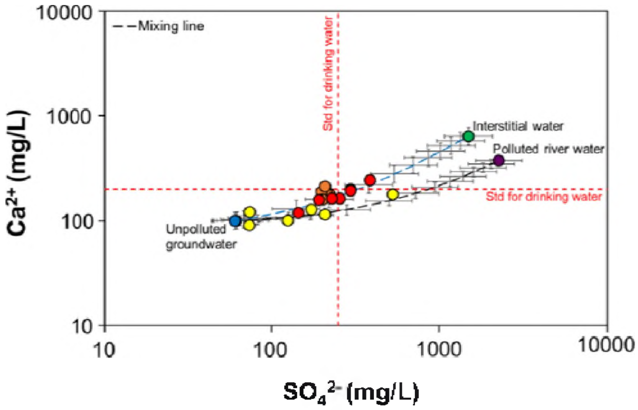

Figure 2 Diagram showing two end-members/two components mixing lines for groundwater samples collected in Slatina Village.

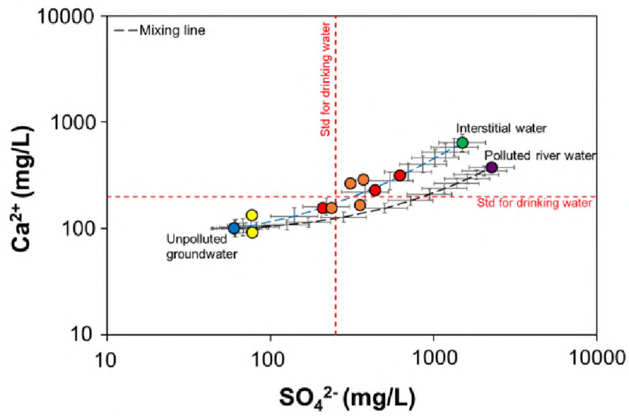

Figure 3 Diagram showing two end-members/two components mixing lines for groundwater samples collected in RgotinaVillage.

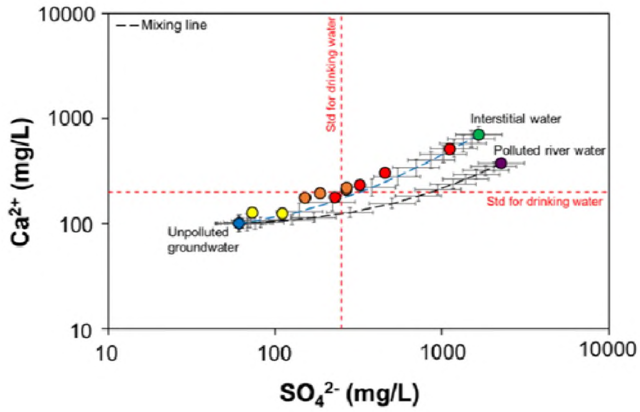

Figure 4 Diagram showing two end-members/two components mixing lines for groundwater samples collected in VražogrnacVillage.

Based on the distribution of actual Ca^{2+} and SO_4^{2-} concentrations of groundwaterin mixing diagrams (Figures 2, 3 and 4), groundwater samples collected near polluted rivers and from the intermediate parts are plotted on the mixing line created for interstitial water in tailings and unpolluted groundwater. These results indicate that mechanism of groundwater pollution in the study area is the infiltration of interstitial water in tailings into groundwater. In the mixing diagram created for groundwater samples collected at Slatina Village, some samples are plotting on the mixing line created for polluted river water and unpolluted groundwater (Figure 2). However, these samples were collected far from the Bor River. Therefore, the possibility of mixing between groundwater and polluted river water in this region of Slatina Village is denied.

4. CONCLUSIONS

Mixing analyses showed that the mechanism of groundwater in the area downstream of the Bor mine is infiltration of interstitial water in tailings along the banks of polluted Bor and Bela Rivers into groundwater, not mixing between polluted river water and groundwater. Moreover, higher concentrations of Ca^{2+} and SO_4^{2-} were found in the downstream area of Bela River. Therefore, attention should be alsopaid to the areas located far from the mining facilities not only in its vicinity.

ACKNOWLEDGEMENTS

This study was undertaken as a part of the project "Research on the Integration System of Spacial Environment Analyses and Advanced Metal Recovery to Ensure Sustainable Resource Development that belongs to the SATREPS program (Science and Technology Research Partnership for Sustainable Development) supported by Japan International Cooperation Agency (JICA) and Japan Science and Technology (JST).

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