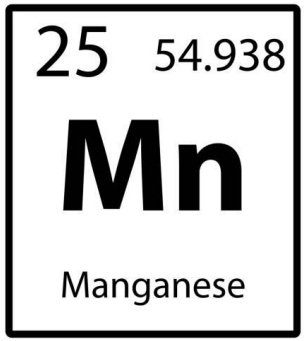
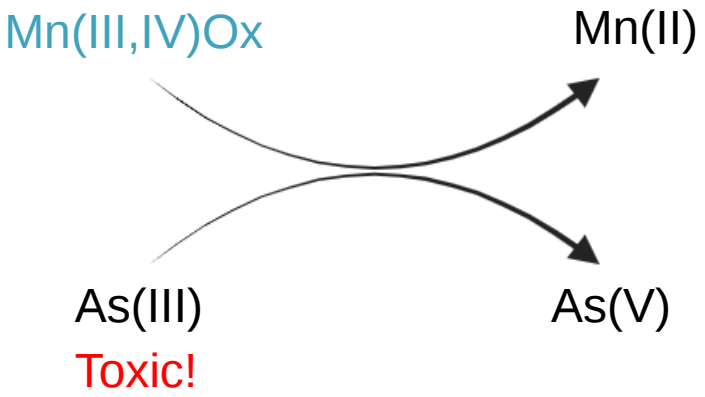
Microbial biofilms structure and manganese (bio)cycling: from lab to field studies

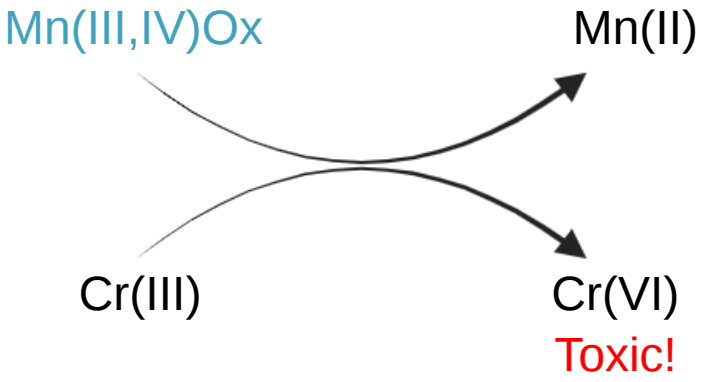
V. Rollot – IPGP (rollot@ipgp.fr), C. Dejean - UPC, F. Guyot – MNHN,
J.M. Diaz – Scripps Inst., A. Gélabert – IPGP

Manganese is a central element in biogeosciences



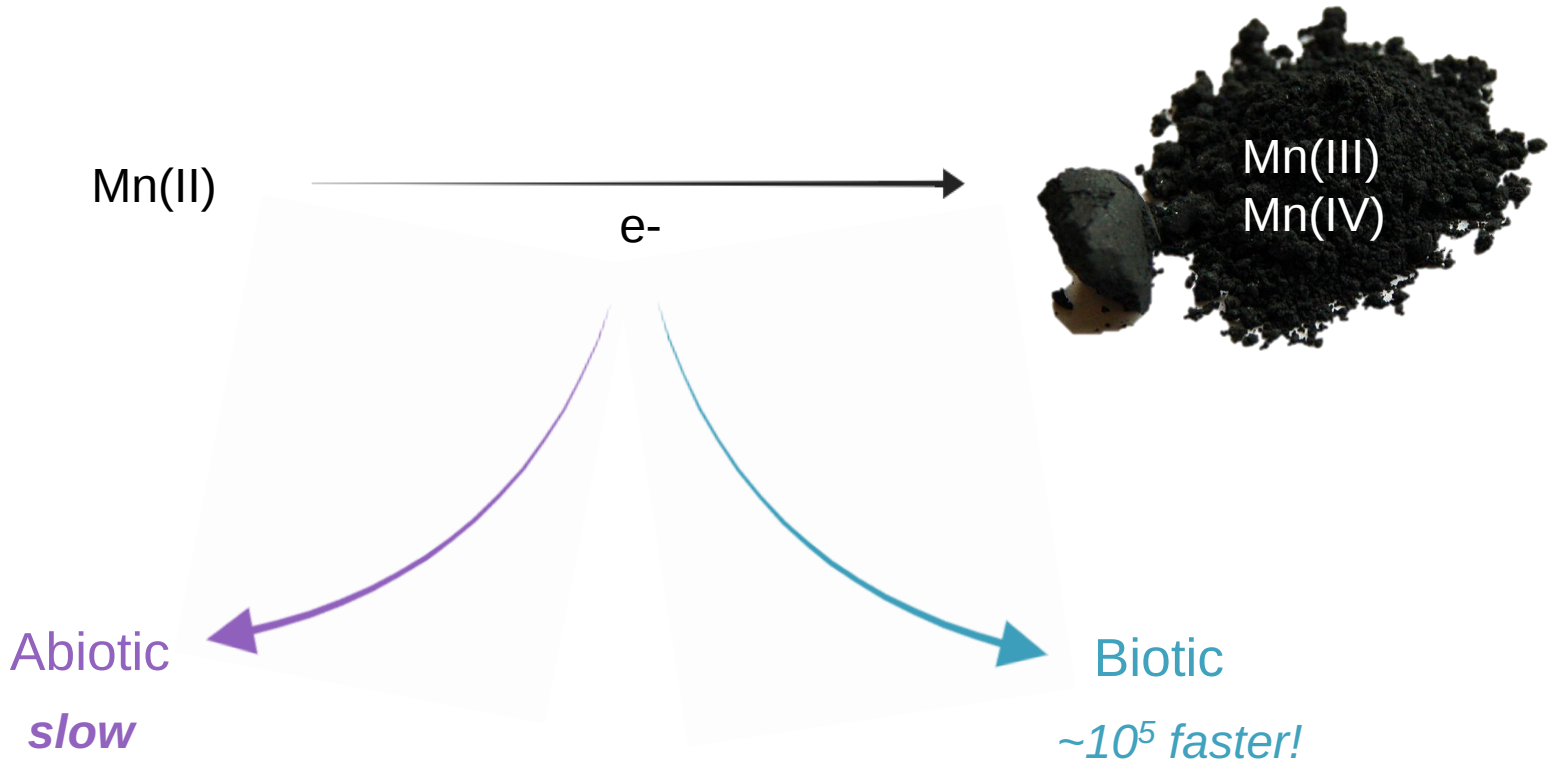


(PM. H, D. L. Sparks et al., 1991)
(Tebo et al, 2004)



(Butler et al, 2015)
(Tebo et al, 2004)

Two ways to form manganese oxides in the environment



(Diem and Stumm, 1984)

(Nealson, Tebo and Rosson, 1988)

Two ways to form manganese oxides biotically

Direct

Enzyme

(Tebo BM et al, 2005)

Two ways to form manganese oxides biotically

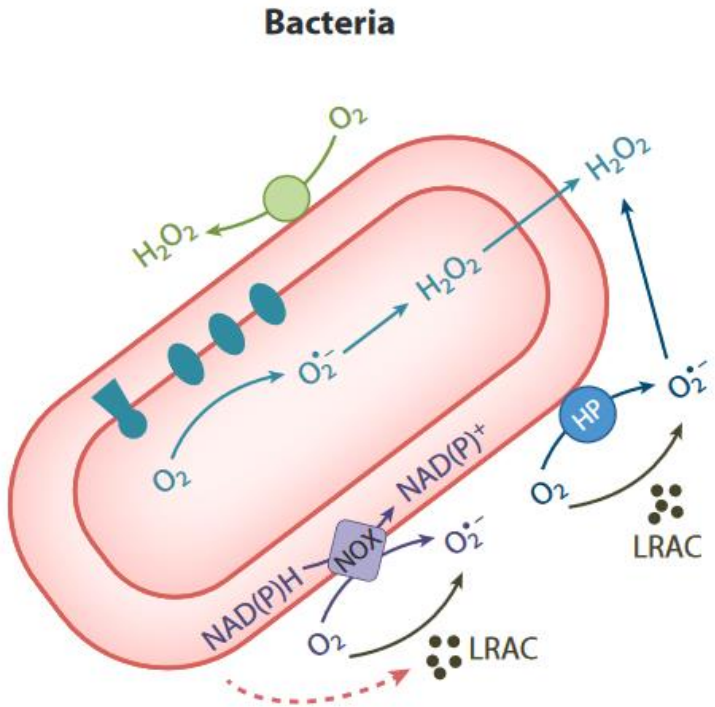
Direct

Enzyme

(Tebo BM et al, 2005)

Indirect

Reactive Oxygen Species (ROS)



(C. Hansel and J.M. Diaz, 2021)
(Learman et al, 2011)

Two ways to form manganese oxides biotically

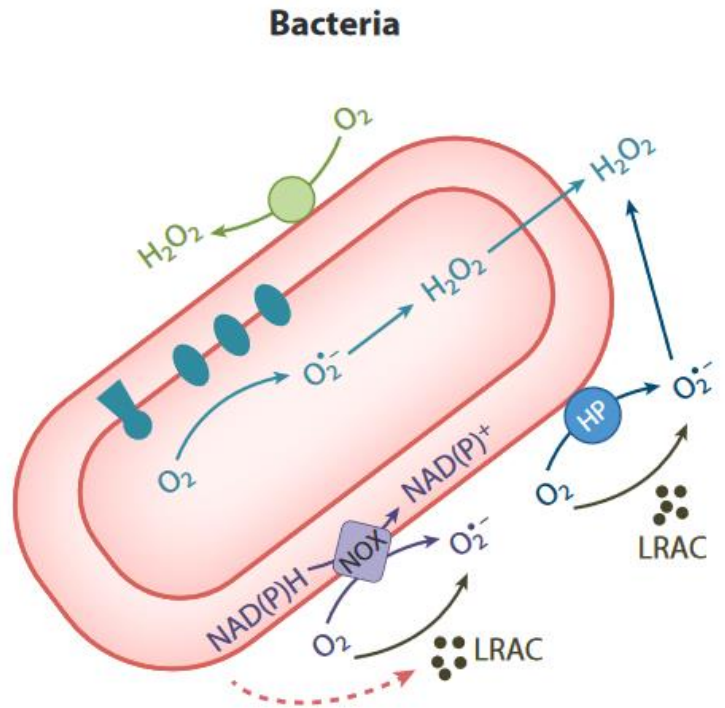
Direct

Enzyme

(Tebo BM et al, 2005)

Indirect

Reactive Oxygen Species (ROS)

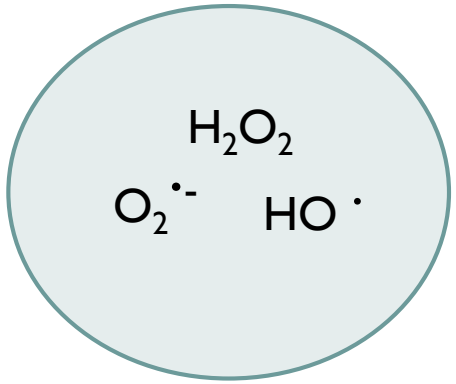


(C. Hansel and J.M. Diaz, 2021)
(Learman et al, 2011)

Microorganisms release reactive oxygen species (ROS)

(Diaz. et al., *Science*, 2013)

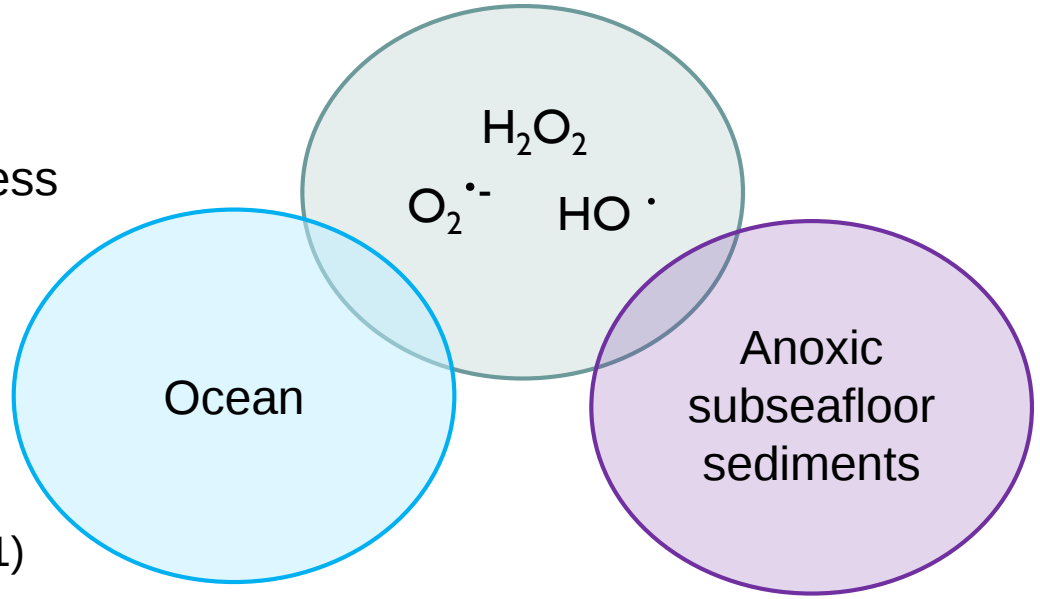
- Transient
- Highly reactive species
- +++ oxidizers
- Key but cryptic process



Microorganisms release reactive oxygen species (ROS)

(Diaz. et al., *Science*, 2013)

- Transient
- Highly reactive species
- +++ oxidizers
- Key but cryptic process



(C. Hansel and J. M. Diaz, 2021)
(Sutherland et al, 2020)

Sink of marine dissolved oxygen
~15 – 50 % photosynth. O_2

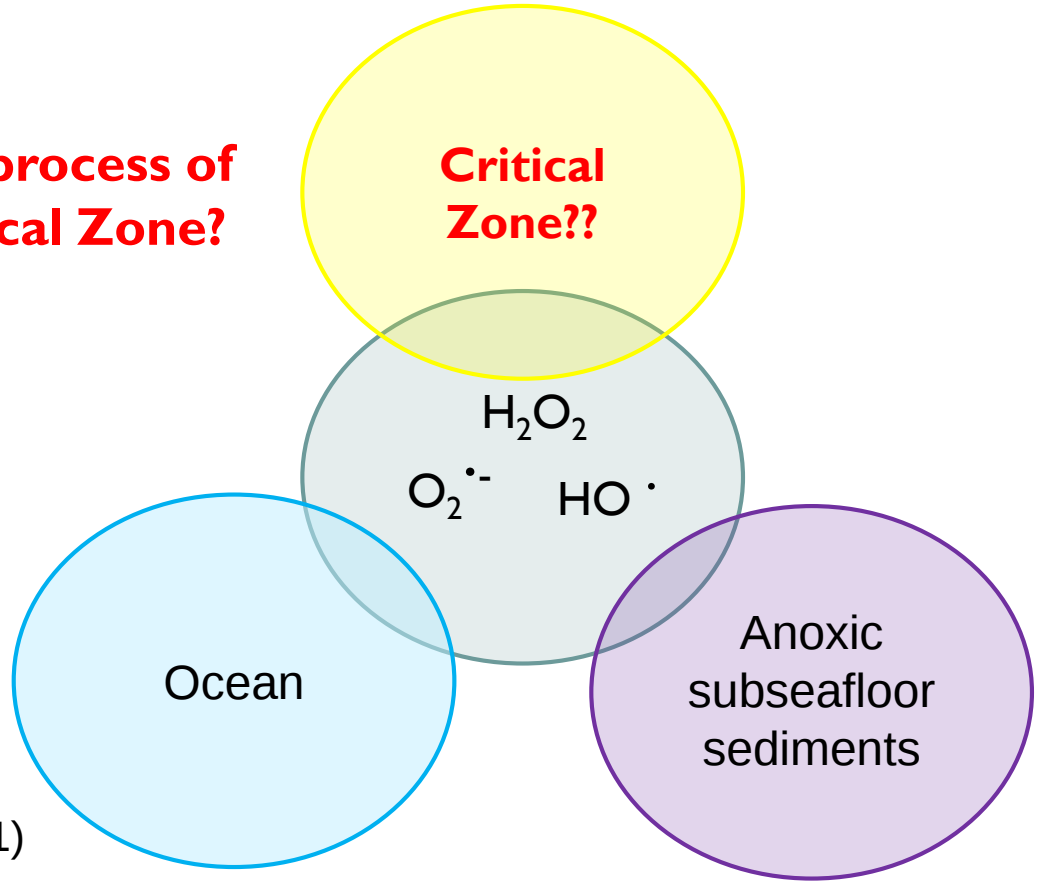
(Sauvage et al, 2021)
(A. I. Garber et al, 2021)

Neutralization of water radiolysis ROS by microorganisms may provide an *in situ* source of oxygen

Microorganisms release reactive oxygen species (ROS)

(Diaz. et al., *Science*, 2013)

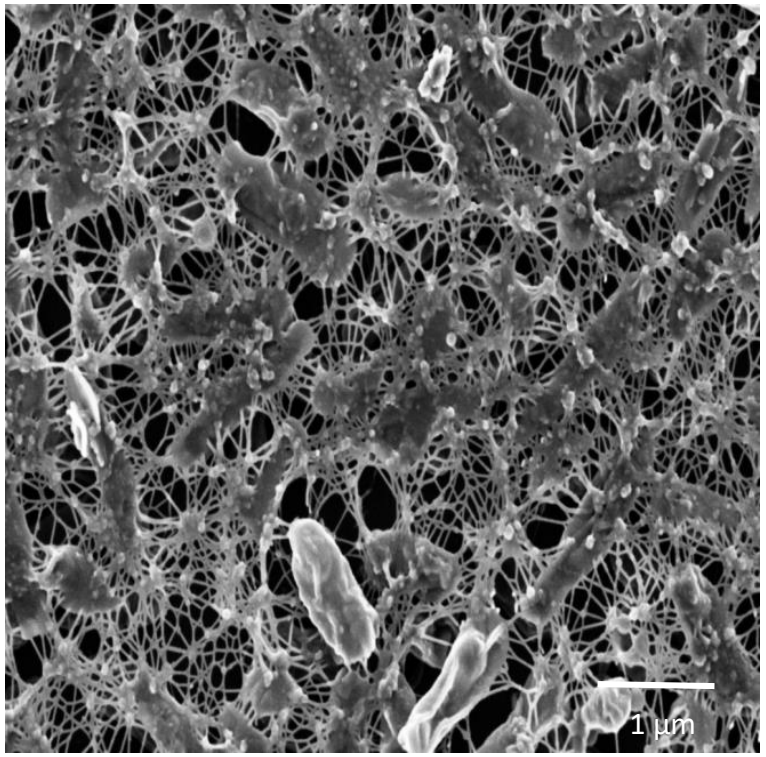
Extracellular ROS = a key process of Mn (bio)cycling in the Critical Zone?



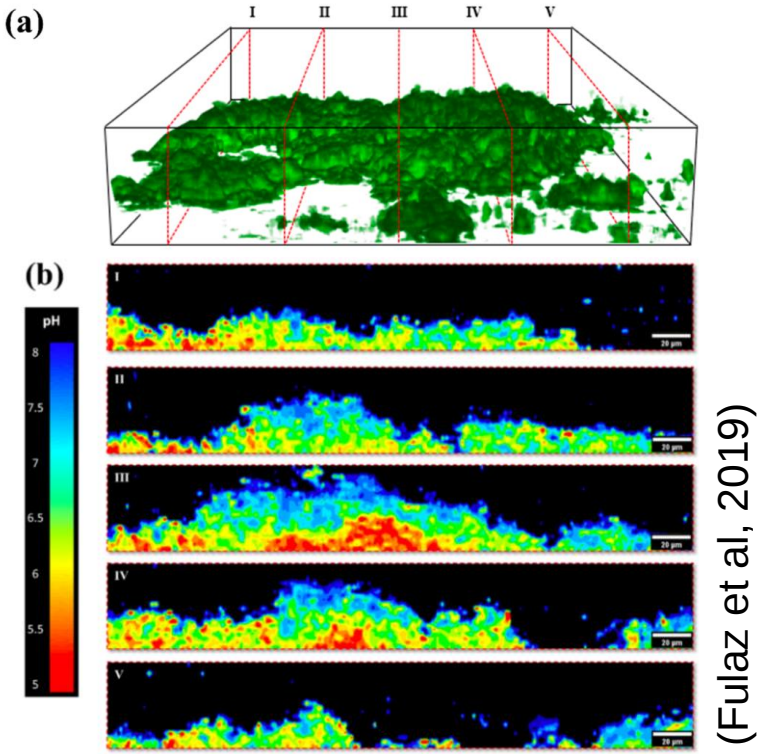
(C. Hansel and J. M. Diaz, 2021)
(Sutherland et al, 2020)

(Sauvage et al, 2021)
(A. I. Garber et al, 2021)

Role of microbial biofilms



©T. Couasnon

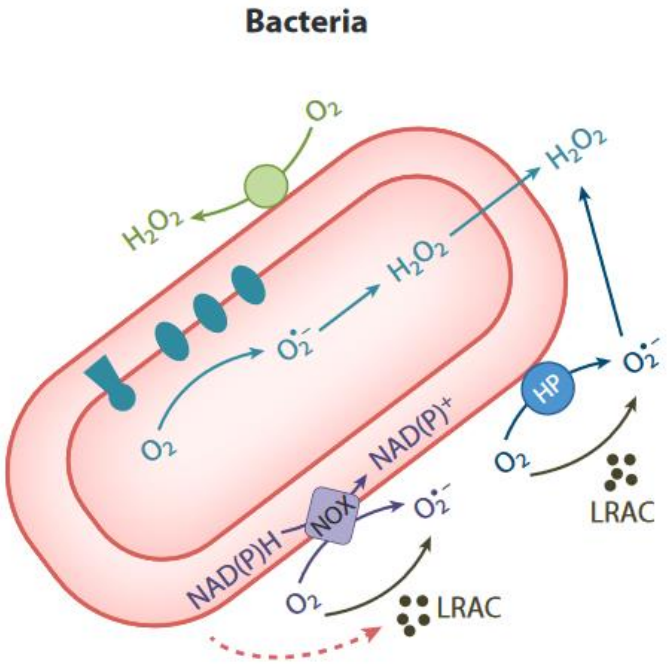


(Fulaz et al, 2019)

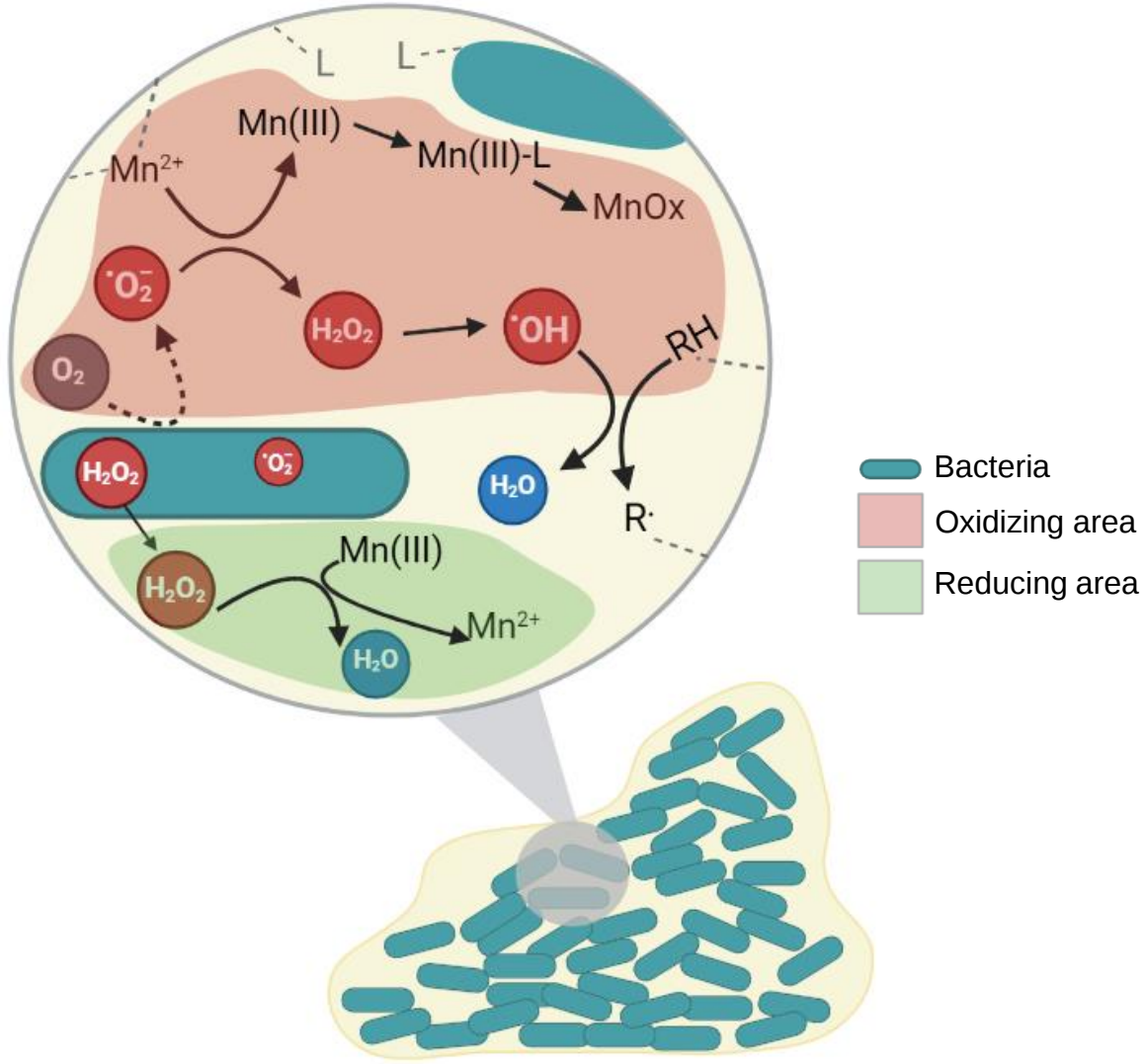
Gel-like structure ⟷ Limited transport ⟷ µ-environments

Hypothesis

Biofilms accumulate ROS creating highly oxidizing pockets



?

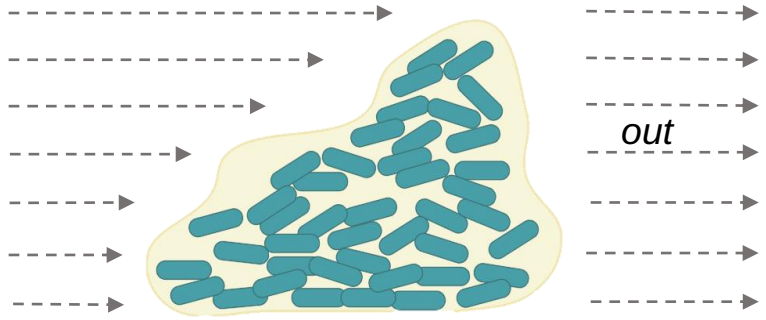


(C. Hansel and J.M. Diaz, 2021)
(Learman et al, 2011)

Laboratory experimental setup

Mn^{2+} solution

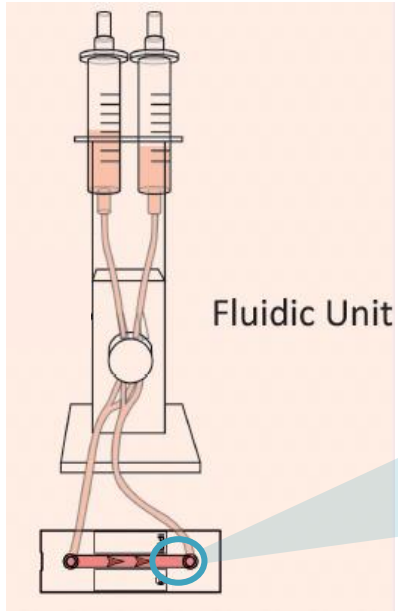
- *$10^{-5}M$*
- *2-4 days*

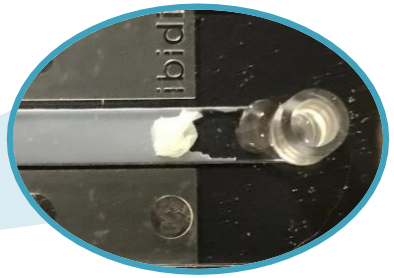


Mn^{2+}

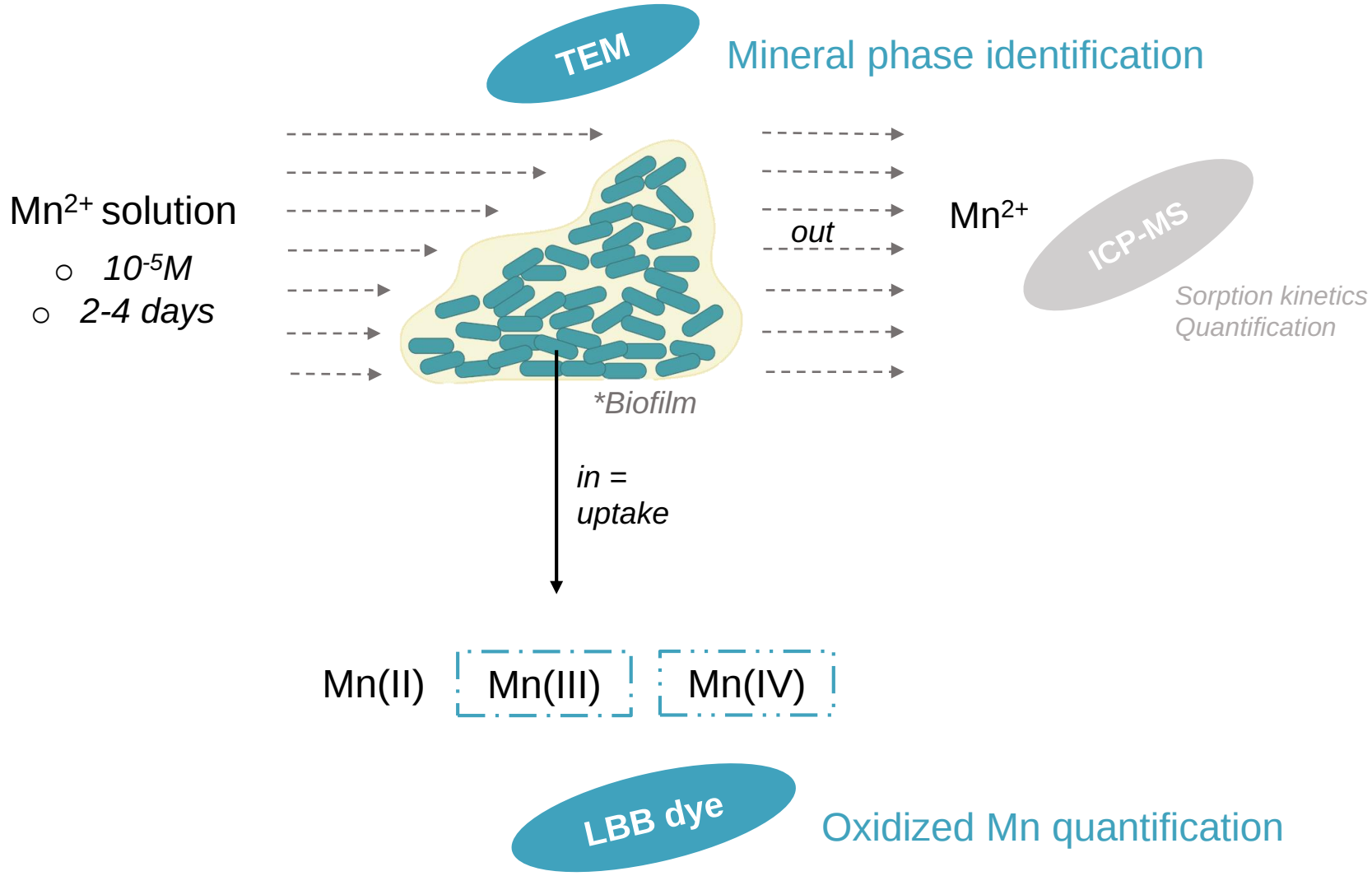
*Strain used ***E. coli*** K12 MG1655 F'tet

- Controlled system
- No Mn-oxidation related enzyme



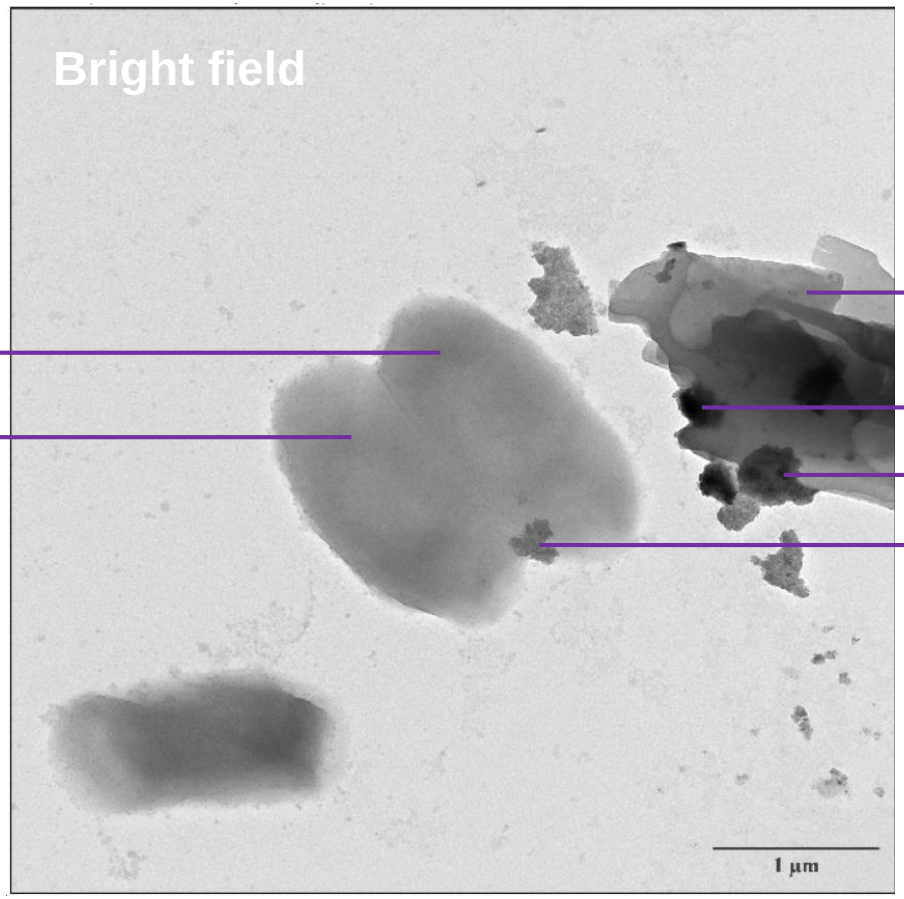


Laboratory experimental setup



*Strain used *E. coli* K12 MG1655 F'tet

Mineral phase identification - TEM

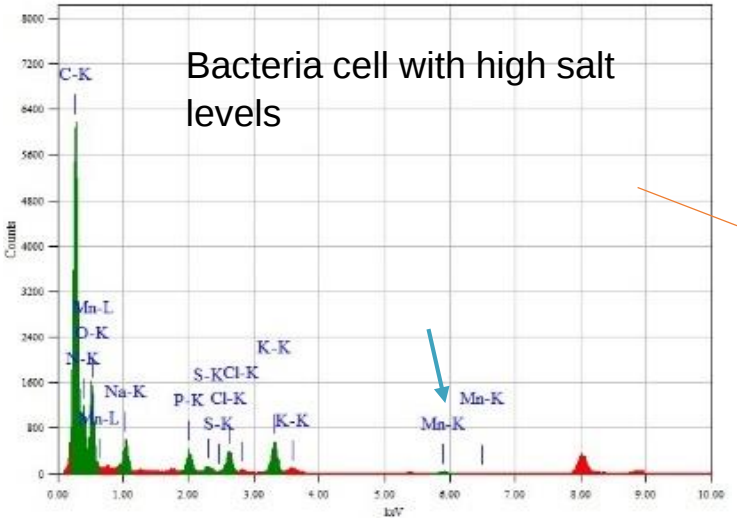


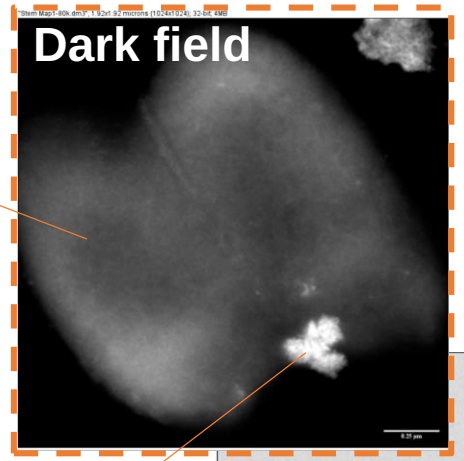
Bacteria

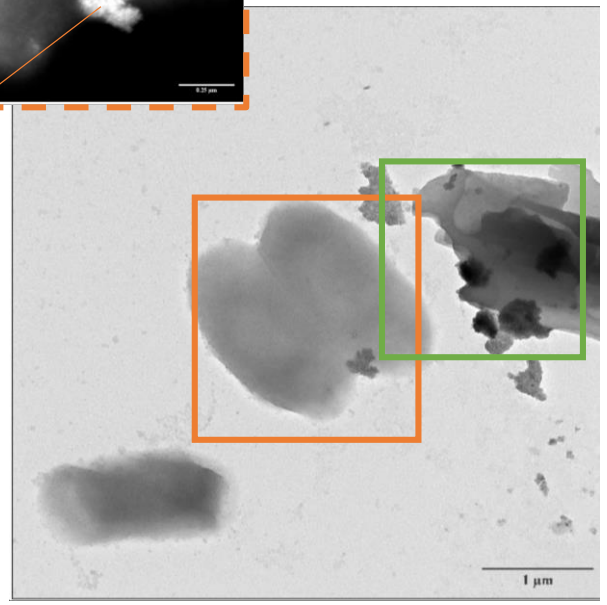
EPS

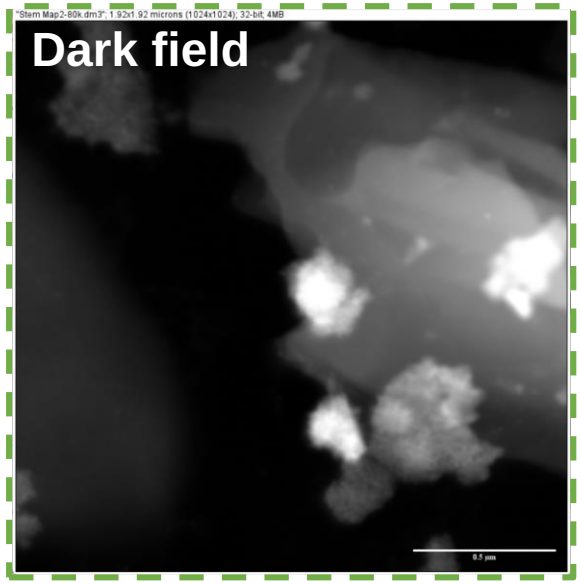
Minerals

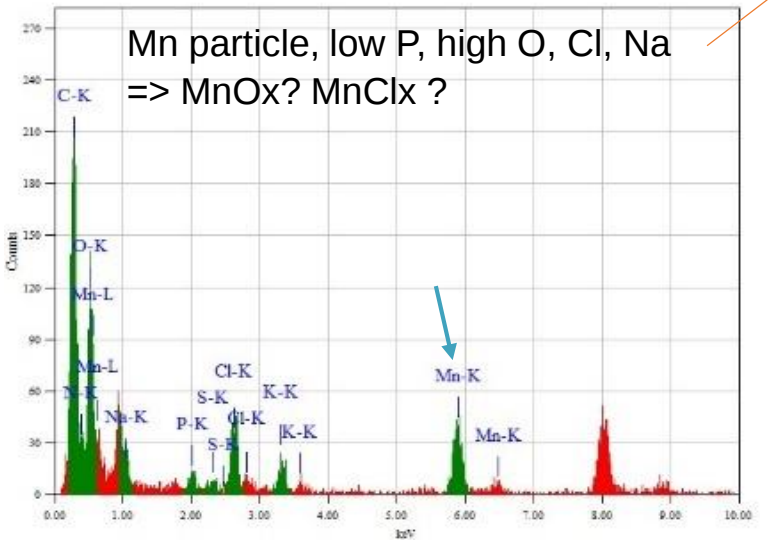
Mineral phase identification - TEM





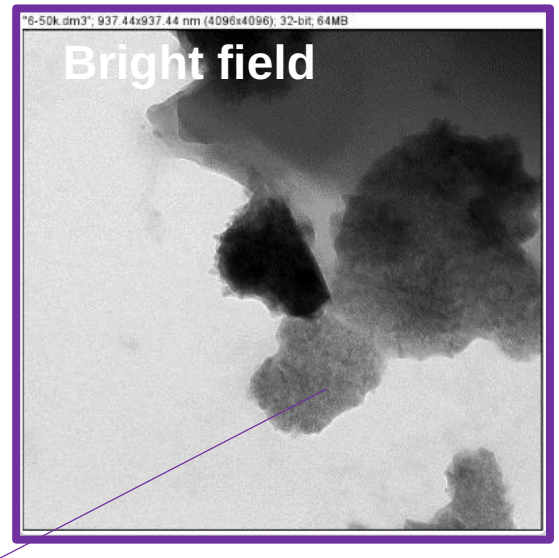


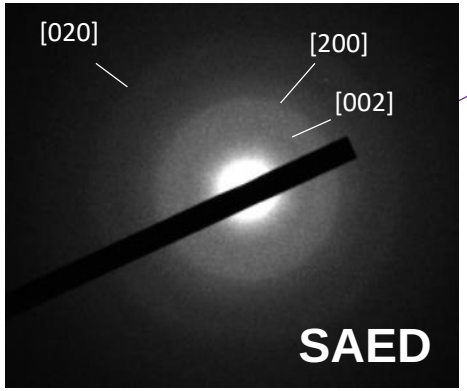


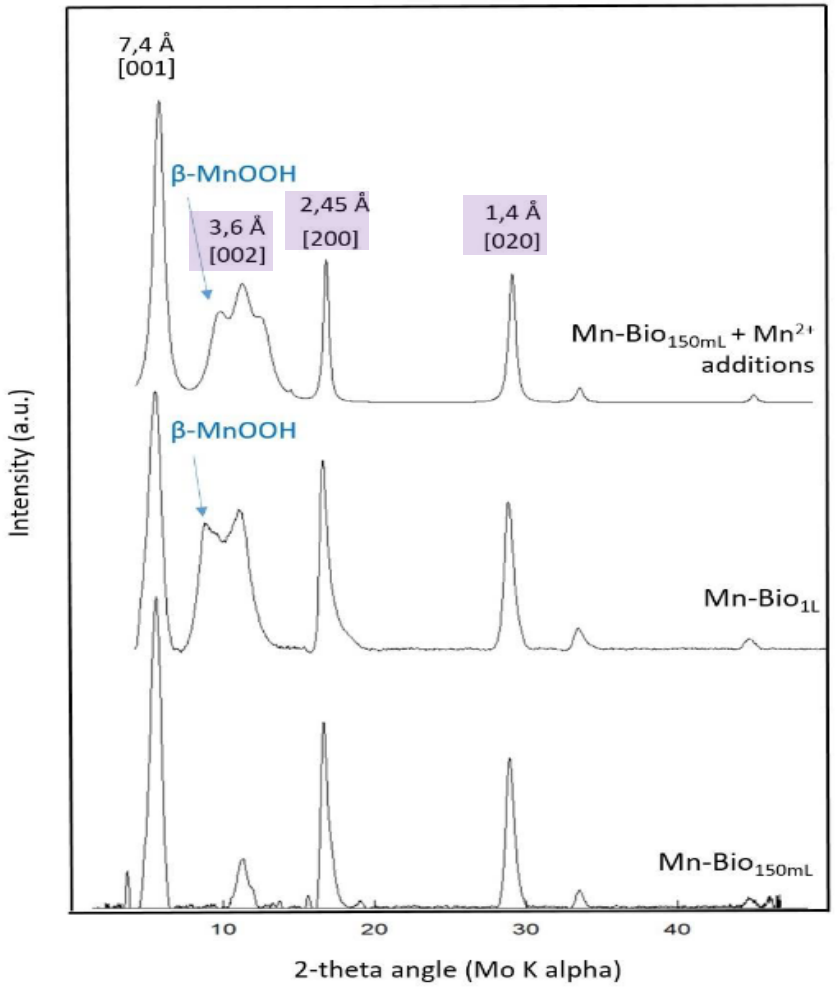


Mineral phase identification - TEM

Minerals are related to a BIRNESSITE structure



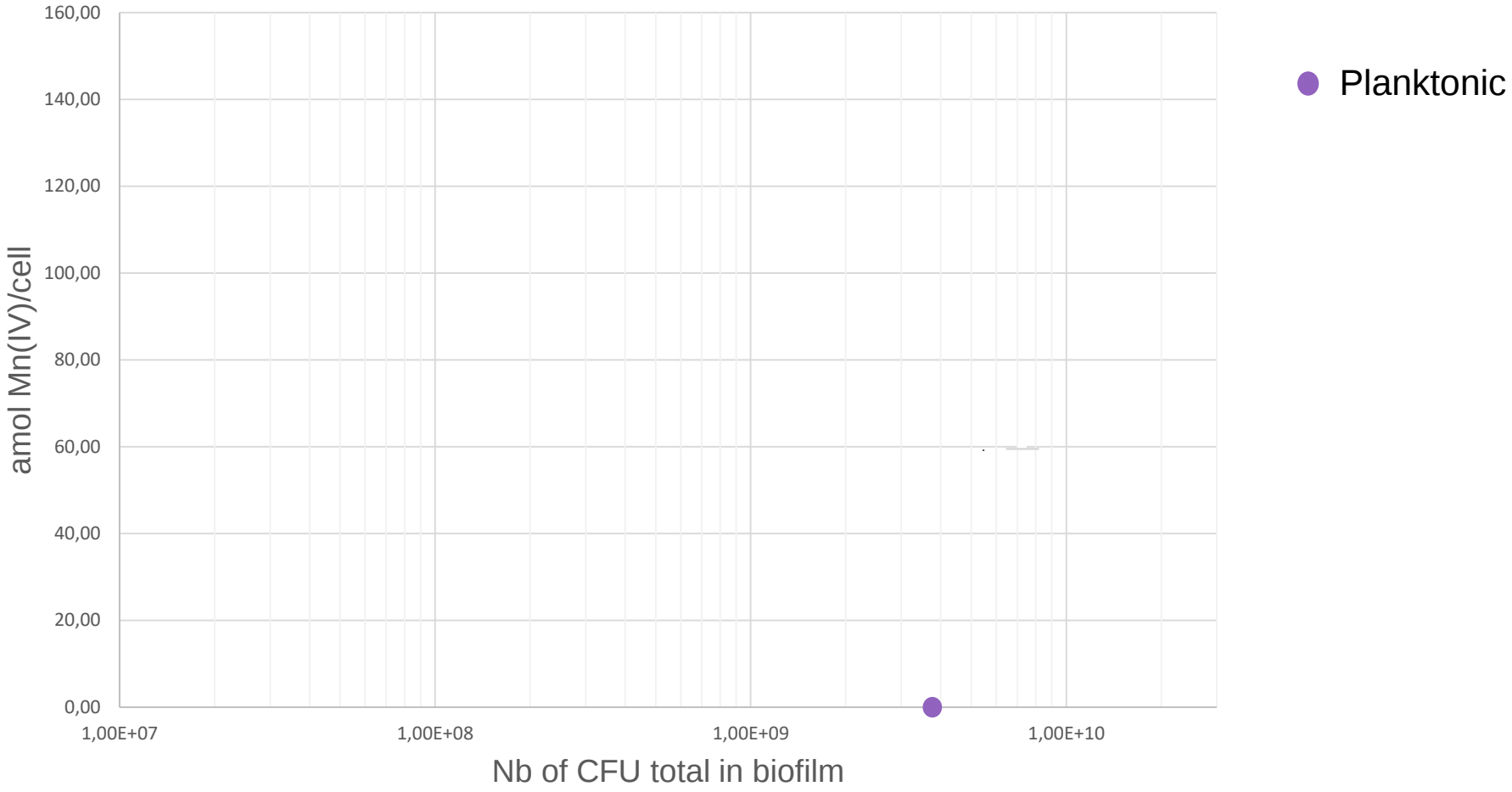




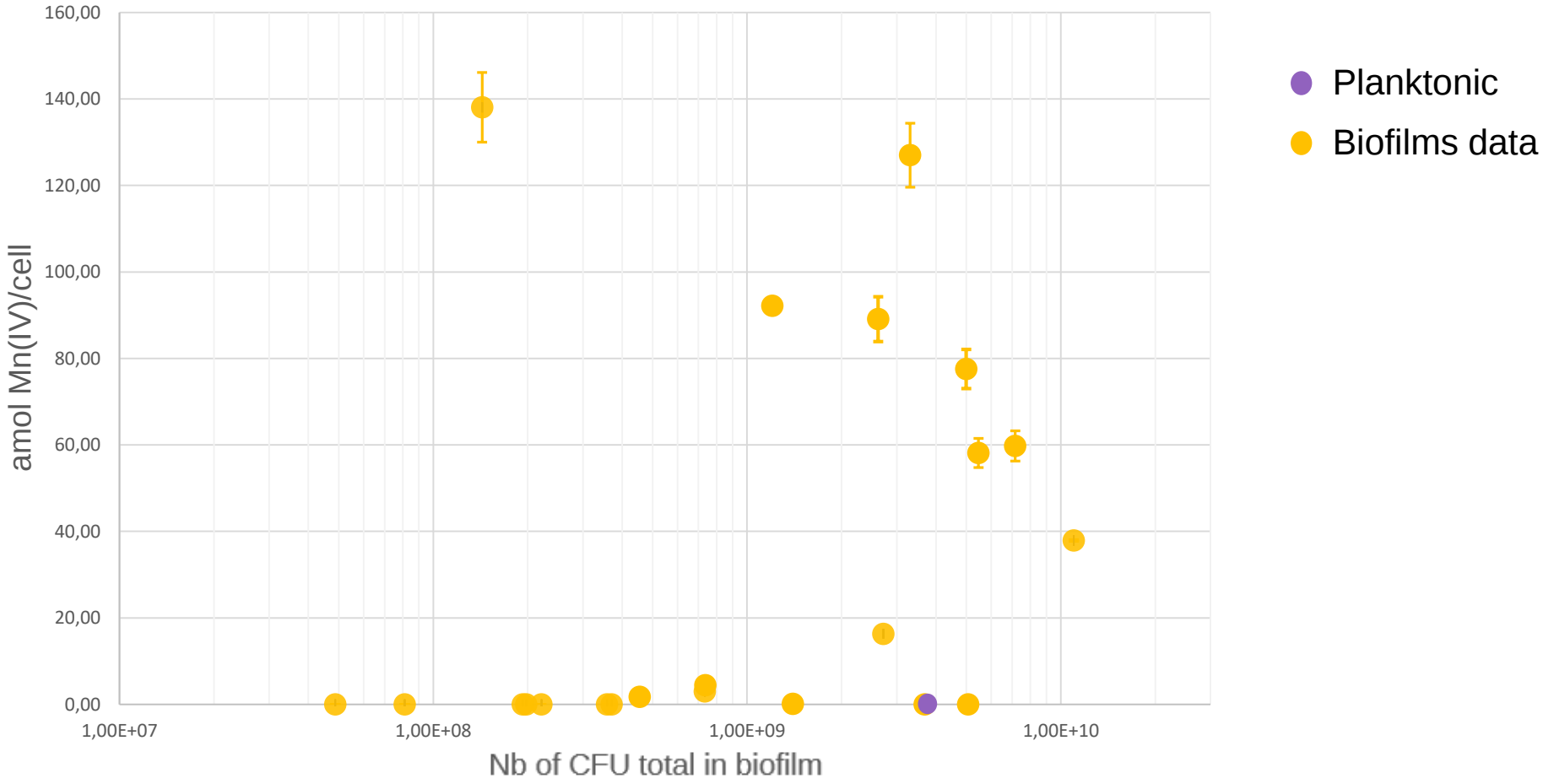
XRD analysis of birnessite biomineral, (L. Galezowski, 2021)

Evidence of Mn oxidation in the biofilm

Oxidized Mn quantification – LBB dye



Oxidized Mn quantification – LBB dye



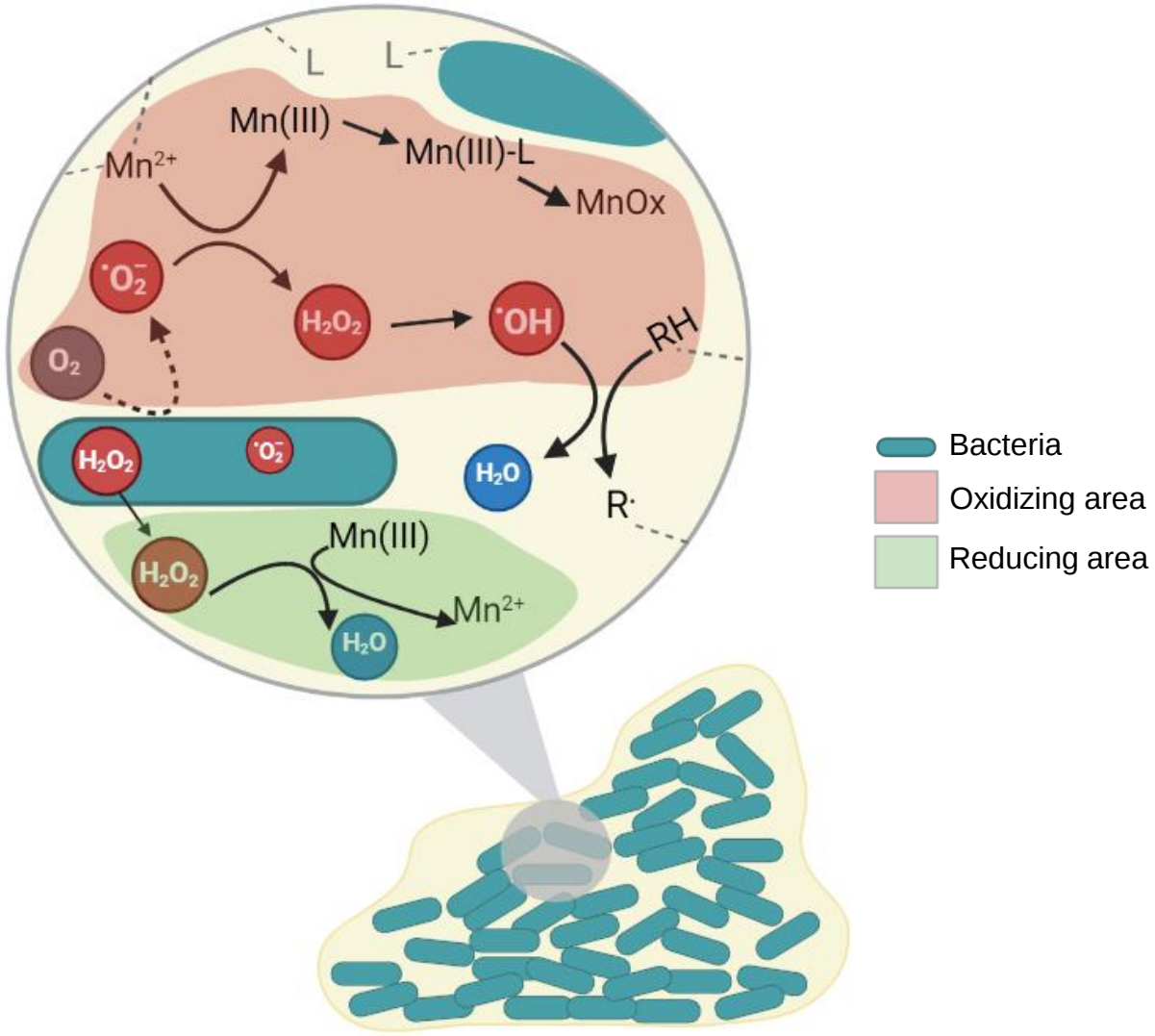
E. coli biofilms are able to oxidize Mn(II)!

Hypothesis

Biofilms accumulate ROS creating highly oxidizing pockets

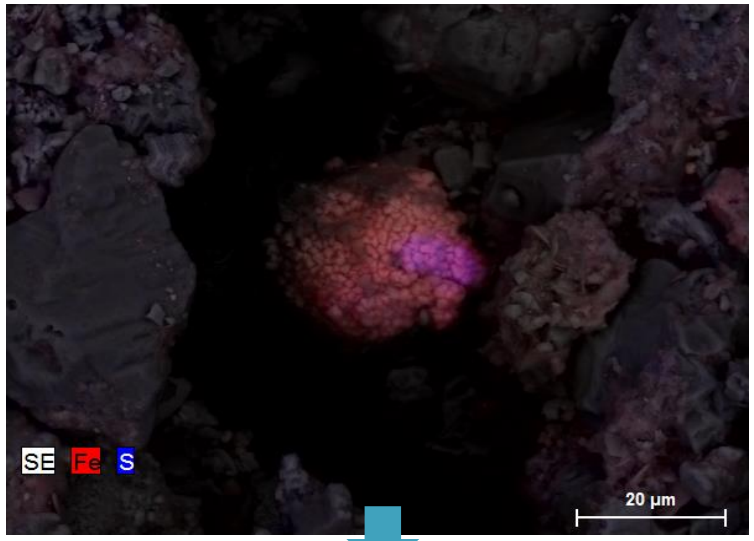
Work in progress:

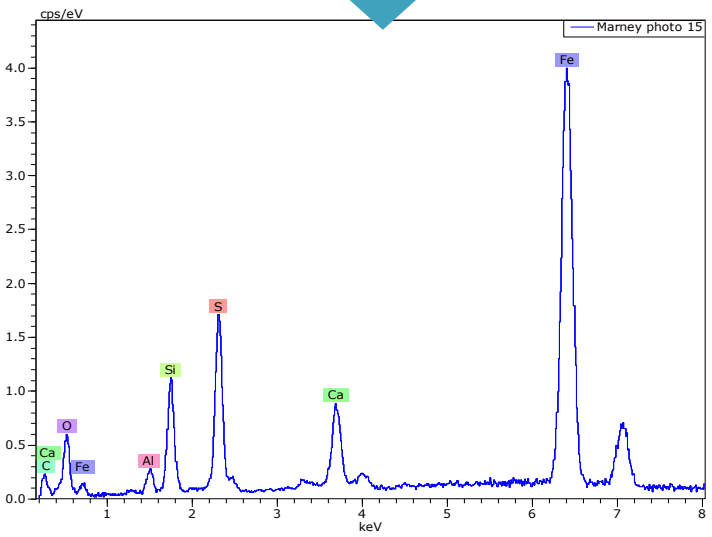
- CLSM imaging targeting ROS
- Field sampling



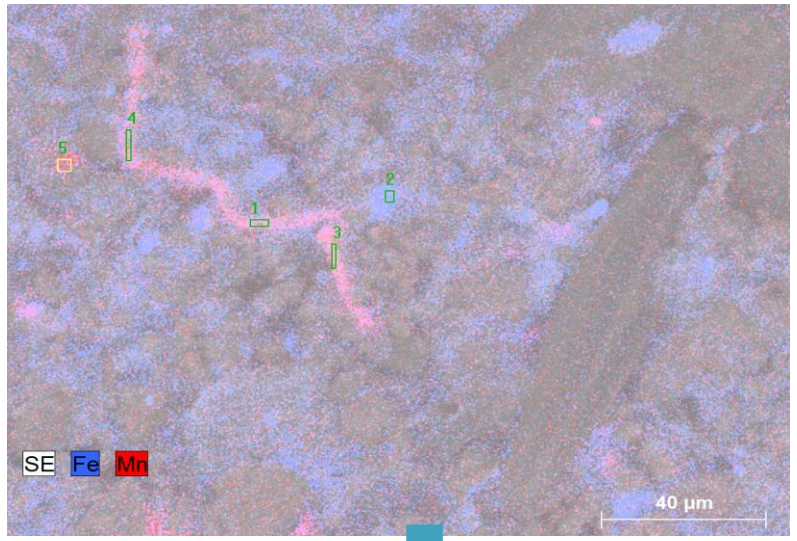
Microenvironments in natural biofilms (Seine river)

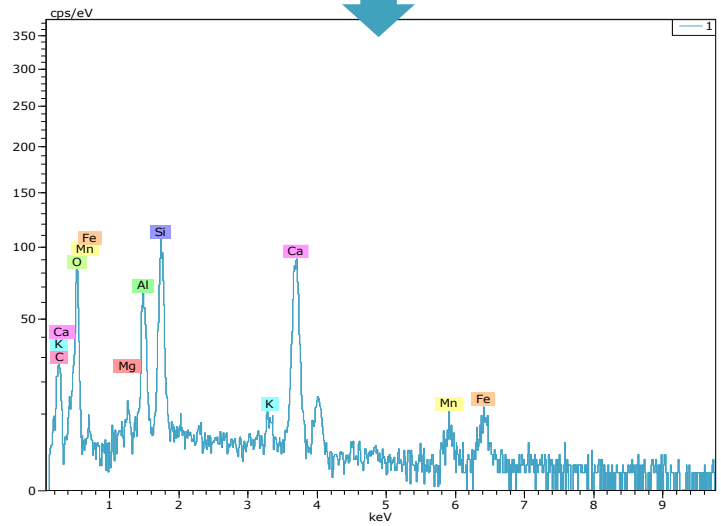
Co autors:
A. Gelabert,T. Berthe, G. Morin, Y. Colin, F. Petit





Framboidal pyrite
Reducing environments





Mn oxides formed *in situ?*
Oxidative environments?

Take home message

- Biofilms seem to get specific redox microenvironments
- *E. coli* biofilms are able to oxidize Mn(II)
- Biological (and abiotic) ROS production in the critical zone needs further investigation -> **Major role for redox-sensitive elements?**

Thank you

François Guyot
Bénédicte Menez
Stephan Borensztajn
Céline Pisapia
Léna Lecourt
Emmanuelle Gérard
Jean-Marc Ghigo