



PREVENTION OF THE LAMPENFLORA WITH POM-IL COATINGS IN THE UNDERGROUND POMMERY CHAMPAGNE CELLAR

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Pommery Champagne cellar

Context



Pommery Company founded in 1858

Mrs Pommery reused 60 quarries dug in the chalk at 30 m depth from Antiquity





- Connection of quarries by 18 km of galleries to make a huge cellar
- Perfect conditions: 14°C, 98 % RH



Art and Champagne

Monumental bas-reliefs in the stone walls

Context



Louise 1986
(Jean Barat)



Silène 1884



Le champagne au 18^{ème} siècle 1883



Les maraudeurs 1882



Fête de Bacchus 1883

Sculptor Gustave Navlet

Lampenflora growth

Problematic



Recurring repairs



Recurring cleaning

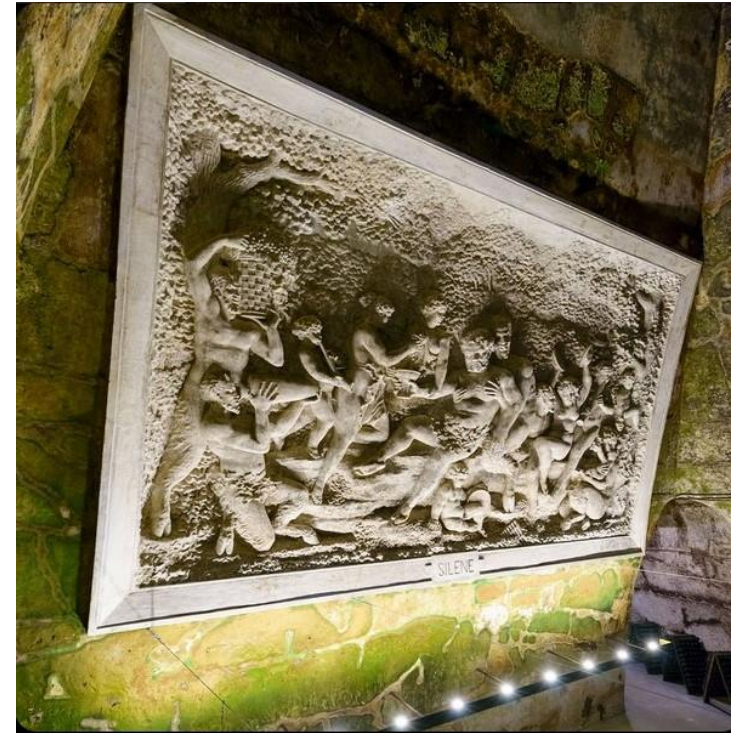
Tourist visits

- ➔ Direct lighting of bas-reliefs
- Now : LED in limited time
- 180 000 tourists / year
- ➔ Increasing lighting and CO₂



Environmental conditions

Artificial lighting



Permanent lighting years ago

Modern artworks

Environmental conditions

Indirect lighting of bas-reliefs



POMMERY #17 FOREVER_Bianca BONDI - Wild and Slow ©



Experience Pommery# from 2003



Focus on 2 bas-reliefs

Fête de Bacchus



Photogrammetry: 41 % of biofilm

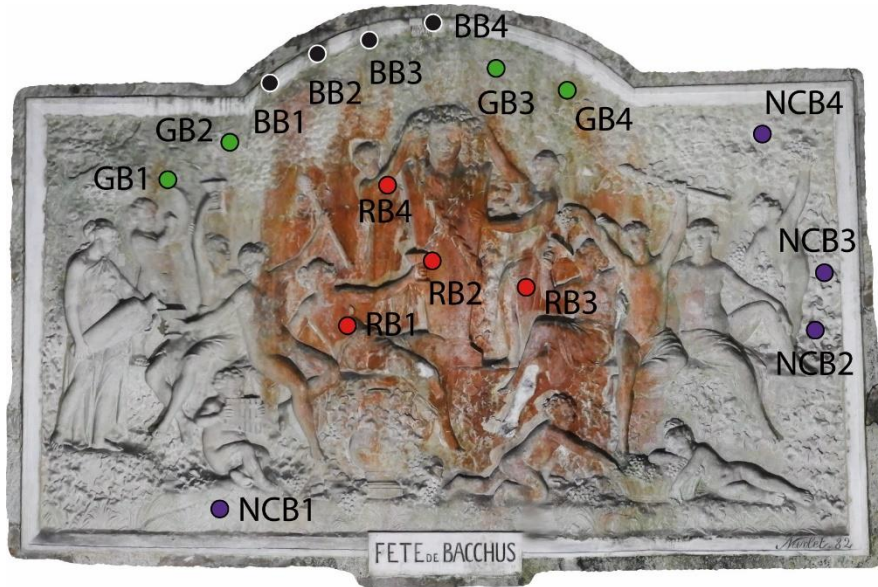
Silène



25 % of biofilm

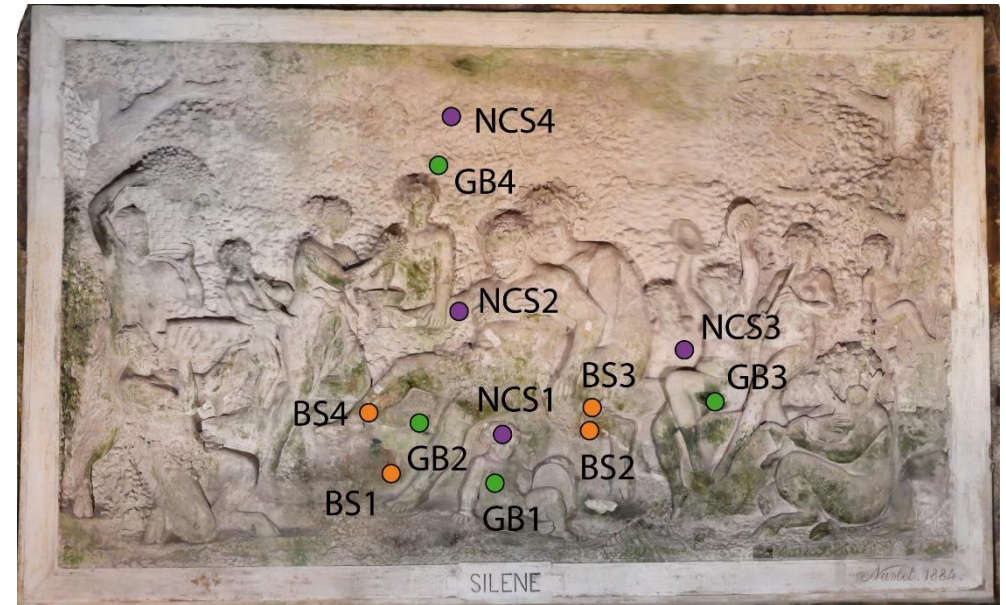
Lampenflora study

Bacchus



- ✓ 3 coloured biofilms: RB: red, BB: black, GB: green
- ✓ 1 non-coloured area

Silène



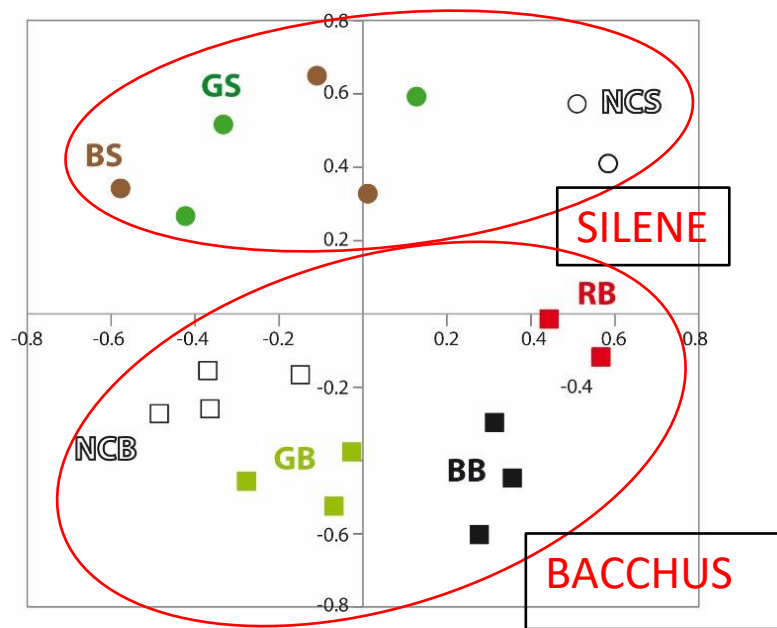
- ✓ 2 coloured biofilms: GS: green, BS: brown,
- ✓ 1 non-coloured area

Sampling : - Metagenomic sequencing (ILLUMINA MiSeq – 16S-18S rRNA), qPCR
- Culture for Sanger sequencing (16S-18S rRNA, *rbcl*)
- Pigment analyses (Chlorophylls, carotenoids, phycobilins)

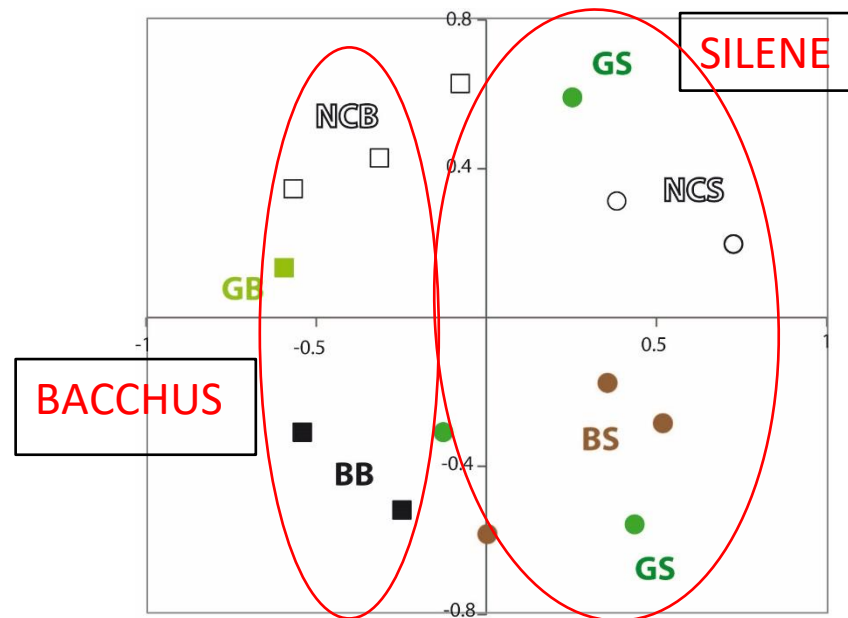
Microbial analysis

- ✓ Low number of eukaryote reads compared to prokaryotes

NMDS OTU-level community composition for prokaryotes



NMDS OTU-level community composition for eukaryotes

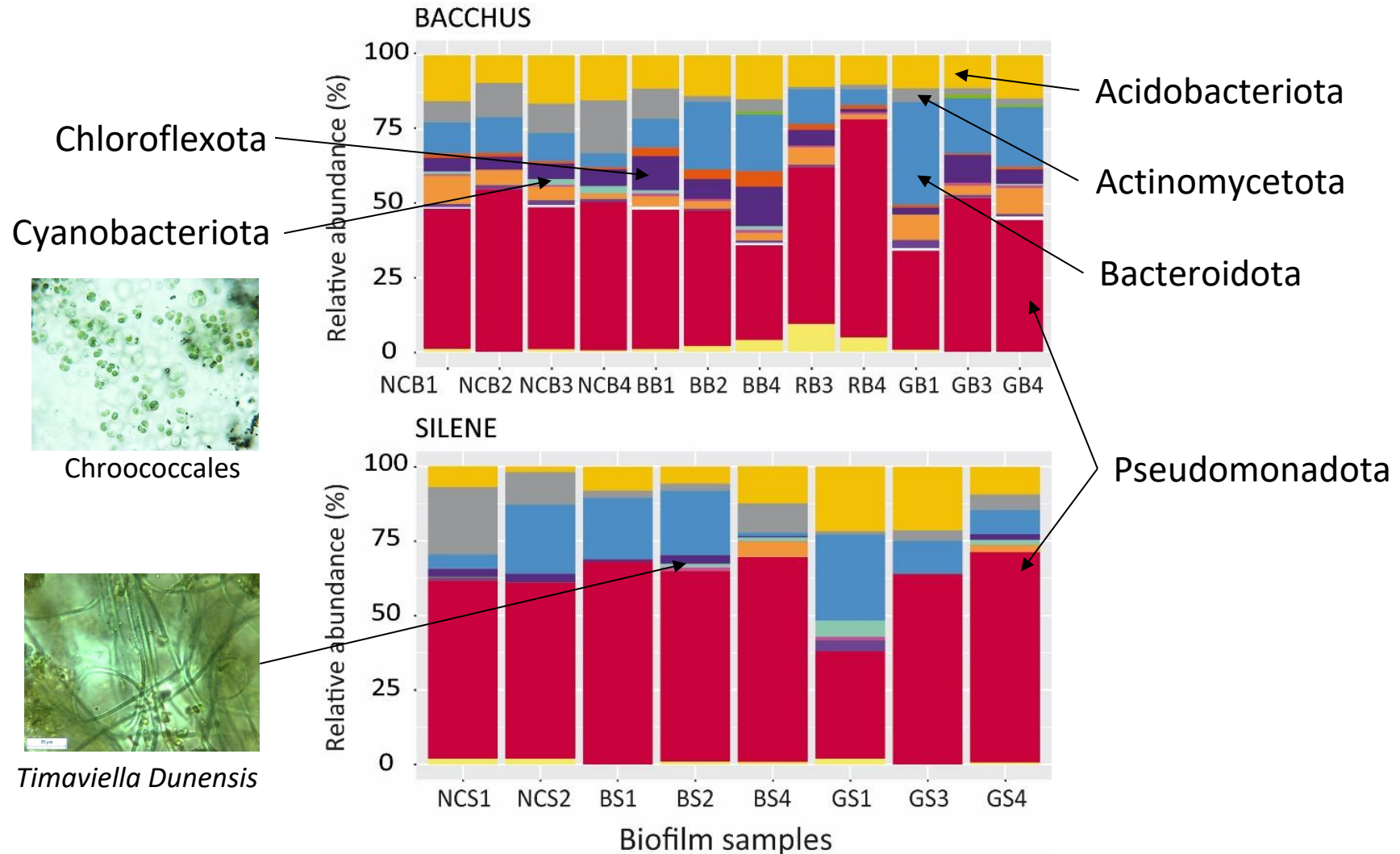


- ➡ Different microbial communities between Bacchus and Silene
- Specific microbial communities for each biofilm

Microbial analysis

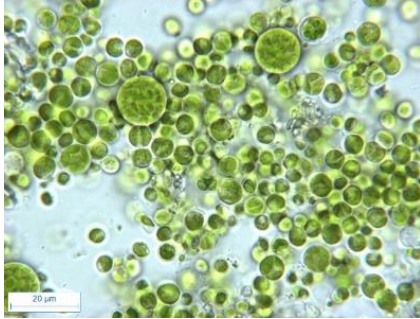
Bacteria

- ✓ On both bas-reliefs: Dominance of bacteria with Pseudomonadota

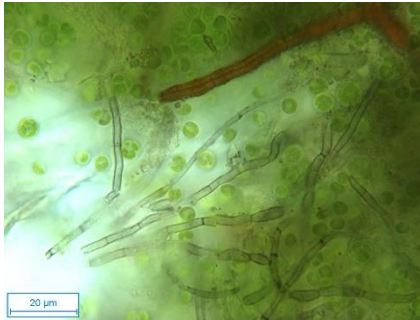


Microbial diversity Eukaryotes

Bacchus



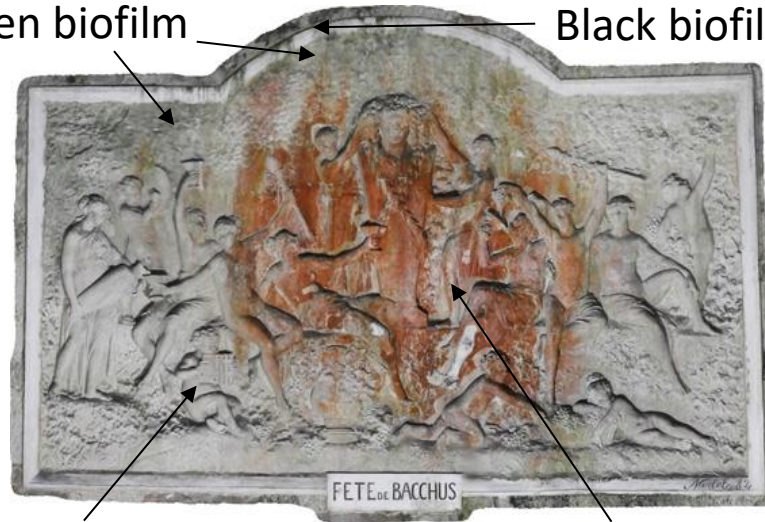
Chomochloris g.
Bractaeococcus sp.



Embryophyta unclassified

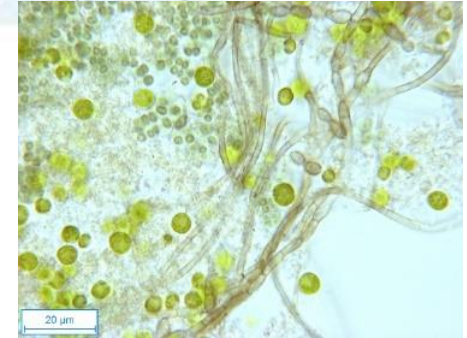
Green biofilm

Black biofilm

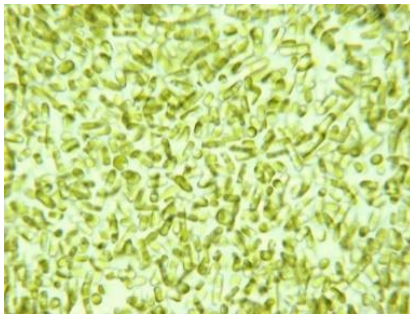


Non-coloured biofilm

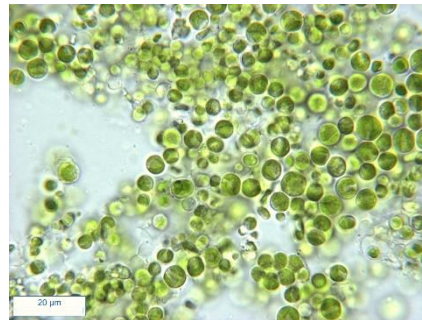
Red biofilm



Embryophyta unclassified
Chromochloris g.

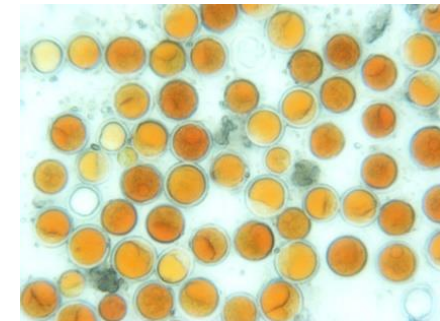


Stichococcus g.



Chromochloris g.

+ Fungi: *Mortierella*



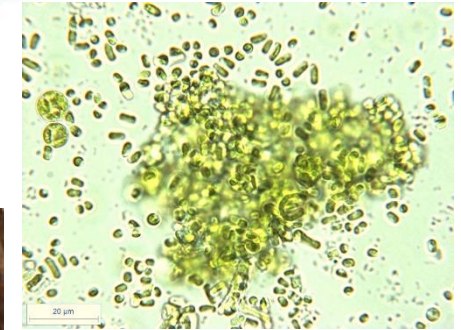
Chromochloris zofingiensis

Microbial diversity

Eukaryotes

Silène

Non-coloured biofilm



Stichococcus g.
Diplosphaera sp

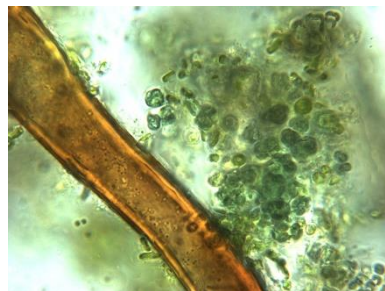
Fungi: Chaetotryiales

Green biofilm
Stichococcus g.
Diplosphaera sp

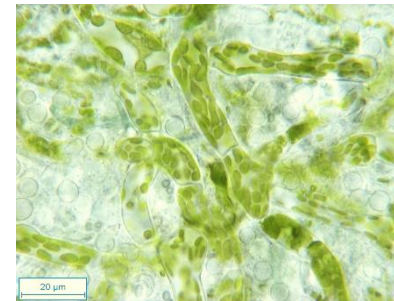
Brown biofilm

Embryophyta unclassified
Eucladium verticillatum
Stichococcus g.

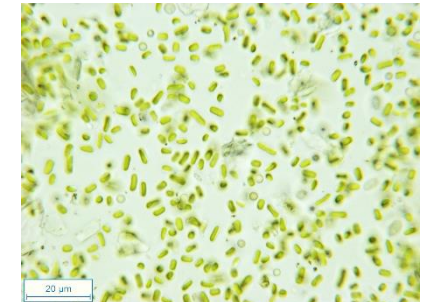
Fungi: Hypocreales



Embryophyta unclassified



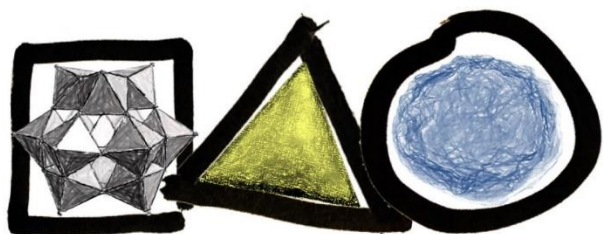
Embryophyta unclassified



Polyoxometalate-Ionic Liquids (POM-ILs)

Polyoxometalates
Nanoparticles

Polymeric materials



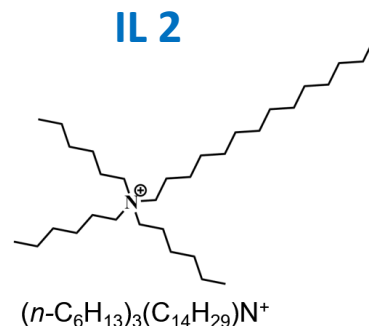
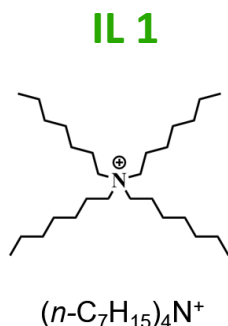
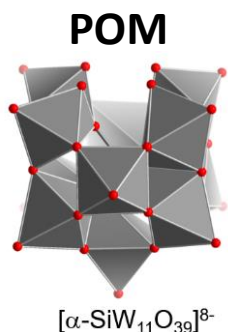
Redox Active Materials Group

Scott G. Mitchell and collaborators

<https://redoxactivematerialsgroup.com/>



Universidad
Zaragoza



➔ Constructing modular nanomaterials with antimicrobial function

➔ POM-IL1 and POM-IL2 as preventive coatings for natural stones

polytungstate anion with two quaternary alkylammonium cations



Franco-Castillo et al., IBB 2022, 173, 105459

Application on a standard wall of the cellar

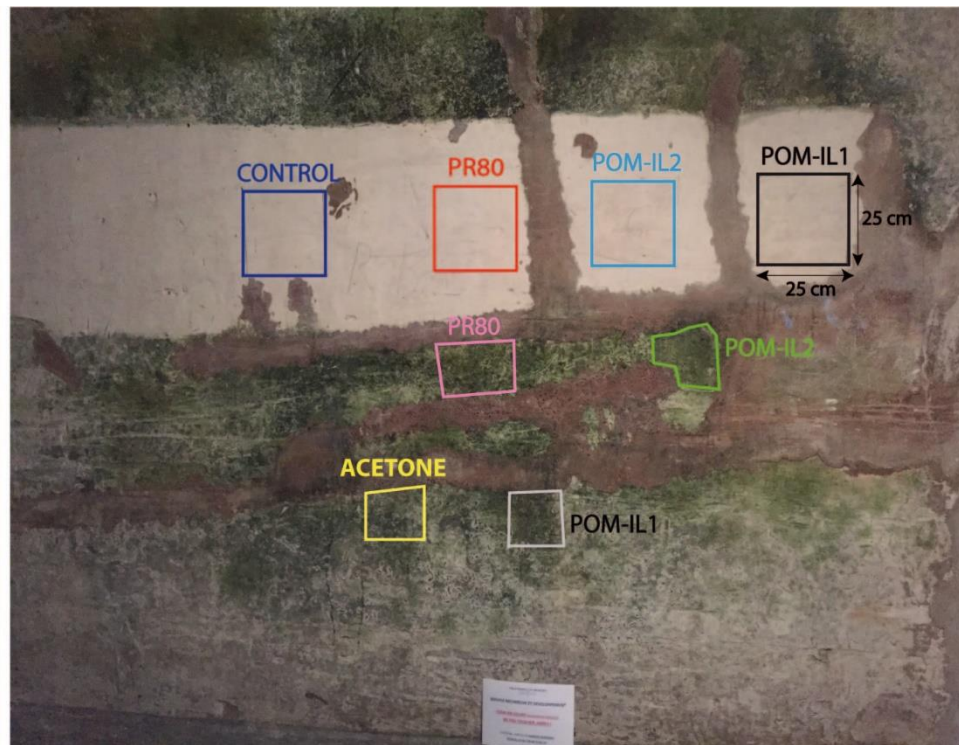


POM-IL 1 et POM-IL 2
120 mg/ml acetone
0,12 l/m



PREVENTOL RI80®
5 % diluted in water
0,20 l/m

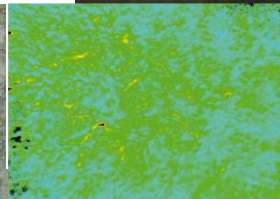
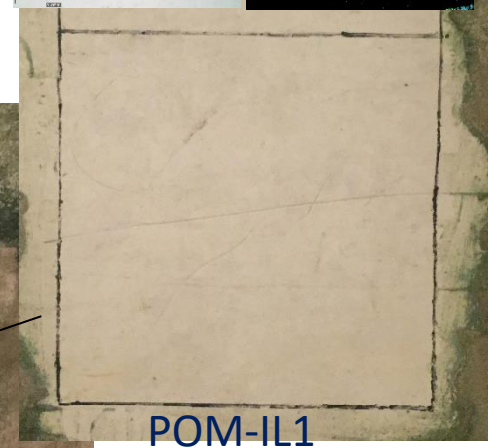
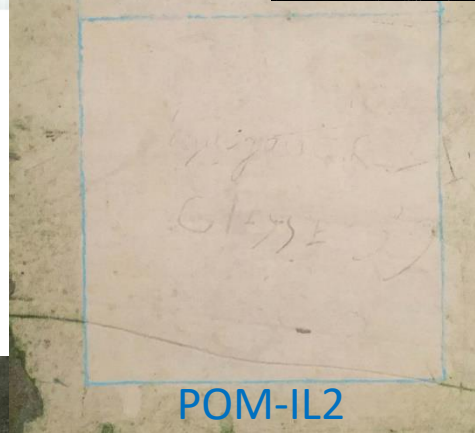
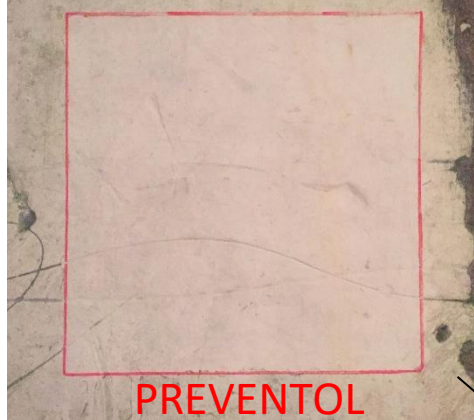
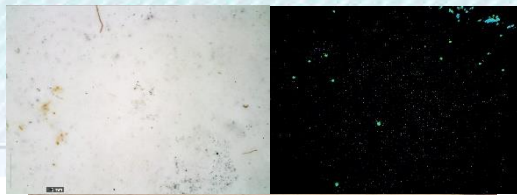
Light 12h/ day



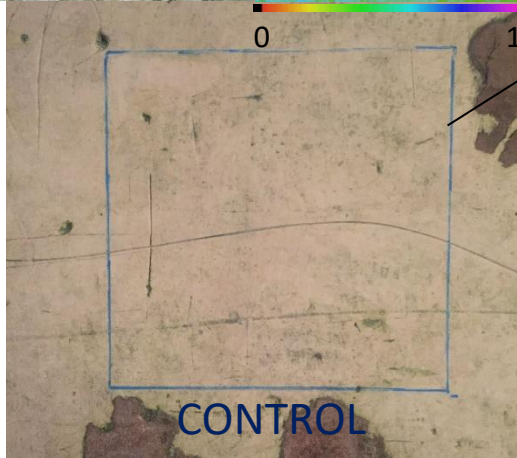
Preventive assay on
a cleaned wall

Curative assay on
an existing biofilm

After 1 year



0 1



Microbial diversity

Results of the shallow shotgun sequencing

✓ Dominance of Prokaryotes (only 1 % of Eukaryotes)

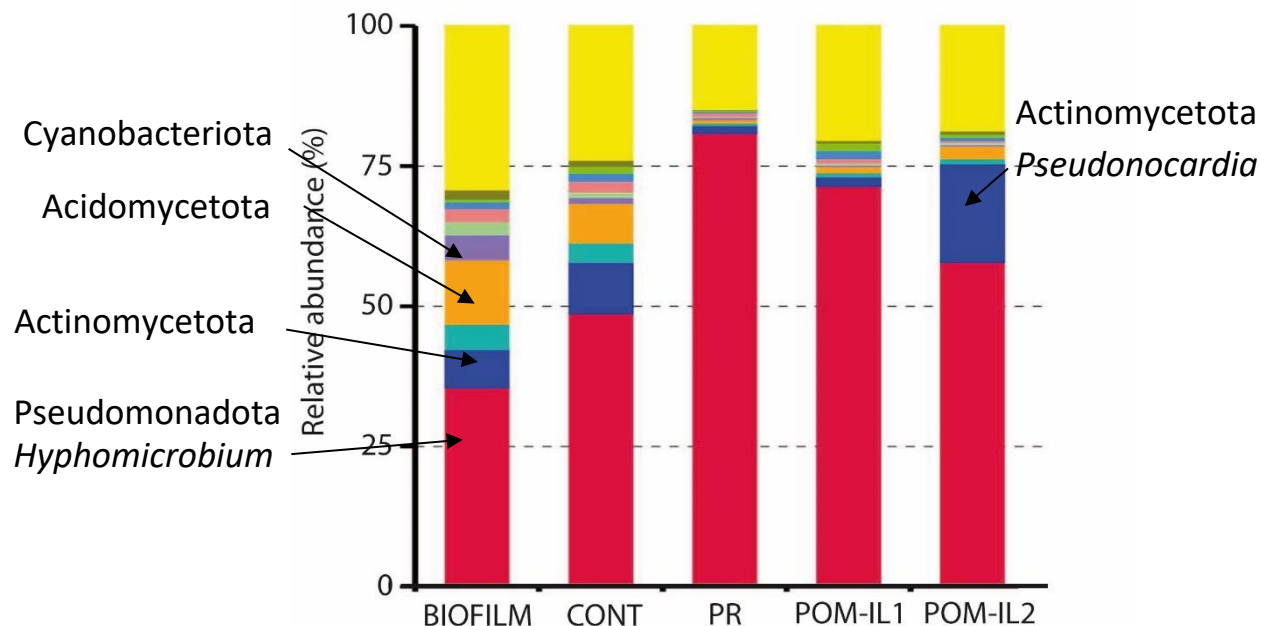
✓ Alpha diversity index:

- Similar richness
- Decrease of the heterogeneity: dominance of taxa

Areas	Chao1	Shannon
Existing biofilm	200	2.8
1 year Control	201	2.3
PR prev	185	0.6
POM-IL1 prev	200	1.1
POM-IL2 prev	201	1.6

✓ On biocide areas:

- Decrease of the bacterial diversity
- Dominance of Pseudomonadota



Microbial diversity

Results of the shallow shotgun sequencing

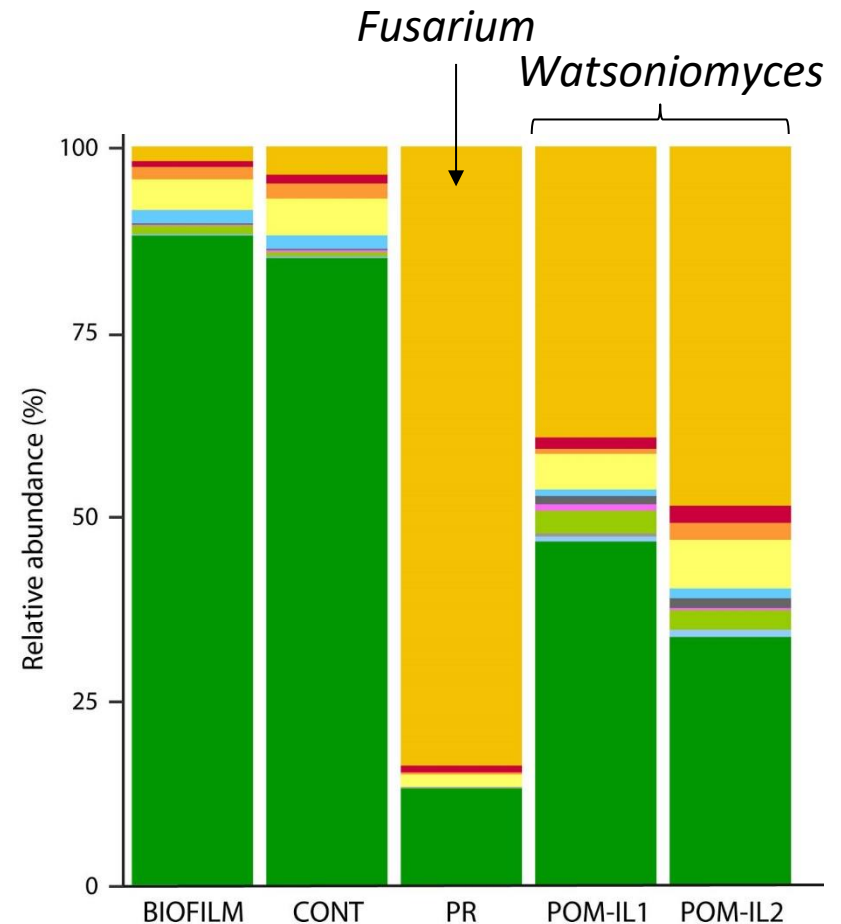
✓ Calculation of relative abundance only with fungi and phototroph eukaryotes :

➡ On controls : dominance of Embryophyta

➡ On biocides : dominance of Fungi

➡ Development of *Fusarium* only on the Preventol area :

Enrichment of ammonium by the degradation of benzalkonium chloride by bacteria



Microbial diversity

Quantitative PCR

Area	16S rRNA (cp/m ²)	rbcL (cp/m ²)	ITS1 (cp/m ²)
Existing biofilm	$4.0 \cdot 10^5 \pm 5.6 \cdot 10^4$	$1.6 \cdot 10^4 \pm 6.6 \cdot 10^2$	$3.3 \cdot 10^{10}$
1 year-Control	$1.6 \cdot 10^5 \pm 9.2 \cdot 10^3$	$2.7 \cdot 10^3 \pm 6.2 \cdot 10^1$	$5.4 \cdot 10^8 \pm 6.0 \cdot 10^7$
PR	$5.5 \cdot 10^5 \pm 5.9 \cdot 10^4$		$1.5 \cdot 10^7 \pm 9.2 \cdot 10^5$
POM-IL1 prev	$4.0 \cdot 10^5 \pm 6.6 \cdot 10^3$		
POM-IL1 cur	$7.6 \cdot 10^5 \pm 1.3 \cdot 10^4$		

Quantification on controls
and PR
Better efficiency of POM-ILs
against fungi

More bacteria on biocidal
areas than on 1-year control

Quantification only on controls
Efficiency of biocides against phototrophs

Lack of competition with other
microorganisms

Conclusions and perspectives

Biocides

- Efficiency of biocides in preventive method against phototrophs
- Preventol RI80 needs a higher concentration and dose to be competitive
- All biocides have a weaker efficiency against bacteria
- POM-ILs are more efficient against fungi than Preventol
- *Fusarium* grows only on Preventol RI80 area: suppose a degradation of the biocide by bacteria

Management of lights

- Changing the pathway of visitors: no modern artwork in bas-relief rooms
- Testing wavelengths of lights to limit the photosynthesis

Thank you for your attention

