Circular economy: turning industrial effluents into resources using microbiology

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1. Introduction

Selenium (Se) and bacteria are intimately linked in a complex interplay. Selenium serves both essential and energy generation functions for bacterial metabolism, in addition to behaving as a powerful toxicant (Staicu & Barton 2021). Conversely, bacteria are involved in all valence state transformations (reductive and oxidative) of Se, thus acting as a key vehicle for the cycling of this element in nature. With the advent of the Industrial Revolution, the natural cycles of numerous chemical elements, including Se, have been altered. Selenium pollution is present in many industrial effluents such as those generated by fossil fuel combustion for energy production (e.g. Flue Gas Desulfurization/FGD), metal refining and oil refining, mining activities etc. (Staicu et al. 2022). On the other hand, Se has important market value being used in solar cells, photoelectric devices, fungicides or dietary supplements (Fresneda-Ruiz et al. 2023). These Se-rich waste streams can be treated by bioremediation using a microbial-driven biotechnological approach, thus generating resources in the framework of circular economy (e.g. Se^0, biogas, clean water) (**Fig. 1**; Cordoba & Staicu 2018).

2. Considerations

- Certain industrial effluents can contain up to several **mg/L of soluble Se oxyanions**: selenite, SeO_3^{2-}, and selenate, SeO_4^{2-}.
- **Se** is present in **industrial streams** mainly as $\mathbf{SeO_4^{2-}}$, which cannot be reduced to elemental Se, **Se^0**, using physical-chemical methods.
- **Phylogenetically-diverse** bacteria can **reduce SeO_4^{2-}** to **Se^0** via detoxification and respiratory strategies (**Fig. 2**).
- **Se-laden waste streams** are **organically-poor**, requiring the addition of organic carbon and electron donors (e.g. acetate, lactate).
- **Methanogens are not inhibited by the metabolism of Se oxyanions**, even in excess concentrations, therefore the biogas yield will not be affected by the reduction of Se oxyanions to Se^0 (Staicu et al., *in preparation*).

Figure 1. Conceptual model of an Upflow anaerobic sludge blanket (UASB) reactor fed with Se-laden industrial effluent (based on Staicu & Barton 2021).

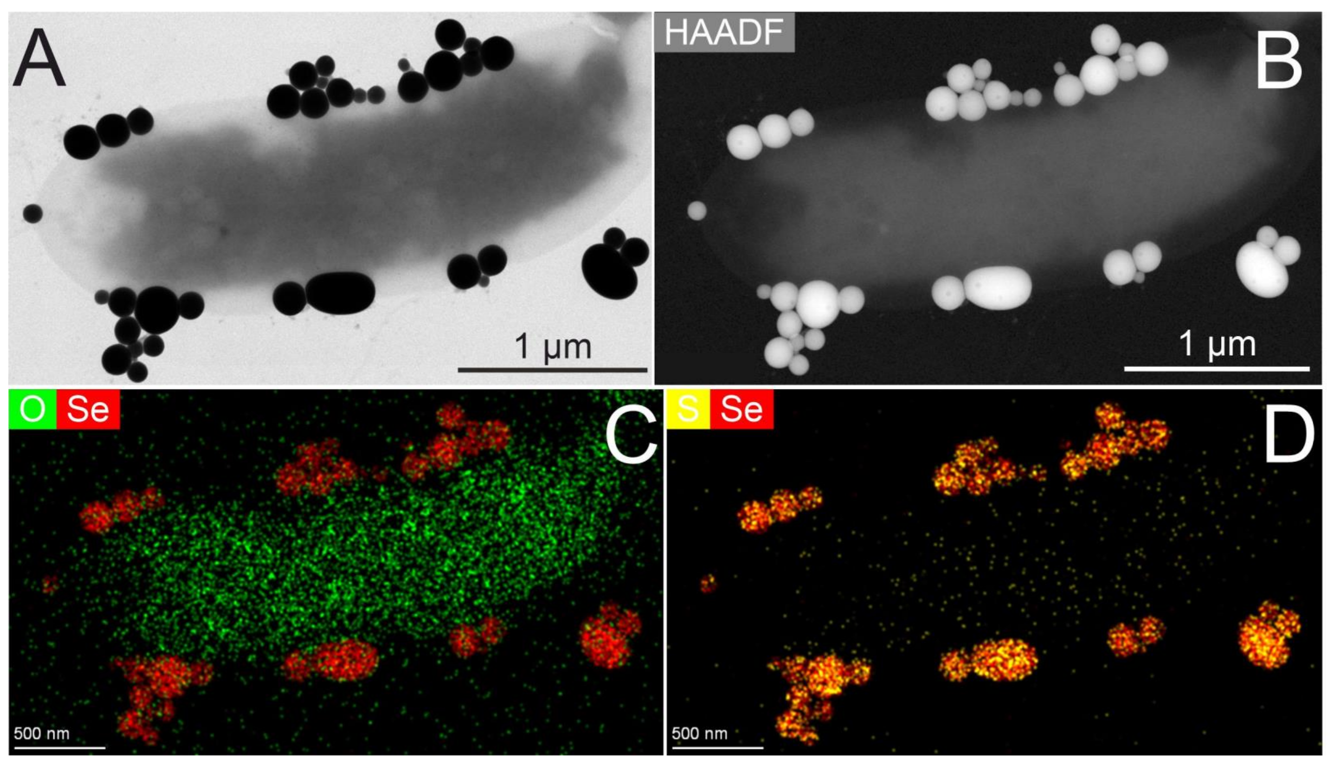

Figure 2. Extracellular Se^0 produced by *Shewanella* sp. O23S (from Staicu et al. 2022).

3. Challenges

- Recovery and purification of Se^0
- Finding a cheap carbon source & electron donor
- Finding granular sludge able to reduce SeO_4^{2-}

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