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Sustainable mining: effect of bio(surfactants) on microbial arsenic removal

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Introduction

Sustainable mining aims to reduce the negative effects of mining activities while ensuring that resources are available to future generations. A key aspect is the application of green technologies, such as bioleaching, which helps reduce the environmental impact of the mining industry.
The adsorption of surface-active compounds of both chemical and biological origin alters the surface properties of solid particles. Such phenomena can be used to enhance the extraction of valuable metals from the ore or control the release of metal and metalloids from the solid phase, preventing undesirable effects of bacterial activity in post-mining areas.

Figure 1. Sampling area

Main aim

Investigation of rhamnolipids (RL) and lipopolysaccharides (LPS) influence on bioleaching of mineral waste and possible electrostatic interactions between mineral, bacteria and surface-active agents. A comparison of the effect of biosurfactants with their chemical counterparts such as cetyltrimethylammonium bromide (CTAB) and sodium dodecyl sulfate (SDS).

Materials & Methods

The mineral material was taken from a large stockpile of historical mining waste originating from arsenic and gold-ore mines (Figure 1). Surface modification was done by conditioning the mineral waste with RL, LPS, CTAB and SDS solution for 24h. Leaching experiments were carried out in shaken flasks with 10% solid (w/v). A particle size of 1-1.25 mm was used. Deionised water and chemical-grade reagents were used. Microorganisms were grown in 9K medium, inoculum 10% v/v, pH 2.5. 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), and fine particles using Zetasizer 2000 (Malvern, United Kingdom) at a constant ionic strength of 10^{-3} M KCl, pH 2.5.

Results

► The highest arsenic concentration in leachate after 28 days of the process (Figure 2a) was observed for minerals modified by RL (1280 ppm) and the lowest for SDS (380 ppm). Other conditions were: 986 ppm for CTAB, 765 ppm for mineral without modifications, and 650 ppm for LPS.
► The zeta potential of minerals in the presence of CTAB and LPS increased towards positive values with increasing surfactant concentration. In the case of RL and SDS, increasing concentration led to a shift in zeta potential towards more negative values (Figure 2b).
► The porous medium's strong negative surface charge density favours bacterial adhesion (bacterial cell zeta potential was 4.5 mV).
► In the case of CTAB and LPS zeta potential of the mineral surface was positive, resulting in repulsion between particles and bacterial cells.

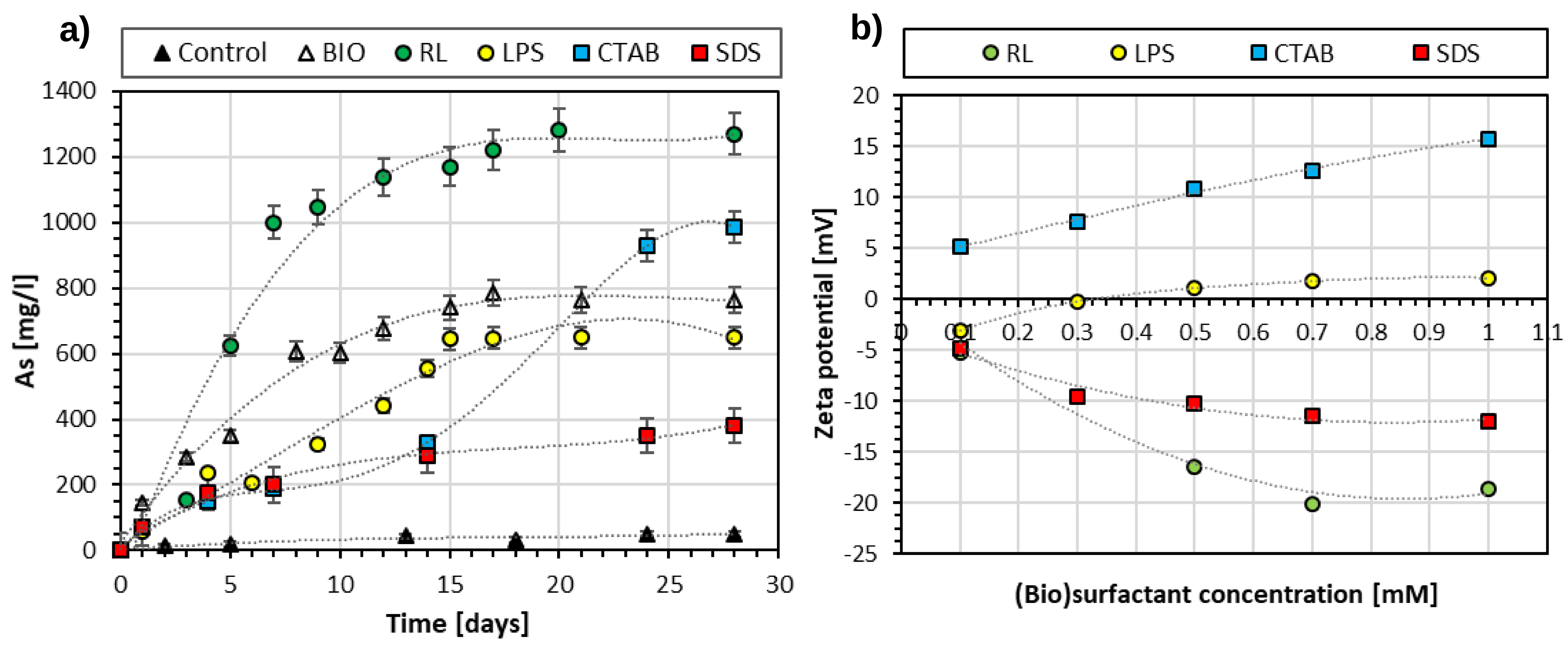

Figure 2. Changes of a) arsenic concentration and b) zeta potential of arsenic waste in the presence of (bio)surfactants (pH 2.5); Control – a process without bacteria and surface modification; BIO – bioleaching of non-modified mineral material; RL, LPS, CTAB, SDS – bioleaching of arsenic waste after contact with rhamnolipids, lipopolysaccharides, CTAB and SDS, respectively

Conclusions

► Adsorption of surface-active reagents onto mineral modifies its surface charge, affecting bioleaching.
► The highest metal bio-extraction was observed for arsenic waste modified by RL, while the lowest for SDS.
► The strong negative zeta potential of mineral particle surface in the presence of RL provides conditions for bacterial adherence, leading to intensification of arsenic extraction.
► Strong adhesion also occurred in the presence of SDS, but as it is toxic for microorganisms, such interaction caused inhibition of metalloid release.
► In the case of electrostatic repulsion between mineral particles and bacteria, reduced arsenic extraction was observed.

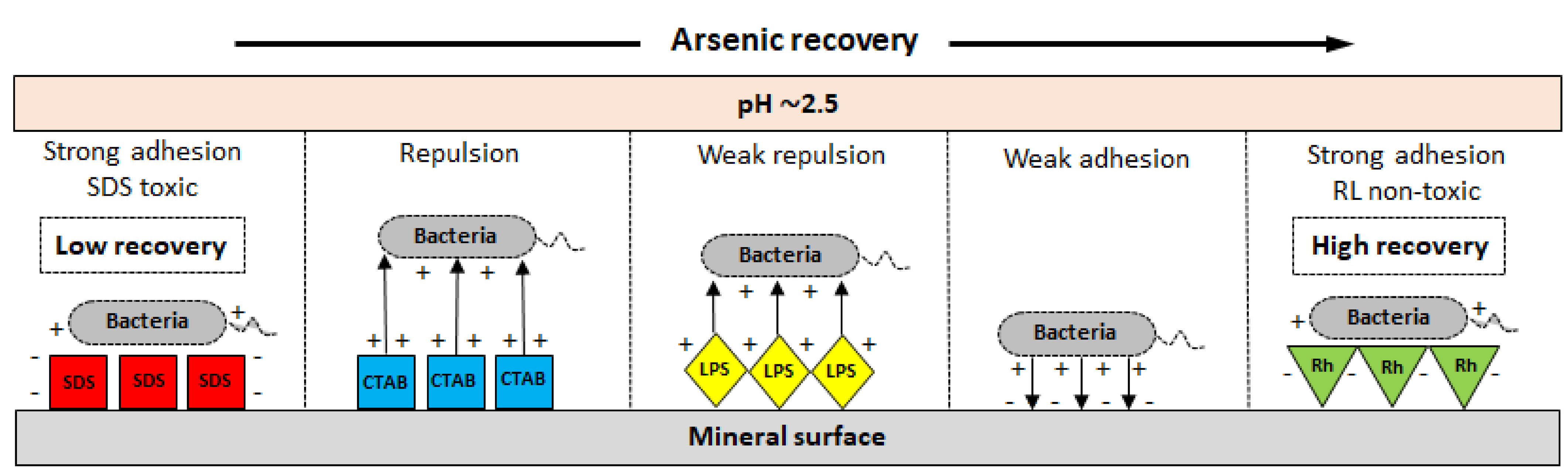

Figure 3. Possible electrostatic interactions during bioleaching of arsenic waste in the presence of RL (rhamnolipids), LPS (lipopolysaccharides), CTAB (cetyltrimethylammonium bromide), SDS (sodium dodecyl sulfate);

References
1. Pawlowska, A., Sadowski, Z., Winiarska, K., 2021. https://doi.org/10.3390/min11121303

Acknowledgments
The funding from the National Science Centre (Poland), grant No. 2021/43/D/ST10/02784 is gratefully acknowledged.