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Article

Effect of metabolic state on *Paraclostridium bifermentans* surface properties and the implications for lead removal

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Keywords: keyword 1; keyword 2; keyword 3 (List three to ten pertinent keywords specific to the article; yet reasonably common within the subject discipline.)

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1. Introduction

Pb(II) is a highly water-soluble, mobile, and toxic pollutant that continues to cause a variety of human health problems. Chronic exposure to Pb(II) causes significant harm to most organs [1]. The conversion of Pb(II) into insoluble precipitates can, however, greatly reduce its mobility and toxicity [2]. This is conventionally achieved with electrochemical treatment and chemical precipitation [3]. Bioprecipitation with microbes has gained attention as a promising method to immobilize aqueous Pb(II) as lead phosphate [4,5], lead sulfide [6], or elemental lead [7].

A consortium of bacteria has been isolated from lead-contaminated soil at a battery recycling plant in Gauteng, South Africa, and has been shown to remove up to 93 % of Pb(II) from solution [8] by precipitating it out as PbS and Pb(0) [9]. Following kinetic studies on the consortium, Hörstmann et al. [10] proposed a two-phase exponential decay model to describe Pb(II) removal and attributed an initial rapid phase to adsorption. Subsequent research investigated this attribution by demonstrating that significant Pb(II) removal with the consortium took place following sterilization with NaN_3 [11], highlighting the involvement of adsorption as a rather than the metabolically dependent precipitation.

Significant adsorption of Pb(II) onto bacteria has been widely reported on Gram-positive genera such as *Bacillus* [12–14] and *Rhodococcus* [15], as well as Gram-negative genera like *Enterobacter* [16,17] and *Pseudomonas* [18–21]. The chemical composition of bacteria surfaces for both Gram-positive and Gram-negative bacteria are rich in negatively charged functional groups that result in an overall negative surface charge and facilitate the attraction of positively charged metal cations like Pb(II) [23].

Several authors have noted that heavy metal onto living bacteria is noteably lower than on living [15,28,29]

These functional groups also allow for chemisorption to take place, where hydrogen ions are exchanged for Pb(II) ions [24].

[22]

Chemisorption not only prevents lead from entering cells, but Functional group complexation can be a prominent adsorption mechanism for some bacteria that use it to concentrate terminal electron accepting ions on the cell wall surface

Several subterranean anaerobic bacteria have been reported to respire using a range of terminal electron acceptors, including heavy metal pollutants [25]. Respiration involving the reduction of soluble oxidised-metals can lessen the mobility of the metal.

Several authors have used acid-base titration to improve understanding of bacteria surfaces [26] as well as using surface models to predict the effects of pH on metal binding to cell surface [27].

Studies have also been conducted to determine effects of metabolic state on metal adsorption [28,29]

[30]

[29]

[28] Noted that

[31] Highlighted significant hysteresis and time dependence in acid-base titrations of *Shewanella putrefaciens*.

[32]

Lead is a big problem

A consortium has been found: consortium properties like performance: chapter + carla + all the cets. Lteral citation fest.

Is surface complexation a mechanistic step or is? Does rxn happen on surface?

The introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance. The current state of the research field should be reviewed carefully and key publications cited. Please highlight controversial and diverging hypotheses when necessary. Finally, briefly mention the main aim of the work and highlight the principal conclusions. As far as possible, please keep the introduction comprehensible to scientists outside your particular field of research.

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Materials and Methods should be described with sufficient details to allow others to replicate and build on published results. Please note that publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

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This is an example of a quote.

3. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

3.1. Subsection

3.1.1. Subsubsection

Bulleted lists look like this:

- First bullet;
- Second bullet;
- Third bullet.

Numbered lists can be added as follows:

1. First item;
2. Second item;
3. Third item.

The text continues here.

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All figures and tables should be cited in the main text as Figure 1, Table 1, etc.

Figure 1. This is a figure. Schemes follow the same formatting. If there are multiple panels, they should be listed as: (**a**) Description of what is contained in the first panel. (**b**) Description of what is contained in the second panel. Figures should be placed in the main text near to the first time they are cited. A caption on a single line should be centered.

Table 1. This is a table caption. Tables should be placed in the main text near to the first time they are cited.

Title 1	Title 2	Title 3
Entry 1	Data	Data
Entry 2	Data	Data

Text.
Text.

3.3. Formatting of Mathematical Components

This is the example 1 of equation:

$$a = 1, \tag{1}$$

the text following an equation need not be a new paragraph. Please punctuate equations as regular text.

This is the example 2 of equation:

$$a = b + c + d + e + f + g + h + i + j + k + l + m + n + o + p + q + r + s + t + u + v + w + x + y + z \quad (2)$$

Figure 2. This is a wide figure.

Please punctuate equations as regular text. Theorem-type environments (including propositions, lemmas, corollaries etc.) can be formatted as follows:

Theorem 1. *Example text of a theorem.*

The text continues here. Proofs must be formatted as follows:

Proof of Theorem 1. Text of the proof. Note that the phrase "of Theorem 1" is optional if it is clear which theorem is being referred to. □

The text continues here.

4. Discussion

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

5. Conclusions

This section is not mandatory, but can be added to the manuscript if the discussion is unusually long or complex.

6. Patents

This section is not mandatory, but may be added if there are patents resulting from the work reported in this manuscript.

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Sample Availability: Samples of the compounds ... are available from the authors.

Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

Appendix A

Appendix A.1

The appendix is an optional section that can contain details and data supplemental to the main text—for example, explanations of experimental details that would disrupt the flow of the main text but nonetheless remain crucial to understanding and reproducing the research shown; figures of replicates for experiments of which representative data are shown in the main text can be added here if brief, or as Supplementary Data. Mathematical proofs of results not central to the paper can be added as an appendix.

Table A1. This is a table caption. Tables should be placed in the main text near to the first time they are cited.

Title 1	Title 2	Title 3
Entry 1	Data	Data
Entry 2	Data	Data

Appendix B

All appendix sections must be cited in the main text. In the appendices, Figures, Tables, etc. should be labeled, starting with "A"—e.g., Figure A1, Figure A2, etc.

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