Bioremediation of Uranium using anaerobic Bacteria

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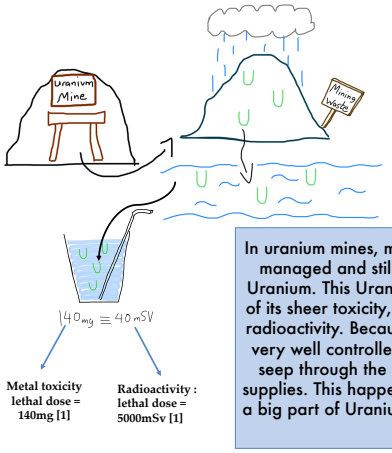
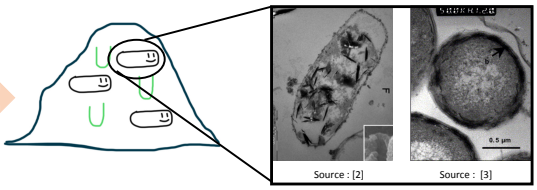
Nuclear energy is one of the most reliable energy source nowadays, unfortunately it still produces a certain amount of very toxic waste. We all heard of the radioactive nuclear waste that exits the nuclear power plants. However there is another form of pollution that comes from uranium that is much less contained.



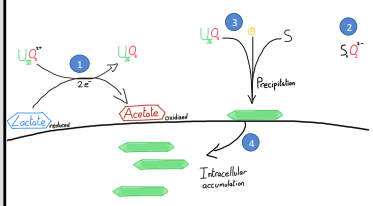
In uranium mines, most of the waste is not properly managed and still contains a certain amount of Uranium. This Uranium is most dangerous because of its sheer toxicity, and not as much because of its radioactivity. Because those wastes are not always very well controlled, it happens that Uranium will seep through the ground and can pollute water supplies. This happens not only from mining wastes, a big part of Uranium pollution comes from military activity.



One way to treat this pollution is bioremediation : stimulating microorganisms to treat contaminations. Interstingly, uranium mining waste piles are a good source for metal binding bacteria that can be used. Because those areas are toxic, bacteria shouldn't be able to live there. However some bacteria are able to survive with some particular processes such as bioaccumulation which can be useful for bioremediation.

Bioaccumulation is the faculty to accumulate substances inside or on the surface of the cell. Then, some biotransformations occur in order to immobilize the substance, making it less toxic.

Intracellular bioaccumulation in Shewanella sp. HN-41



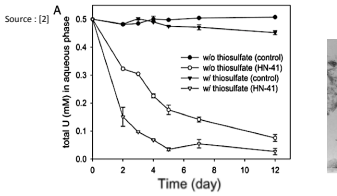
Uranium VI (such as UO_2^{2+}) is highly soluble in water whereas Uranium IV (UO_2) is insoluble.

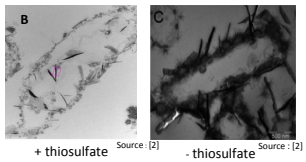
1- Reduction U(VI) : $C_3H_6O_3 + UO_2^{2+} \rightarrow CH_3COO^- + CO_2 + 3H^+ + UO_2$

2- Dismutation of thiosulfate $S_2O_3^{2-} \rightarrow S + SO_2 + H_2O$

3- Precipitation of U(IV) with phosphorus and sulfide.

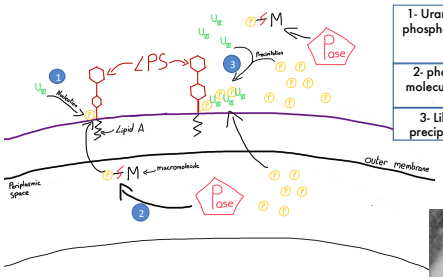
4- Intracellular accumulation of needle-like precipitates





In addition of thiosulfate, Shewanella sp. HN-41 changes its accumulative behavior from extracellular (C) to intracellular (B). The presence of the bacteria inside a solution decreases the concentration of uranium in solution and the rate of this process is enhanced by adding thiosulfate (A).

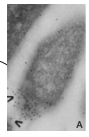
Extracellular bioaccumulation by Citrobacter sp.



1- Uranium VI starts nucleating with the phosphate groups of lipid A on the outer membrane

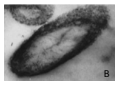
2- phosphatases (A) cleave phospho-molecules and phosphates are released

3- Liberated phosphates and U(VI) precipitate on the outer membrane (B)



Phosphatase in the periplasm and in the extracellular space [6]

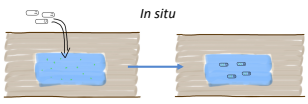
Citrobacter is able to accumulate U(VI) on the surface of its outer membrane(B). The advantage of this technique is that it prevents saturation. As a consequence, it has been shown that it is able to accumulate up to 900% of its cellular dry weight.



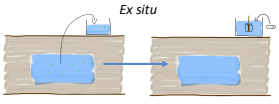
Uranyl-phosphate bioaccumulation on the cell surface [7]

Possible Application in bioremediation

These bacteria are able to accumulate uranium immobilizing it. Thus, the concentration of uranium in groundwater can decrease



In *in situ* remediation, the bacteria are directly placed into the polluted area and can then be filtered out. However it is often difficult to ensure the survival of the bacteria.



In ex *situ* remediation, the water is first pumped out and then treated with bacteria. Although this method is more expensive and complicated, it has the advantage of allowing the use of bioengineered bacteria

Conclusion

Although other decontamination methods (use of chemicals) does exist, there are expensive and not very efficient. Bioremediation seems to be a good alternative.

There is also the possibility to use those bacteria in order to decontaminate areas that are contaminated by other heavy metals such as Cu, Cd, Pb.

It is also possible to bioengineer GMOs to increase the decontamination of known pollutants or to find new pathways to bioremediate new types of pollutants (xenobiotics such as PCBs or radionuclides).

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