



Inhibition of arsenic bioleaching from mining wastes

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Introduction

The extraction and processing of ores generate substantial quantities of mine waste, typically deposited in atmospheric conditions, where sulfide minerals become thermodynamically unstable and may lead to environmental contamination, releasing potentially toxic elements. Oxidative dissolution of sulfides as a result of bioweathering causes acidity, releasing sulfate, iron, and associated metal ions to pore waters, characterized by a pH below 4, and yellow-orange or red color. The quality of acid mine drainage depends on many factors, including mineralogical and geochemical properties, hydrogeological conditions, and the activity of lithoautotrophic microorganisms [1]. In Poland, acidic waters are predominantly found in areas where coal mining waste or metal ores have been deposited.

Reduction of metal(loid) release from acidic post-mining waste can be done by altering solid surfaces with surface-active compounds, similar to methods used in mineral processing like flotation or flocculation.



Figure 1. Africa reservoir, The Former Coal Mine Babina, Poland

Main aims:

- ▶ To examine whether the post-mining waste may pose a threat to the environment due to arsenic release in an acidic conditions associated with the presence of microorganisms;
- ▶ Inhibition of arsenic release from mining waste by solid surface modification;
- ▶ Investigating changes in surface properties of mineral waste during bioextraction to explain bacteria-mineral interactions;

Materials & Methods

The mineral material was taken from a large stockpile of mining waste originating from historical arsenic and gold-ore mines in Złoty Stok (Poland). A particle size of 1-1.25 mm was used. The waste contained (m/m%): Si 34.3, Fe 20.3, As 8.29, Ca 7.69, Al 5.3, Mg 4.15, K 3.73, and 1.4 S [2]. Surface modification was done by conditioning the mineral waste with 0,01 M cetyltrimethylammonium bromide, CTAB and sodium dodecyl sulfate, SDS (Sigma-Aldrich), for 24h. Leaching experiments were carried out in shaken flasks with 10% solid (w/v). Deionised water and chemical-grade reagents were used. Microorganisms were grown in 9K medium, inoculum 10% v/v, pH 2.0. During the process, samples were taken to analyse arsenic content, ferrous and ferric iron concentration, redox potential, pH, and specific surface area. Metal concentration was determined using the inductively coupled plasma optical emission spectrometry technique (Agilent 5110 ICP-OES Agilent Technologies, Australia). The zeta potential of leaching residues was determined using a Surpass3 analyzer (Anton Paar, Austria), at a constant ionic strength of 10⁻³ M NaCl, pH 2.0.

Results & Discussion

Initial experiments showed, that the presence of surface-active compounds affects biological extraction of arsenic. Recovery without modifications yielded 59.5% (after three weeks of the proces, Figure 2a). When mineral waste was conditioned with surfactants, lower leaching efficiency was observed (44.5% and 36.6% for CTAB and SDS, respectively). The effect of the leaching process on the specific surface area is presented in Figure 2b. A correlation of the final surface area with an arsenic recovery was observed. The higher the efficiency of the process, the higher the measured value of the area was.

The surfactant adsorption caused changes in the waste material's surface properties. The zeta potential of arsenic waste was more negative after contact with SDS due to the presence of negatively charged sulfate polar heads of surfactant and became more positive when incubated with cationic surfactant, CTAB (presence of cation head group N⁺-(CH₃)₃). All leaching residues become positive at the end of the process. In the case of the control sample (without bacteria) such an effect can be a result of the iron(III) precipitates at the mineral surface (Figure 3), and in the case of other samples, probably due to the adhesion of bacterial cells exhibiting positive surface charge.

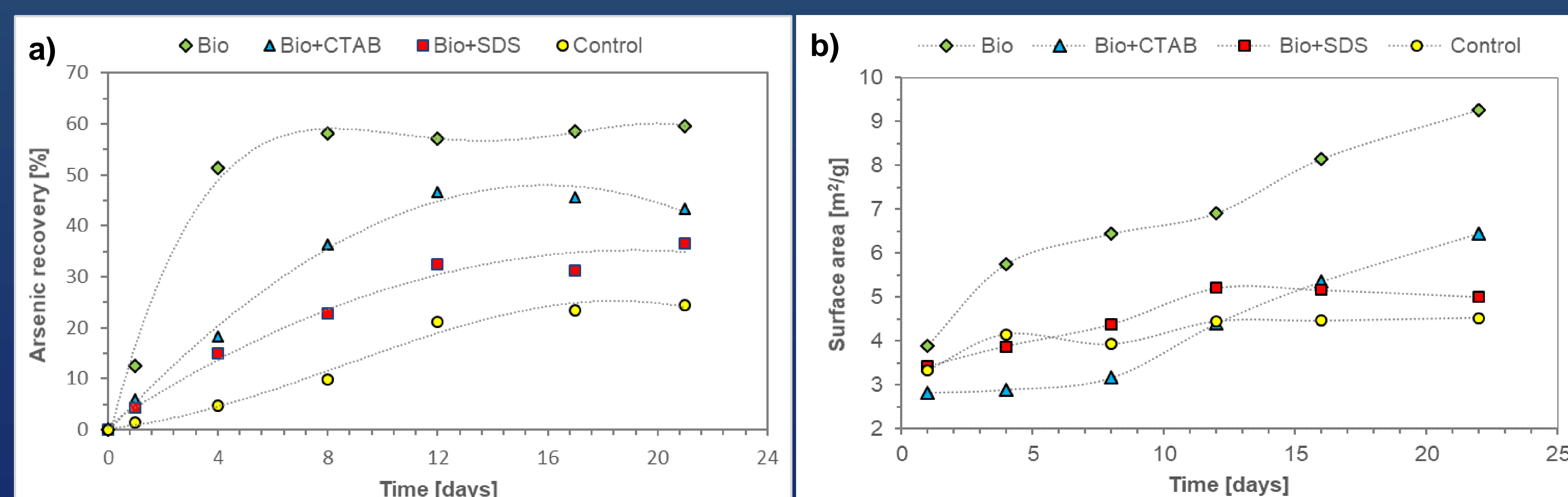


Figure 2. Changes of a) arsenic concentration and b) specific surface area during bio-extraction; **Control** – a process without bacteria; **Bio** – leaching of pure arsenic waste using microorganisms; **Bio+CTAB** – bioleaching of arsenic waste after contact with cetyltrimethylammonium bromide (CTAB); **Bio+SDS** – bioleaching of arsenic waste after contact with sodium dodecyl sulfate (SDS).

Conclusions

- ▶ Under acidic conditions, arsenic is mobilized from mining waste due to the presence of indigenous microorganisms;
- ▶ The higher degree of metal extraction corresponds to a higher specific surface area of the waste;
- ▶ Preliminary research has shown the potential of using surface modification as a method to prevent the formation of acidic leachates; SDS and CTAB adsorption reduced the arsenic extraction by 23% and 15%, respectively;



Figure 3. Mineral particles of arsenic waste after bioleaching

Table 2. Zeta potential values of bacteria and arsenic waste (pH 2.0, ionic strength 10⁻³ KCl)

Sample	Zeta potential [mV]
Before bioleaching	
Bacteria	4.70 ± 0.82
Waste	-0.45 ± 0.08
Waste with CTAB	5.71 ± 0.98
Waste with SDS	-8.24 ± 1.02
After bioleaching	
Waste	1.20 ± 0.24
Waste with CTAB	2.63 ± 0.78
Waste with SDS	1.86 ± 0.23
Control (without bacteria)	11.0 ± 2.23

Acknowledgments

This work was supported by grant no. 2021/43/D/ST10/02784, financed by the National Science Centre, Poland

References

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2. Pawłowska, A., Sadowski, Z., Winiarska, K., 2021. <https://doi.org/10.3390/min11121303>