ACID MINE DRAINAGE IN THE SLANÁ RIVER: WATER POLLUTION AND POTENTIAL FOR RESOURCE RECOVERY

Ema Guštafíková[1, 3], Zuzana Bártová[2], Daniel Kupka[2]

[1] Earth Science Institute of the Slovak Academy of Science, Dúbravská cesta 9, 840 05 Bratislava
[2] Institute of Geotechnics SAS, Watsonova 45, 040 01 Košice
[3] Department of Mineralogy, Petrology and Economic Geology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava

INTRODUCTION

Mining activities play a key role in the global economy but are also a major source of environmental pollution. In Slovakia, abandoned mines cause serious risks through the formation of acid mine drainage (AMD). Since February 2022, AMD from the flooded Siderit mine in Nižná Slaná (**Fig. 1**) has been continuously polluting the Slaná River, causing its reddish colour and elevated levels of iron, manganese, sulfates, and arsenic (**Fig. 2a-e**). No permanent treatment solution has yet been implemented, and contaminated water still flows into the river.

Despite its environmental hazards, AMD also represents a potential resource, metals such as iron and arsenic can be recovered through biological oxidation and targeted precipitation.

Fig. 1: Nižná Slaná location

AIM: TO DEVELOP A SIMPLE LABORATORY METHOD FOR THE REMOVAL AND RECOVERY OF IRON AND ARSENIC FROM AMD, WITH POTENTIAL APPLICATION IN PRACTICAL REMEDIATION OF WATER POLLUTION.

Fig. 2a-e: The Slaná River and AMD discharge from the Siderit mine in January 2025

METHODS

Water samples were collected from the AMD discharge at the Gabriela shaft (Nižná Slaná) in January 2025. Samples were filtered through 0.22 µm filters and stabilized with HNO_3. The bacterial oxidation of Fe^{2+} to Fe^{3+} was carried out in laboratory bioreactors (**Fig. 3**) using naturally occurring iron-oxidizing bacteria under controlled aeration and temperature conditions.

After oxidation, the pH was adjusted to ~ 3 with 20% KOH to promote precipitation of secondary mineral phases. The precipitated solids were separated by vacuum filtration (**Fig. 5**). The remaining filtrate was analyzed by atomic absorption spectrometry (AAS) to determine metal removal efficiency (Fe and As).

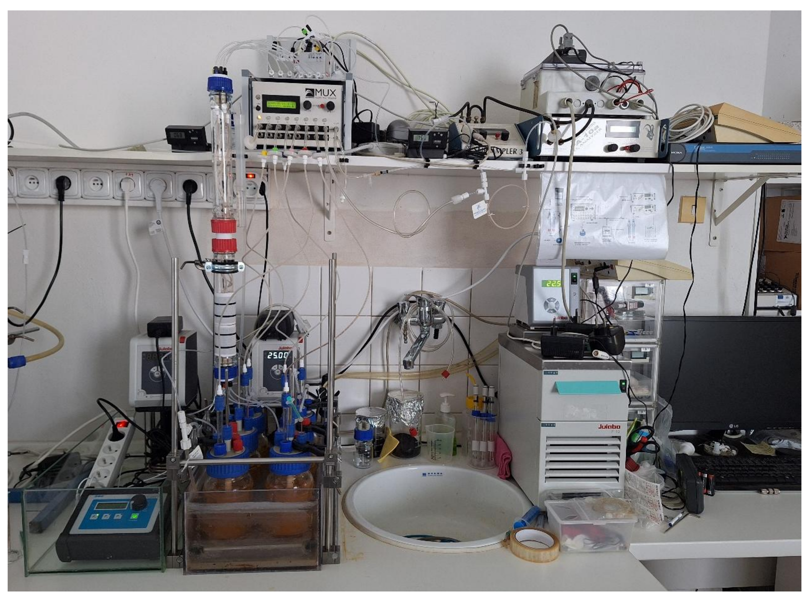

Fig. 3: Bacterial oxidation experimental setup

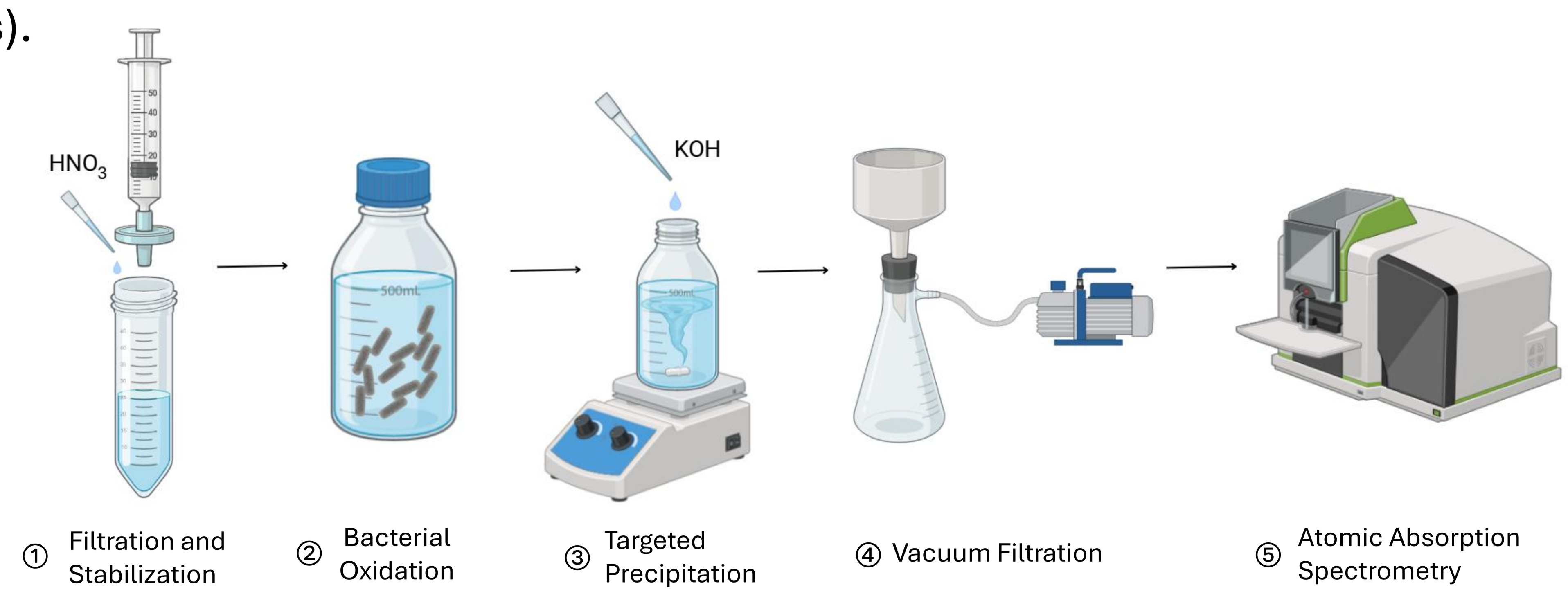

Fig. 4: Schematic overview of the experimental procedure

Fig. 5: Separated filtrate and precipitate

RESULTS

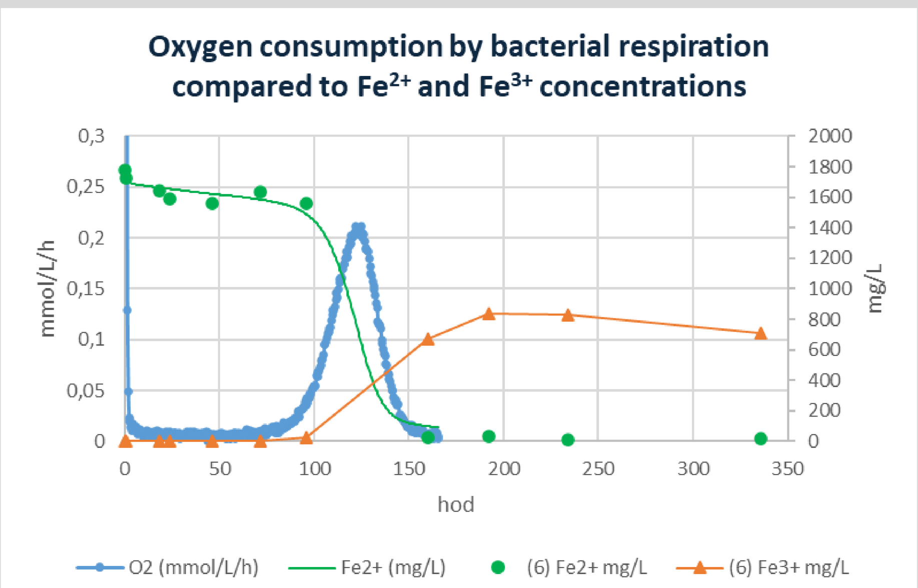

Fig. 6: O_2 consumption by bacteria compared to Fe^{2+} and Fe^{3+} concentrations

Biological oxidation of Fe^{2+} in water samples from the Gabriela shaft was monitored for 21 days in laboratory bioreactors. Oxygen consumption correlated with the oxidation of Fe^{2+} to Fe^{3+} (**Fig. 6**). During the process, pH decreased from 6.30 to 2.49 and redox potential increased from –41 to 574 mV. Spectrophotometric analyses showed a decline in Fe^{2+} and a corresponding increase in Fe^{3+}.

After oxidation, pH adjustment to ~ 3 induced targeted precipitation of secondary minerals. Atomic absorption spectrometry confirmed a decrease in Fe concentration from 1771 µg ml^{-1} to 2.93 µg ml^{-1} (>99.8%) and As from 15.55 µg ml^{-1} to 7.2 ng ml^{-1} (>99.9%), demonstrating high removal efficiency [1].

DISCUSSION

The observed pH decrease and rise in redox potential confirm effective microbial oxidation of Fe^{2+}. Incomplete Fe^{2+} conversion reflects Fe^{3+} precipitation during oxidation. The removal of As was likely caused by its co-precipitation with Fe^{3+}. Overall, the combined biological–chemical process (**Fig. 4**) achieved near-complete metal removal, underscoring its potential for AMD remediation and recovery of valuable elements from mine waters.

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REFERENCE: [1] Guštafíková, E., 2025. *Analysis of acid mine drainages after treatment using Fe-oxidizing bacteria and targeted precipitation of secondary mineral phases.* Master's thesis. Pavol Jozef Šafárik University in Košice, 71 pages.