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Assessment of low magnetic electric fields on drinking water biofilm formation

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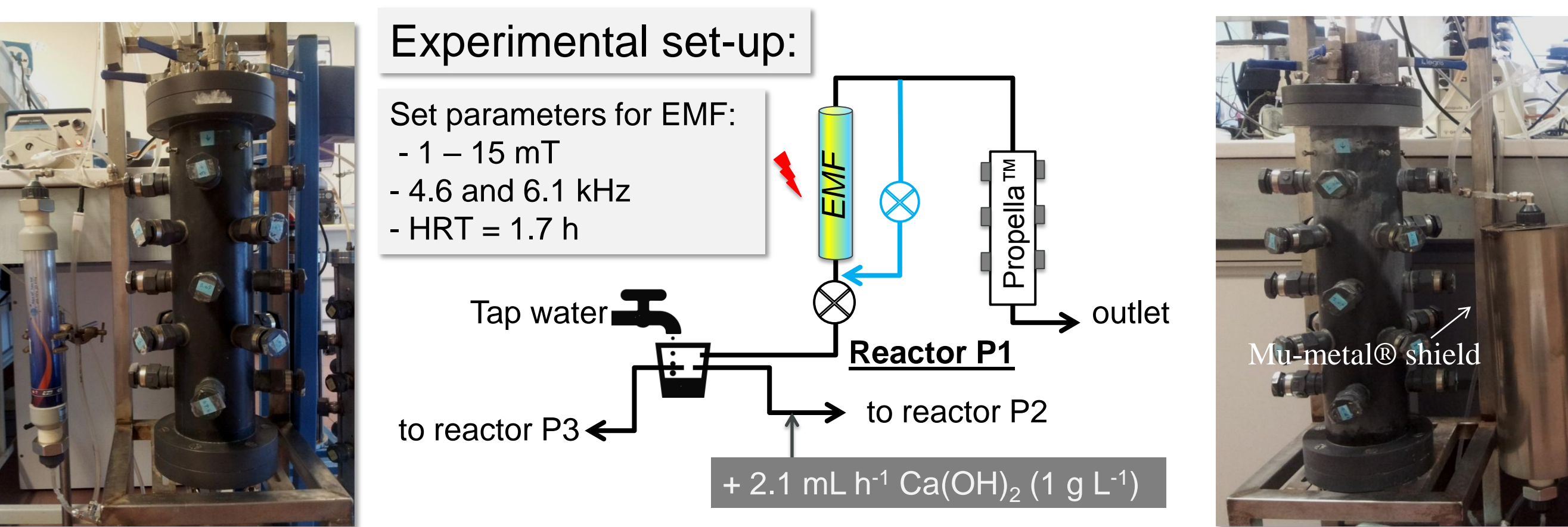
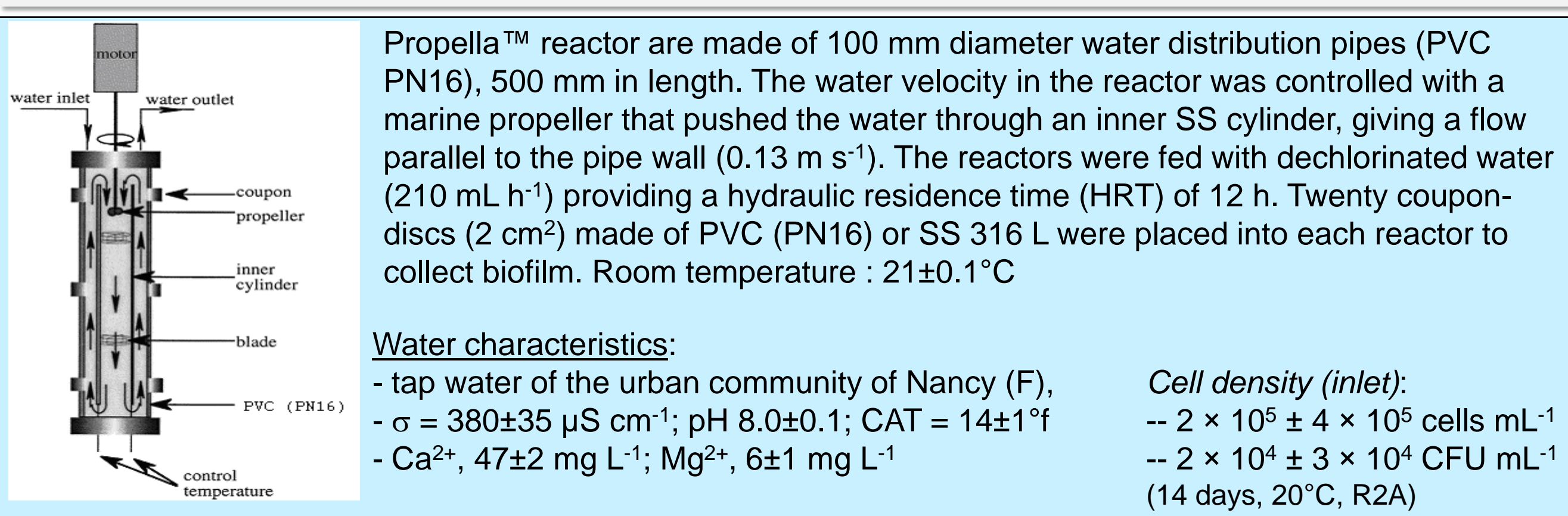


INTRODUCTION

Preservation of the microbial quality of drinking and biofilm activity mitigation in drinking water distribution systems represents major objectives for water suppliers and water authorities. Although, a disinfectant residual assists in reducing bacteria growth in the bulk water, its efficiency against biofilm is very limited. Therefore, solutions to better control the biofilm accumulation/activity remain still relevant and for example **low magnetic electric field** used first for limiting carbonate precipitation could be one of these solutions. Only the effects of low intensity EMF with high frequencies have been recently reviewed [1]. Few studies have been carried out with low-intensity electromagnetic fields with low frequencies (EMF_{lowHz}) (50 Hz) and “extremely low-intensity” to “low-intensity” (from 0.1 mT to 50 mT) on bacterial suspension where the cultivability of pure strains was affected [2, 3]. However, effects of EMF on complex biofilms such those present at the surface of drinking water pipes were not documented. Then, our work aims to **show any effect of EMF_{lowHz} on drinking water biofilms**. To this end, we compared the characteristics of 2 to 3-month old biofilms growing at the surface of PVC or stainless steel coupons in Propella™ reactors. We tested several hypothesis and variables related to EMF effect: (i) it could affect biomass attachment and accumulation of **native biofilm** on clean material (“preventive effect”), (ii) it could remove **mature biofilms** (2 to 3-months old), (“curative effect”), (iii) its effect could be improved in **oversaturated water with respect to CaCO₃** (“lime water”), (iv) the pipe material, **polyvinyl chloride (PVC) versus stainless steel (SS)** could promote different results.

METHODS

Three Propella™ reactors (P1, P2 and P3) were used in parallel:
 - P1 and P3 were **alternatively used as Control (EMF generator off) or as Assay** between each series to remove any “reactor effect”.
 - P2 was used only with lime water

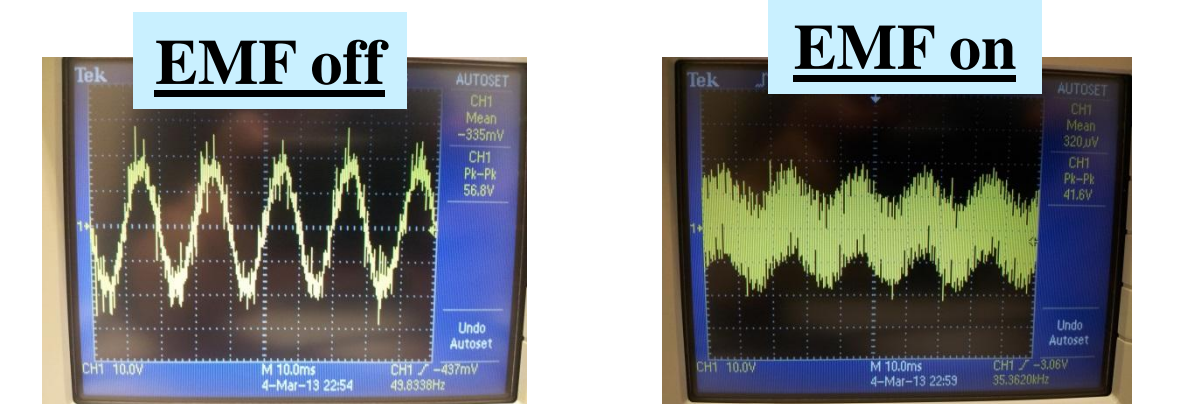
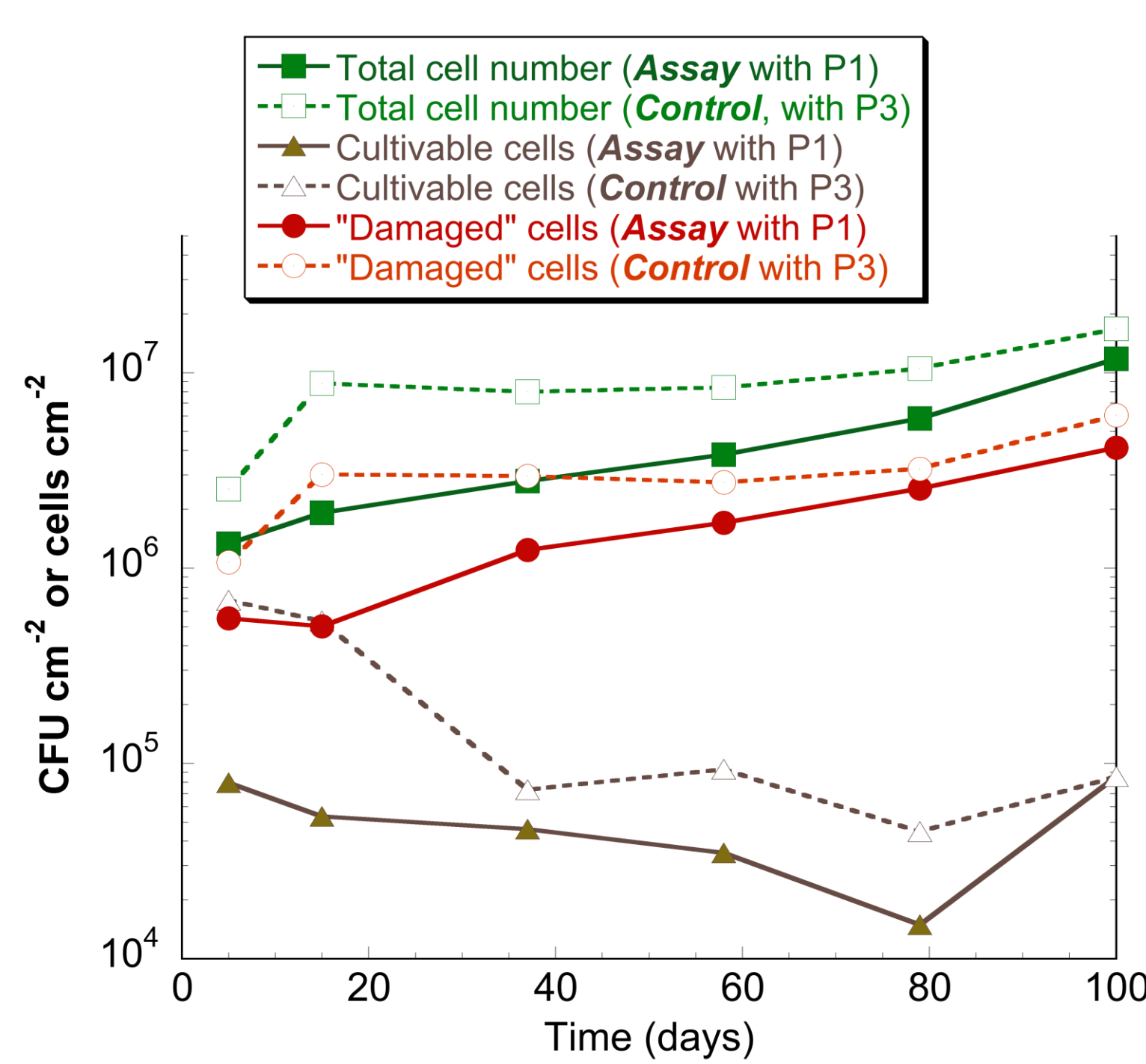


Analyses:
 Biofilm cell count: CFU, total cell number (Sybr Green II), membrane-damaged cells (propidium iodide), chlorine susceptibility [4], solid analysis (Raman spectroscopy, SEM).
 The Mu-metal layer is a nickel-iron alloy limiting magnetic field dispersion.

RESULTS - 1

First series with P1 as Assay (+ EMF) and P3 as Control (no EMF)

(example on SS coupons with slightly aggressive tap water, preventive treatment on biofilm in development)



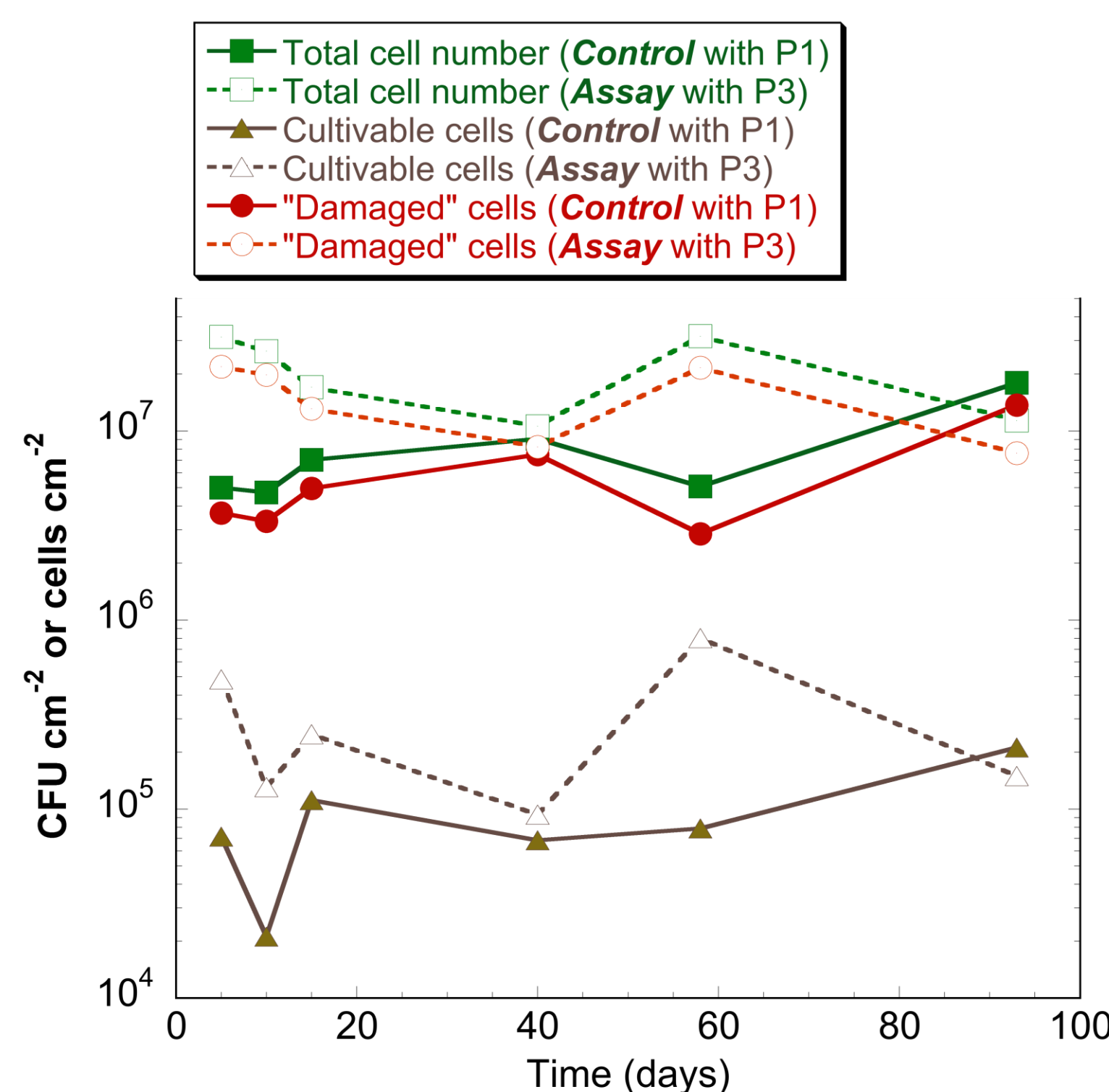
Frequencies and intensity of EMF in water out:
 On Reactor P1, the signal at left is the 50 Hz frequency of the network, at right, signal when the EMF is on.

Lower apparent bacterial colonization on reactor with EMF treatment

EMF would reduce the bacterial colonization ?

Second series with P3 as Assay (+ EMF) and P1 as Control (no EMF)

(example on SS coupons with slightly aggressive tap water, preventive treatment on biofilm in development)



Inversion of the reactor assignment:
 P1 becomes Control (no EMF)
 P2 becomes Assay (with EMF)

Higher apparent bacterial colonization on reactor with EMF treatment !

No significant effect of EMF on bacterial colonization !

The differences observed were mainly due to a “reactor effect” (reactor P3 allow a slightly higher bacterial colonization than reactor P1)

→ Tendencies were the same with PVC coupons and with curative treatment (on “mature biofilms”)

RESULTS - 2

- Preventive and curative effects of EMF with oversaturated water

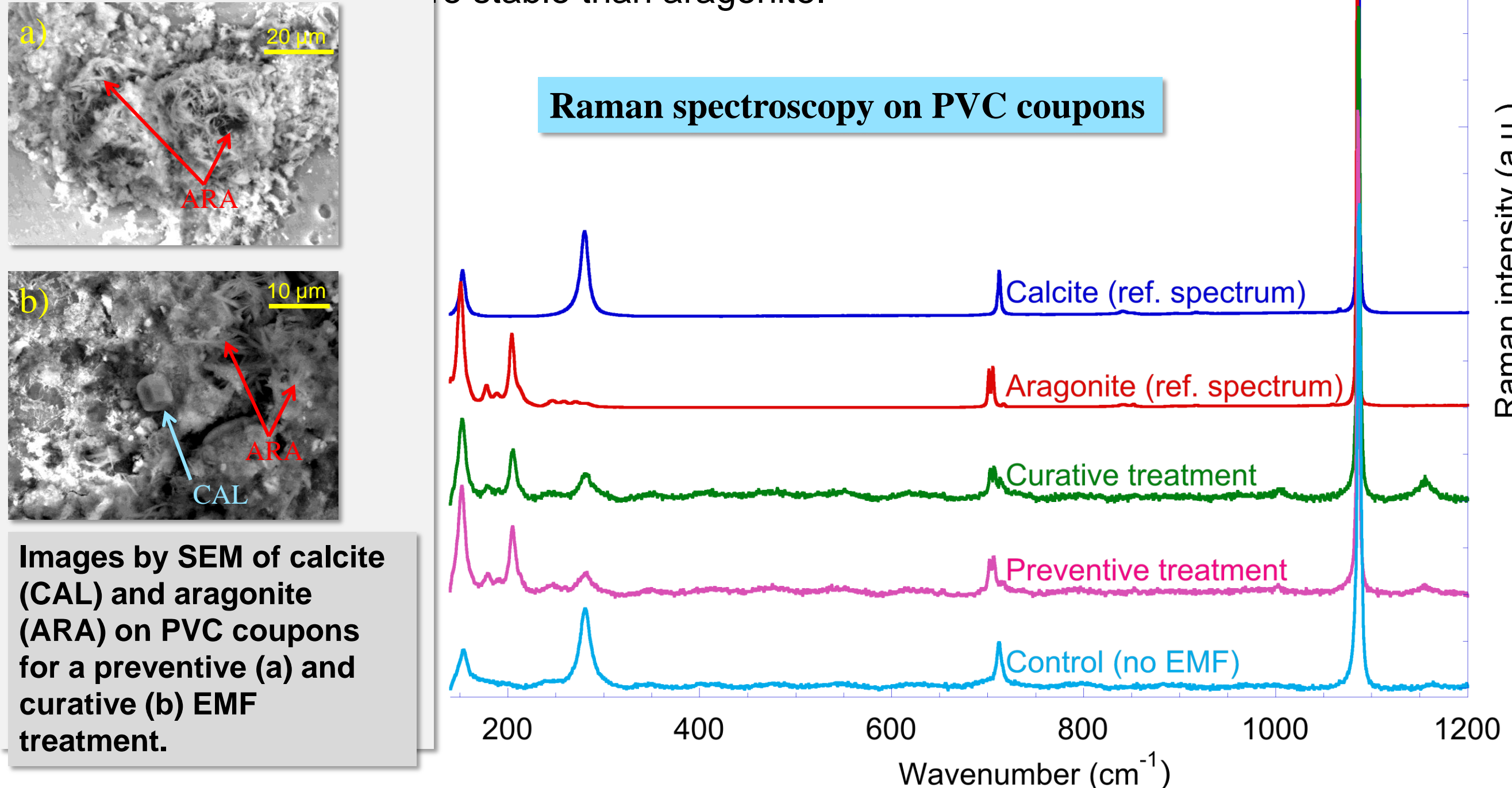
Analyses of biofilms (mature or native) exposed to EMF in an oversaturated water (with respect to CaCO₃) in Reactor P2, didn't show any significant effect on biofilm, on SS and PVC coupons as well, compared to reactor P1 or P3 (Control without EMF and without oversaturated water) or controlled to reactor P2 for period without EMF.

EMF influenced significantly the mineralogy (carbonate polymorphs) as shown by Raman spectroscopy and SEM of the coupon surfaces:

- calcite dominate without EMF

- aragonite dominate with EMF

Calcite is known to be more stable than aragonite.



- Vulnerability to chlorine of biofilms exposed to EMF: no significant effect

CONCLUSIONS

EMF_{low frequencies} effect (biofilm growing on PVC or SS):

→ **No measurable effect** of preventive treatment and curative treatment (native and mature biofilms, respectively) in:

- slightly aggressive water,
- oversaturated drinking water.

→ **No measurable effect** on biofilm susceptibility to chlorine (slightly aggressive water),

→ **Significant effect** on the carbonate polymorphs formed (oversaturated water): mainly **aragonite** (with EMF) rather than calcite (no EMF).

References: [1] Torgomyan H. and Trchounian A. (2013). Bactericidal effects of low-intensity extremely high frequency electromagnetic field: an overview with phenomenon, mechanisms, targets and consequences. *Critical Reviews in Microbiology* 39(1), 102-111; [2] Fojt L., L. Strasak, V. Vetterl, J. Smarda (2004). Comparison of the low-frequencies magnetic field effects on bacteria *Escherichia coli*, *Leclercia adecarboxylata* and *Staphylococcus aureus*. *Bioelectrochemistry* 63, 337-341; [3] Di Campi E., S. Di Bartolomeo, R. Grande, M. Di Giulio, L. Cellini (2010). Effects of extremely low-frequency electromagnetic fields on *Helicobacter pylori* biofilm. *Current Microbiology* 60, 412-418; [4] Mathieu L., Bertrand I., Abe Y., Angel E., Block J.-C., Skali-Lami S., Francius G. (2014). Drinking water biofilm cohesiveness changes under chlorination or hydrodynamic stress. *Water Research* 55, 175-184.