intersol 2025
24e Edition
Congrès-Exposition International sur les Sols, les Sédiments et l'Eau
International Conference-Exhibition on Soils, Sediments and Water

SARPI Remediation

Soil and GroundWater Treatment Pilots

PFAS Chemical and biological reduction:

Reasons to believe ?

27 mars 2025. Sofie Herssens, Jean-Baptiste PARA, Boris DEVIC-BASSAGET, directeur technique (speaker)

upds
Union des Professionnels de la Dépollution des Sites.

SARPI VEOLIA

Summary

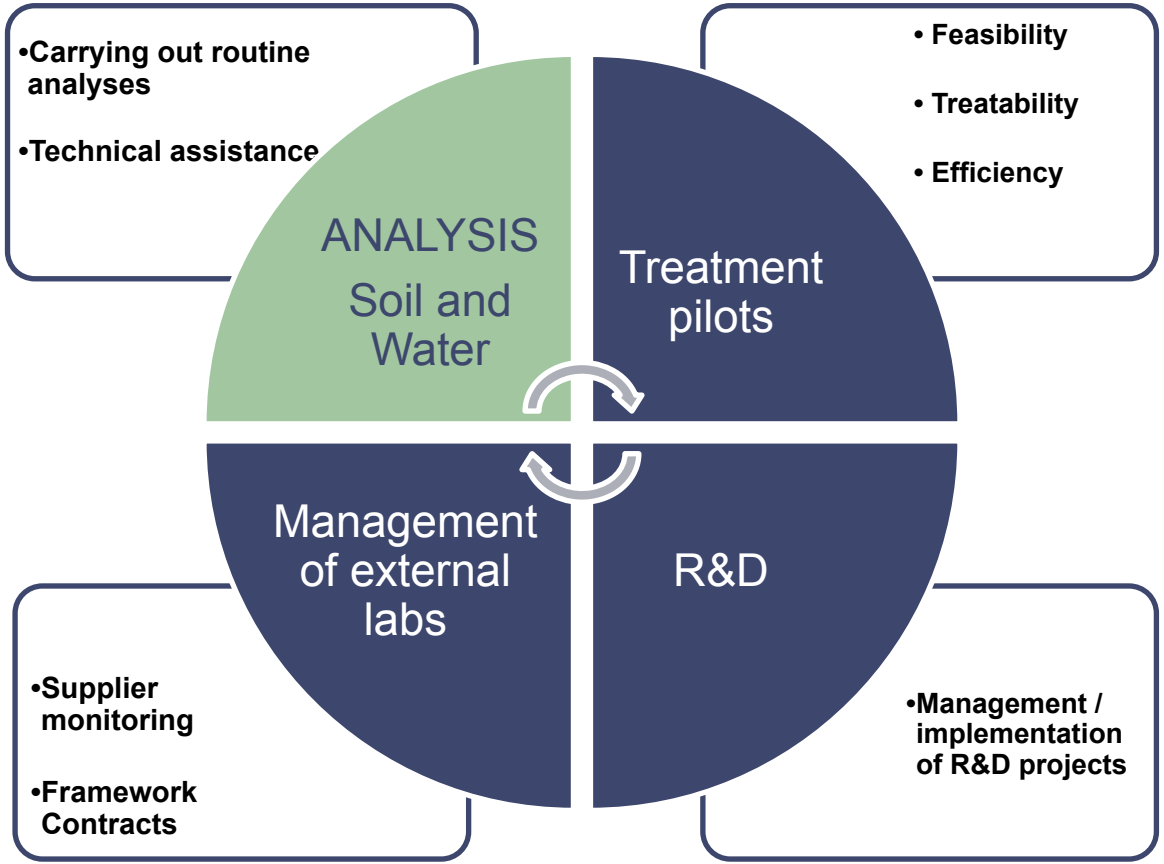
1 **Pilot tests Sarpi Remediation**

2 **REX ISBR/ISCR on PFAS**

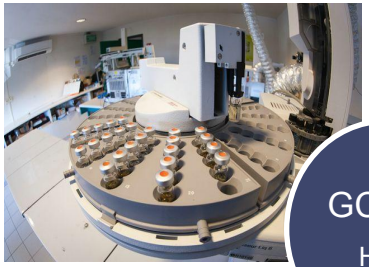
1 - The Sarpi Remediation laboratory

PILOT TESTS

Sarpi Remediation Laboratory



Sarpi Remediation Laboratory



GC/FID
HCT

GC/MS
hs BTEX,
COHV…

Specific
analyzers

ICP/MS
Heavy
metals

GC/MS
liquid
PAH, PCB,
POC…

Sarpi Remediation Laboratory

Sarpi Remediation Laboratory

PFAS

No.	LABORATORY PILOT	DECONTAMINATION TECHNIQUE CONCERNED
1	BIO aerobic reactivation test - SOL	Biotertre (C325b) / Andain (C325b) / Landfarming (C325d) / Bioventing (C315b)
2	BIO aerobic/anaerobic reactivation test - NAPPE ?	BIONAPPE® aerobic (C315a) or anaerobic (C315c)
3	Biodegradation kinetics - SOIL	Biotertre (C325b) / Andain (C325b)/ Landfarming (C325d) / Bioventing
4	Biodegradation kinetics - NAPPE	BIONAPPE® aerobic (C315a) or anaerobic (C315c)
5	Choice of oxidant (DSO, MOT, etc.)	In situ oxidation (C313b) / on site (C323b)
6	Oxidation test (1 oxidant, 3 concentrations)	In situ oxidation (C313b)
7	In situ reduction test by zero iron (T1/2…) ?	Reactive barrier (C316a)
8	Photolysis / photo oxidation test	Water treatment by H2O2 UV (C333b)
9	Study of metallic pollution of a soil (speciation)	Any treatment of metal pollution
10	Study of the distribution of a pollutant	Particle size sorting (C3221b) / screening / washing of Soils(cycling/attrition/backwashing)
11	Characterization of water (carbonate, iron, H2S risk assessment)	Pumping and Treatment (C311d) / Stripping (C333a) / ETP (C311b)
12	Column Sol Washing Test	In situ washing (C313a) - Soil flushing
13	Stripping tests	Water treatment (C333a) / sparging (C311c)
14	Water treatment on filter media (isothermal test or drilling)	Water treatment on resin (C334d), other media (C334b) or CA (C333c)
15	Test of volatilization of light pollutants from a soil	Controlled Forced Volatilization (MECALIS® / ROTALIS®)
16	Product sheet/Valorization: Chemistry / crude (HCT, PAH, PCB, BTEX, COHV, Mtx8), Geotechnics (GTR, granulo, VBS, +/- proctor)	On-site recovery Land reuse / Renaturation
17	Stabilization	Stabilization with and without Solidification- short and long term trials
18	Thermal test	Heat treatment in furnace (TDU) / thermal capacity and conductivity / column tests
19	Sludge dehydration	Jar test / Geotube or filter press
20	Neutralization	pH titration tests for all matrices (sludge/acid tars, etc.)
21	SAFF (surface active foam fractionation)	Extraction of PFAS from polluted waters - Concentration
...	Custom testing	Any thermal, biological, physical or chemical treatment.

2 - The Sarpi Remediation laboratory

ISCR / ISBR pilot on soils polluted with PFAS

ISBR - ISCR Pilot Test

Objective = test the dehalogenation by chemical and biological reduction (Proof of concept)

In Situ Biological Reduction (ISBR)

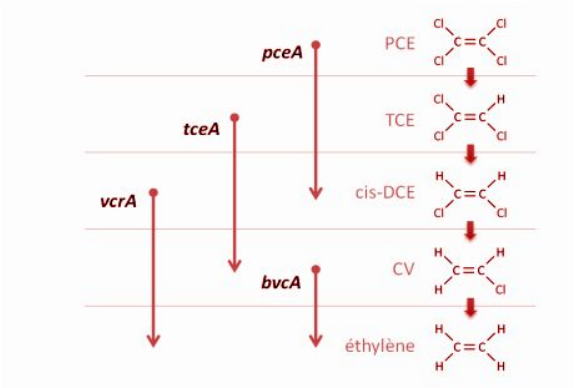
Treated Pollutants

Chlorinated solvents (COHV); CrVI; perchlorates, nitrates,…

Method

Injection of carbonaceous substrates (SC):

- Lactates, easily assimilated (starter)
- Beet molasses /cane
- Vegetable oil (pure or emulsion)



Degradation chain and qPCR

In Situ Chemical Reduction (ISCR)

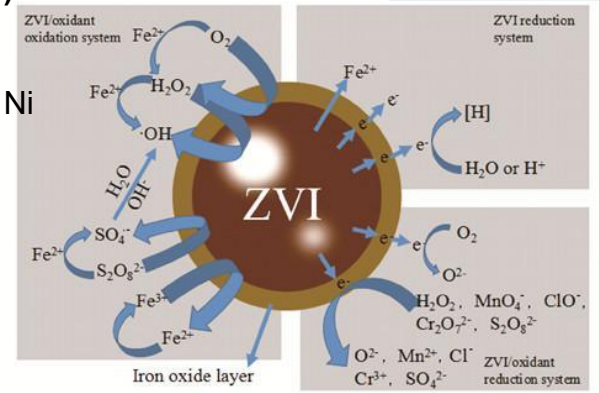
Treated pollutants

Chlorinated solvents (HVOC); CrVI;Chlorates, nitrates, metals (As Ni Cu Hg Pb Mo Sb U…)

Method

Injection of zero valent iron (ZVI):

- Pure (strict ISCR)
- With SC (ISCR+ISBR)
- With SC + Sulphates ⇒sulphate reduction



$$C_X Cl_n H_Y + nFe^0 + nH_2 0 \Rightarrow C_X H_{Y+n} + nCl^- + nFe^{2+} + nOH^-$$

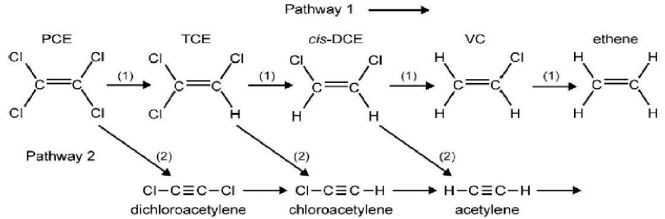


Figure 4-8. Pathways for (1) biotic transformation of chlorinated ethenes and (2) abiotic transformation by iron monosulfide. *Source:* AFCEE 2008, modified from Butler and Hayes

ISBR - ISCR Pilot Test

N° test	Conditions	Typology
E0	control in slurry with water (3 sites CH+FR)	Control
E1	E0 + 1% soil mass of carbon source (50% molasses + 50% soybean oil)	ISBR Anaerobic
E2	E0 + 2% iron 80µm + HCl activation	“strict” ISCR ZVI injection
E3	E0 + 2% CaSO4 + 1% carbon source (molasses 50% + soybean oil 50%)	ISBR + sulfate reduction
E4	E0 + 1% carbon source (molasses 50% + soybean oil 50%) + 2% of Iron 80 µm	ISBR + ISCR
E5	E0+ 2% CaSO4 + 2% of Iron 80 µm	ISCR + sulfate reduction
E6	E0+ 2% CaSO4 + 1% carbon source (molasses 50% + soybean oil 50%) + 2% of Iron 80 µm	ISCR + ISBR + Sulfate reduction

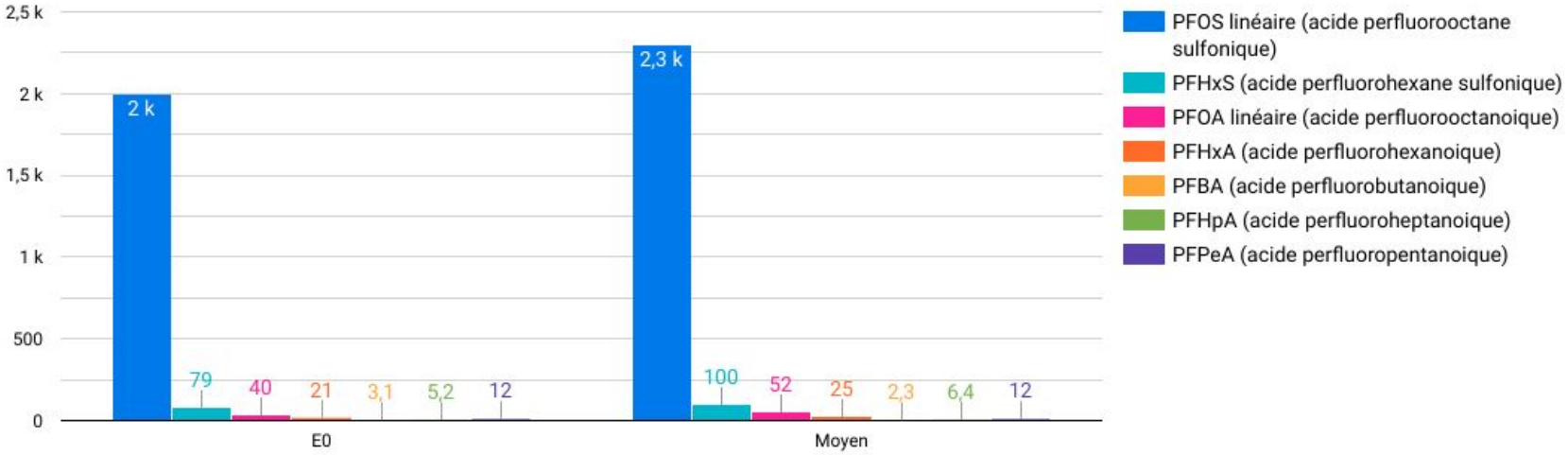
E0: Soil to be tested

Slurrying

E0 E2

ISBR - ISCR Pilot Test

Control (November 2023)



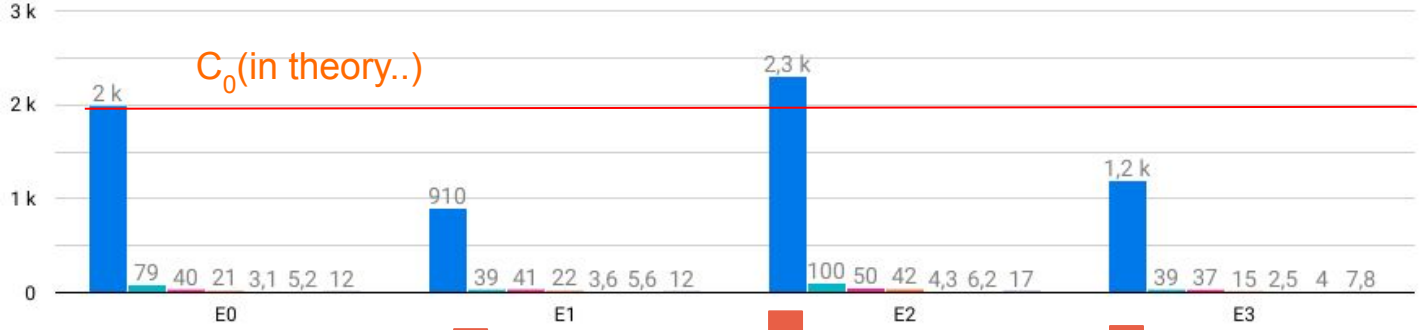
PFAS:
PFOS 91% / 1700-2000 µg/kg DM
PFHxS 3.6% / 75-79 µg/kg MS
PFOA 1.8% / 37-40 µg/kg MS
Others: 4%: PFHxA, PFBA, PFHpA, PFPeA, PFPeS, PFHpS, PFNS…

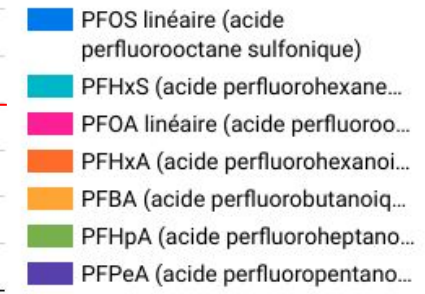
! No TOPA start of test

ISBR - ISCR Pilot Test

Evolution in 156 days (November 23 → April 24)

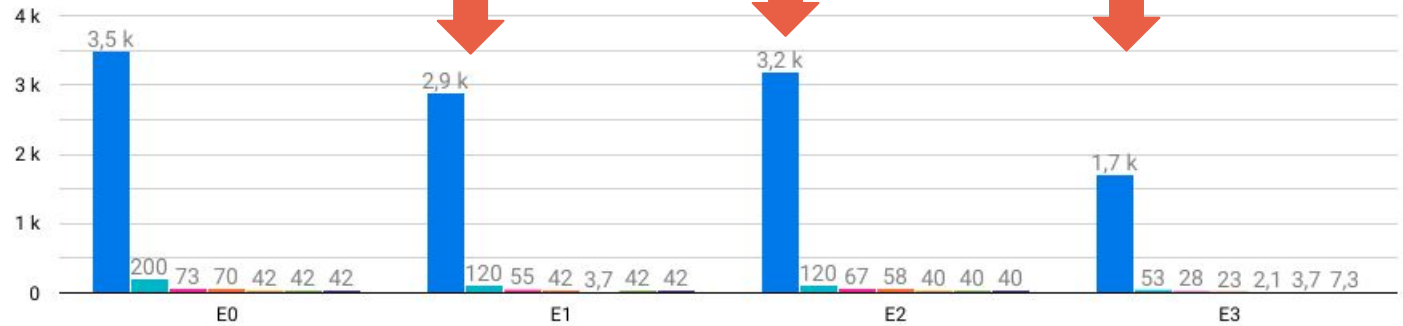
Control Start =T0

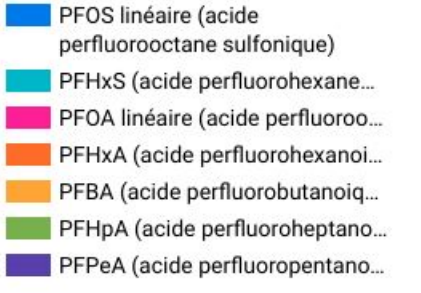




Final = T0+156 J

???

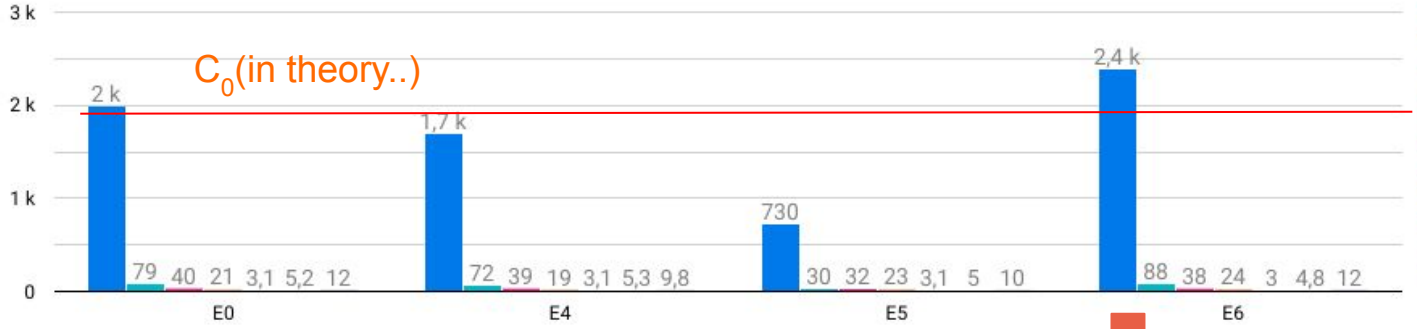


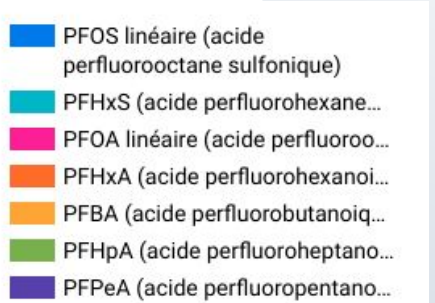


ISBR - ISCR Pilot Test

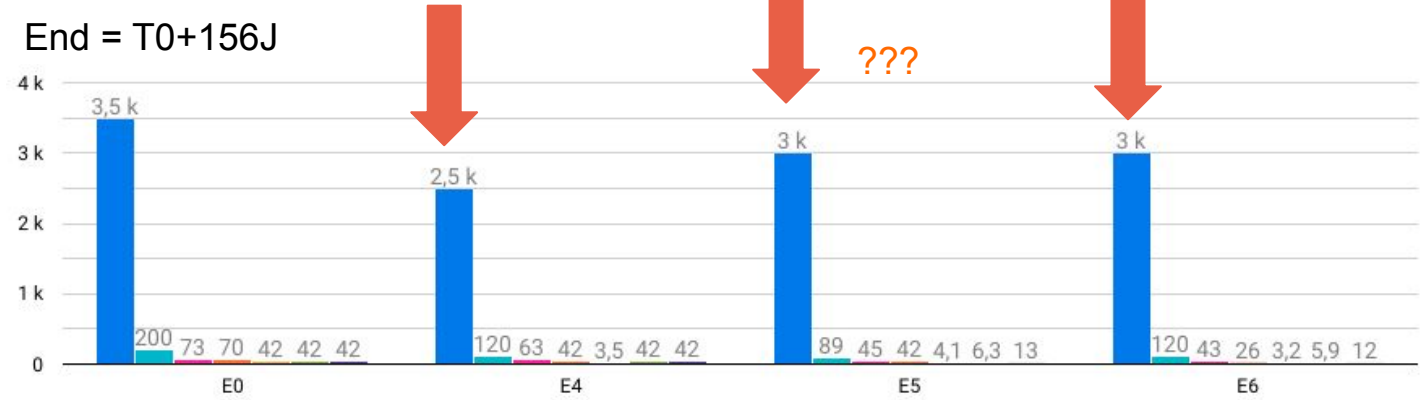
Evolution in 156 days (November 23 → April 24)

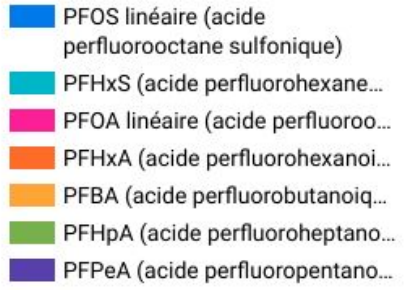
Start =T0





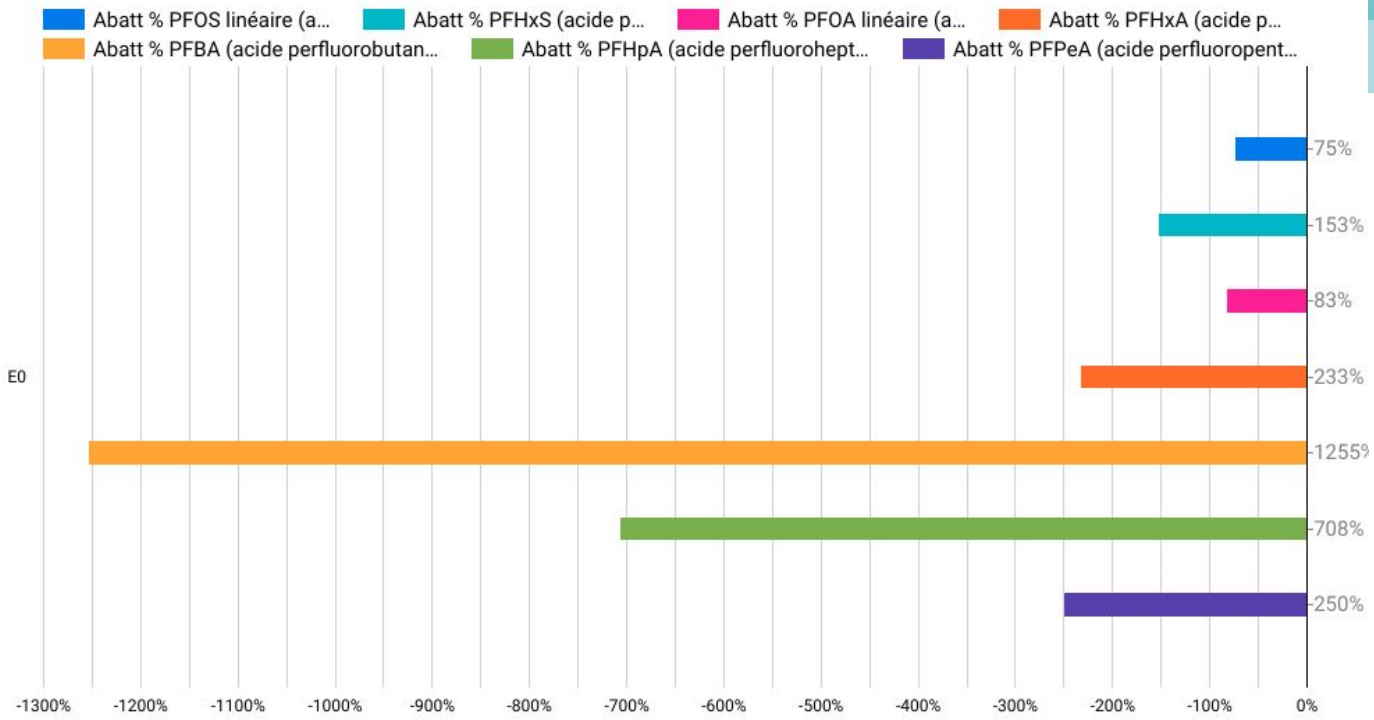
End = T0+156J





ISBR - ISCR Pilot Test

Evolution in 156 days (November 23 → April 24) - Control



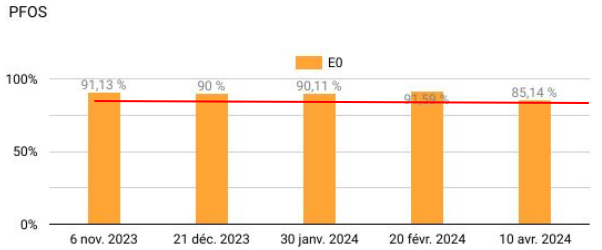
Representativeness of analysis?

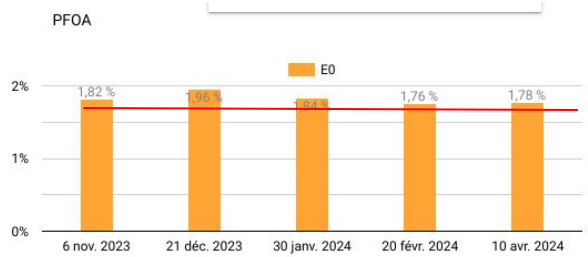
Production of PFAS on Control (same as ISCO oxidation - no TOPA) ?

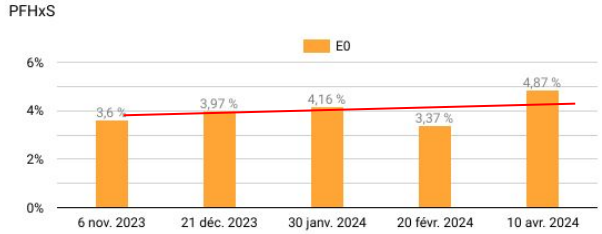
⇒ Qualitative approach in Repartition in % = $C_xF_yS_{0-1}O_{2-3}H$ / sum of PFAS

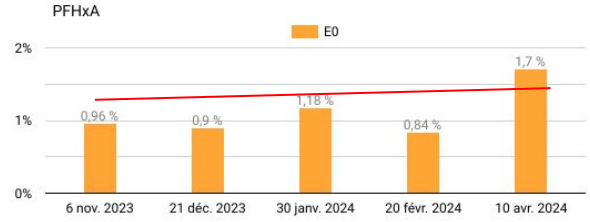
ISBR - ISCR Pilot Test

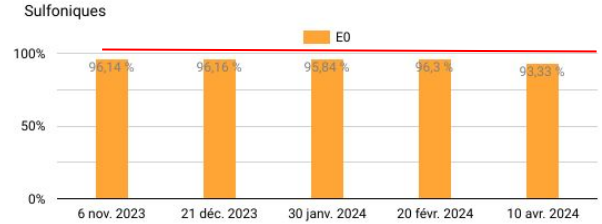
Control (156 days)

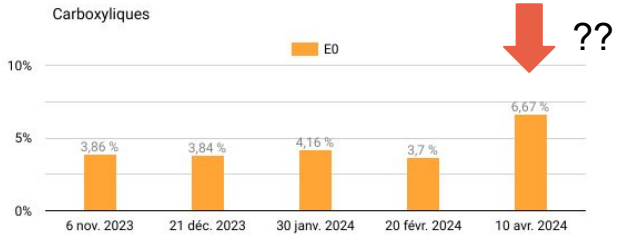










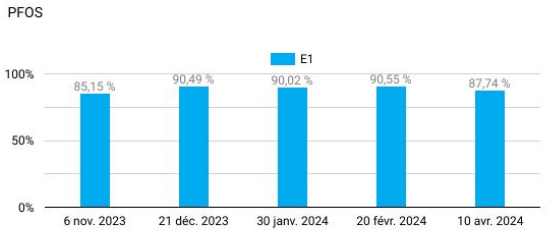


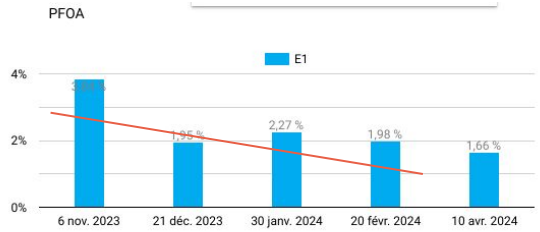
Without uncertainties:

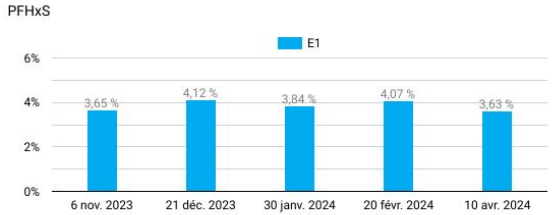
- “Stable”
- Sum of carboxylic acids increases (including PFHxA)

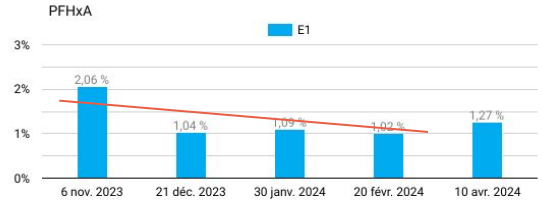
ISBR - ISCR Pilot Test

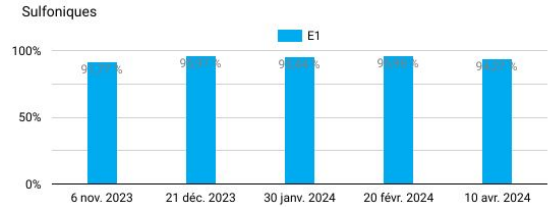
E1 (156 days): Bio Anaerobic ISBR (molasses + oil)

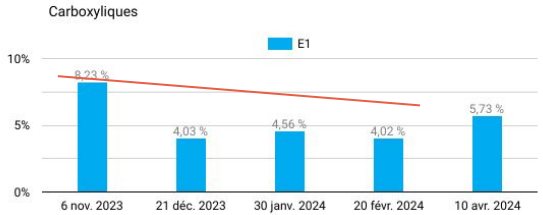








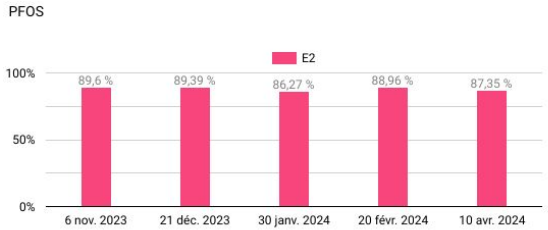


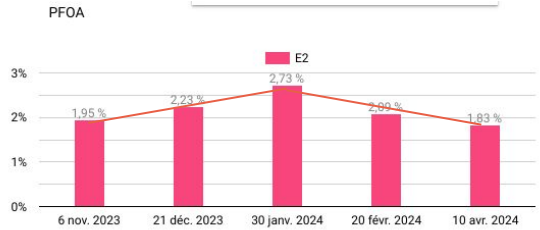


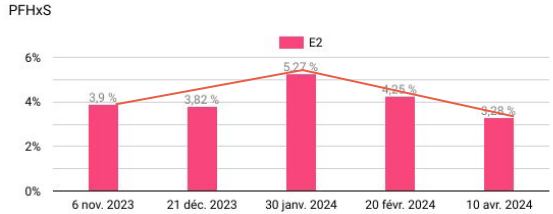
Decrease in carboxylic acids, particularly PFOA, despite low load

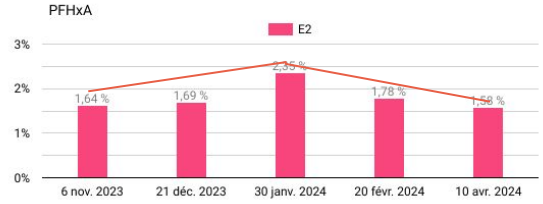
ISBR - ISCR Pilot Test

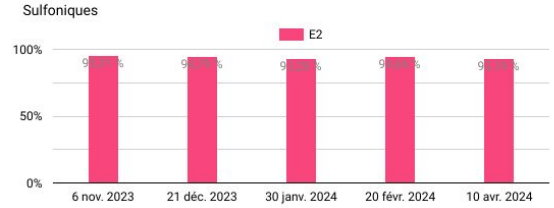
E2 (156 days): Zero activated iron HCl (ISCR “strict”)

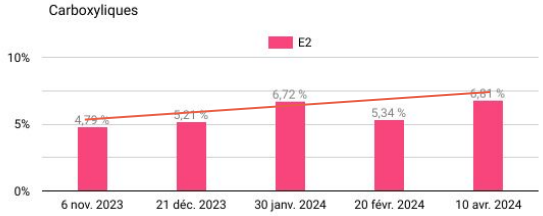










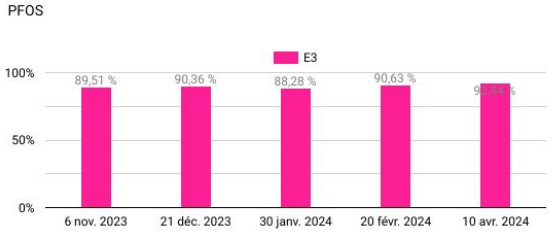


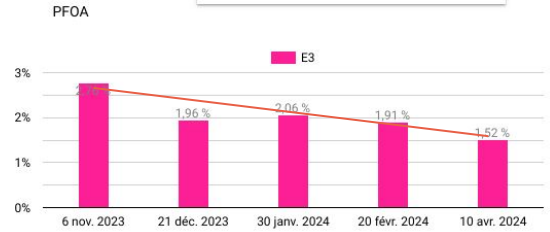
Increase in the middle of the test

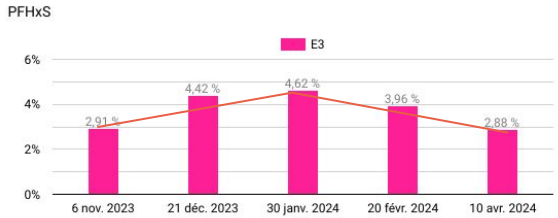
Carboxyls increase (causes PFBA and PFPeA)

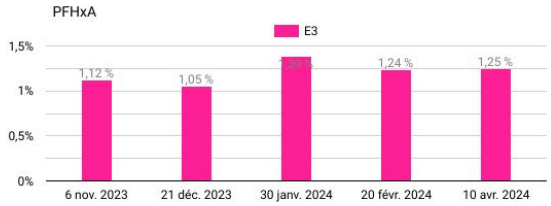
ISBR - ISCR Pilot Test

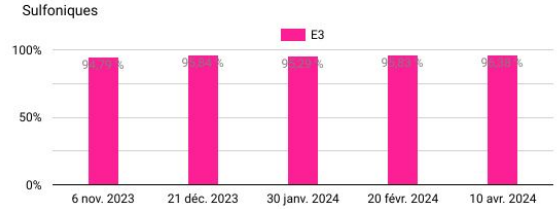
E3 (156 days): Bio Anaerobic ISBR + SR sulfate reduction (molasses + oil + CaSO4)

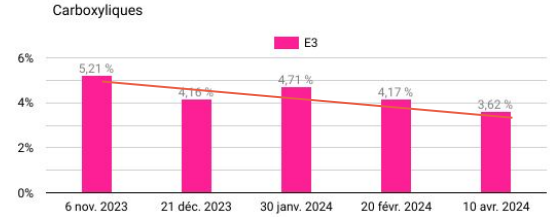








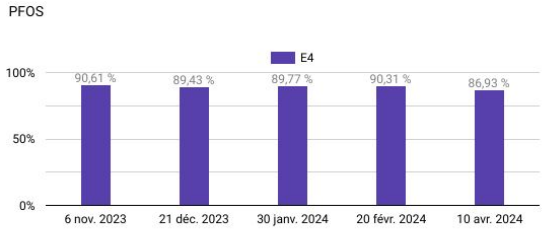


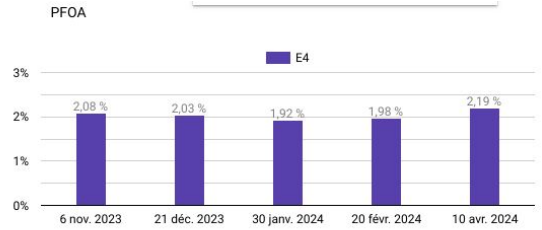


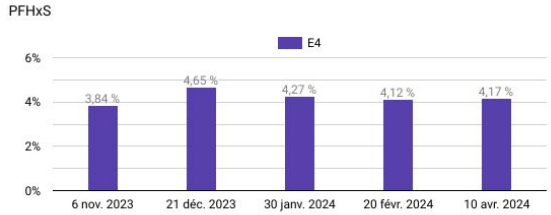
Decrease in carboxylic acids
Constant sulfonic despite temporary increase in PFHSx
No improvement VS ISBR

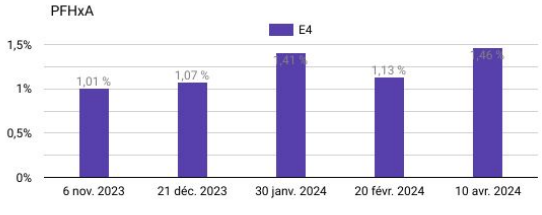
ISBR - ISCR Pilot Test

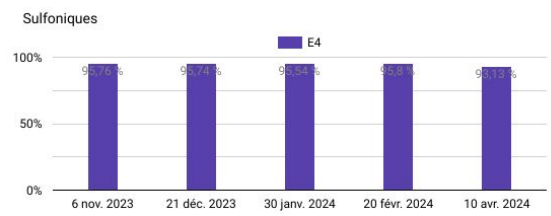
E4 (156 days): Zero iron + bioanaerobic (ISCR+ISBR)

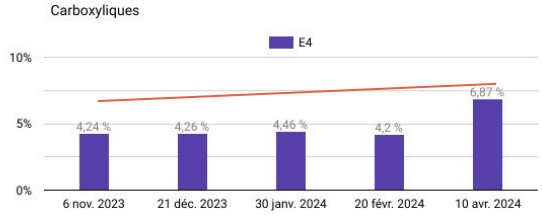












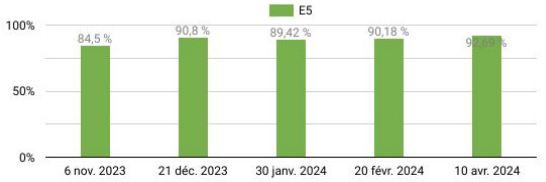
Sulfonic: no action
Carboxylic: growth trend

Inconclusive

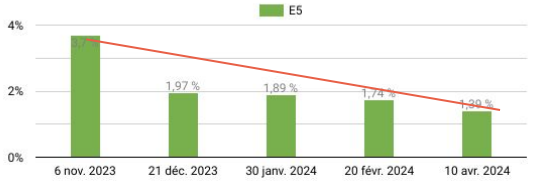
ISBR - ISCR Pilot Test

E5 (156 days): Zerovalent iron + Sulfate reduction (ISCR+SR)

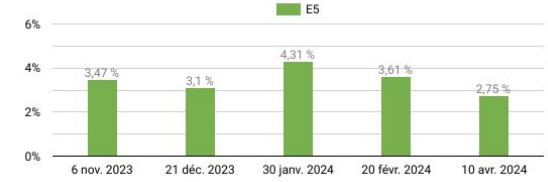
PFOS



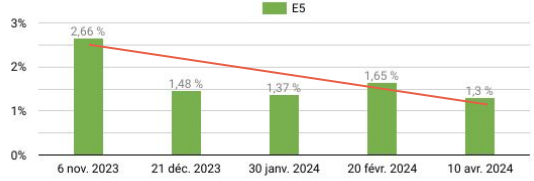
PFOA



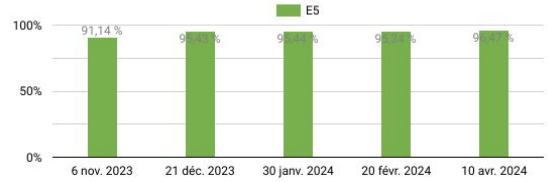
PFHxS



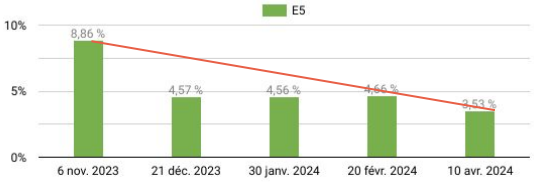
PFHxA



Sulfoniques



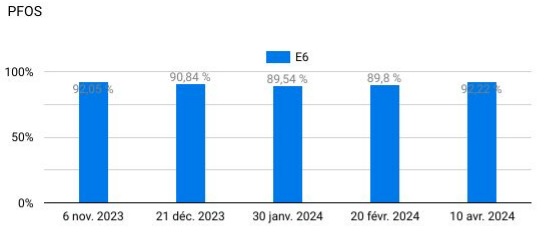
Carboxyliques

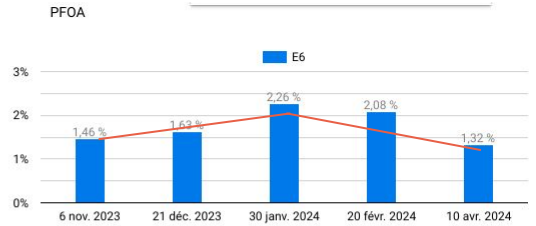


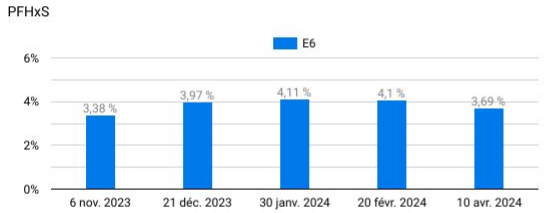
Carboxyls down
but inconsistency vs Control
Low-concentration sulfonic acid

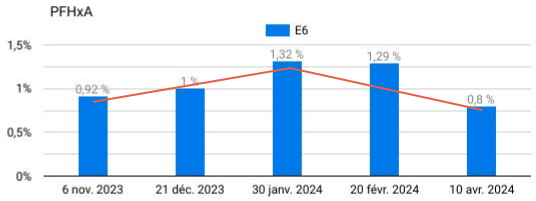
ISBR - ISCR Pilot Test

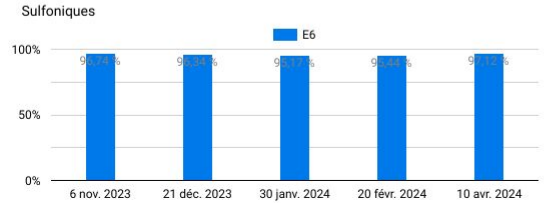
E6 (156 days): Zero iron + Sulfate reduction + Organic (ISCR+ISBR+SR)

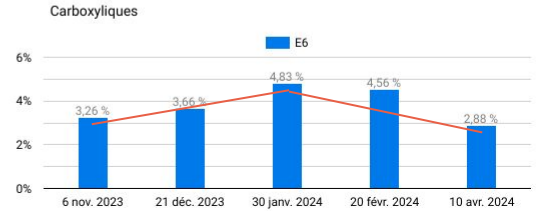












Carboxylic: Increasemomentary
Sulfonic: no effect

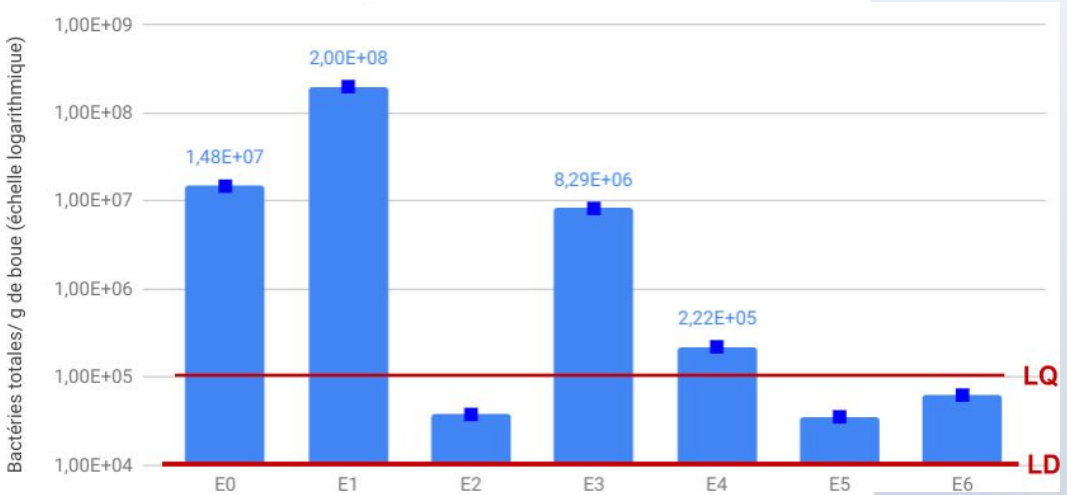
No clear trend

ISBR - ISCR Pilot Test : microbiology

At the end of the tests, after 1 year of storage of the closed test tubes, bacterial population analyses were carried out by the VEOLIA Scientific and Technical Expertise Department.

Protocol:

- A negative extraction control was performed (sterile phosphate buffer solution, PBS 1X)
- DNA assay was performed using the Qubit™ DNA db HS Assay Kit.
- Bacterial quantification is performed by q-PCR targeted on a region of 16S rRNA.
- 16S rRNA qPCR reactions were performed in a reaction mixture containing the following compounds: 2X SsoFast™ EvaGreen® Supermix (Biorad, USA) / primers V3F (CTACGGGAGGCAGCAG) and V3R (TTACCGCGGCTGCTGGCAG) and metagenomic DNA. Each of the extraction triplicates was analyzed in qPCR duplicate.



ISBR - ISCR Pilot Test : microbiology

Name	Treatment	[DNA] ng/µL	Average bacterial concentration in bacteria / g of raw sludge	Comments
Boundaries		Negative control = 0.005	DL = 10^4 / * Non-quantifiable presence	
E0	Control	0.358 (+/- 0.111)	$1{,}48.10^7$	
E1	Anaerobic biodegradation (ISBR)	2,169 (+/- 1,523)	2.10^8	x 10 in organic activity
E2	Strict Chemical Reduction (ISCR)	0.007 (+/- 0.004)	$10^4 < \text{value} < 10^5$ *	Biocidal effect of iron?
E3	Anaerobic biodegradation ISBR + sulfate reduction	0.099 (+/- 0.078)	$8.29.10^6$	Biocidal effect of sulfates?
E4	ISBR + ISCR	0.010 (+/- 0.005)	$2.22.10^5$	Biocidal effect of iron?
E5	ISCR + sulfate reduction	0.031 (+/- 0.046)	$10^4 < \text{value} < 10^5$ *	Biocidal effect of iron?
E6	ISCR + ISBR + Sulfate reduction	0.008 (+/- 0.002)	$10^4 < \text{value} < 10^5$ *	Biocidal effect of iron?

ISBR - ISCR Pilot Test : Conclusion

⇒ Treatment by reduction according to 6 routes during 156 days (biological / chemical / Sulfate reduction and their combination): inconclusive

⇒ Possibility of creation of degradation by-products from precursors: possible (no TopAssay analysis on control sample), but unlikely (PFAS level remained stable within a range of +/- 50%)

⇒ Bacterial inhibition by activated zerovalent iron effective, but even not activated

⇒ Bacteria activated by carbon source, but weakly. No PFAS attack

⇒ Major analytical inconsistency despite using the same laboratory.

⇒ In any case, this study seems to confirm why PFAS are called eternal pollutants

There are other solutions for soil treatment: soil washing / thermopiles / stabilization

To find out more …

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