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

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Mercury in situ remediation by Thermal desorption

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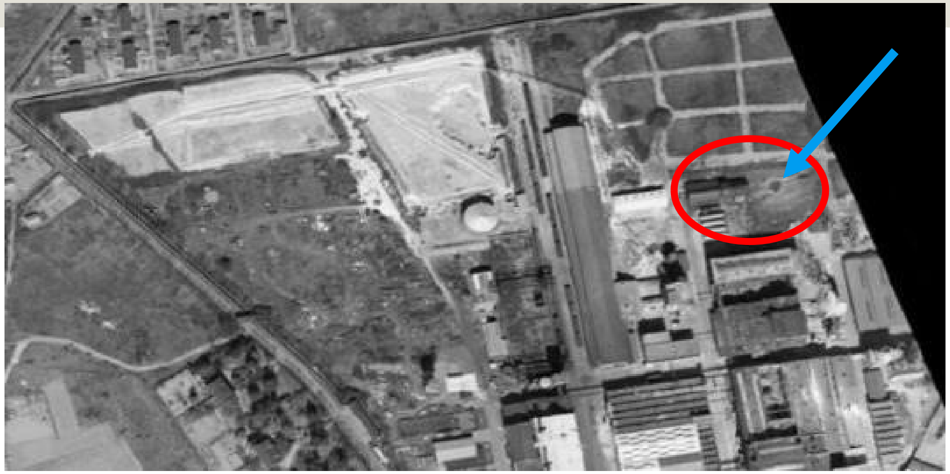
0. Site history
1. Remediation Options
2. Thermal Design
3. In situ thermal Desorption
4. Performance assessment

Site History

- 1922 – Start of site activities on agricultural lands
- 1928 to 1961 – Chemical production using mercury as catalyst → 2 former ovens for regeneration of the catalyst plus probable discharge of mercury-containing waste in a series of sumps
- 1961 – New chemical process without mercury as catalyst
- 2020 – Stop of all the activities and start of the dismantling process
- 2022 - 2023 – Assessment of feasibility of remediation options



1961

1986

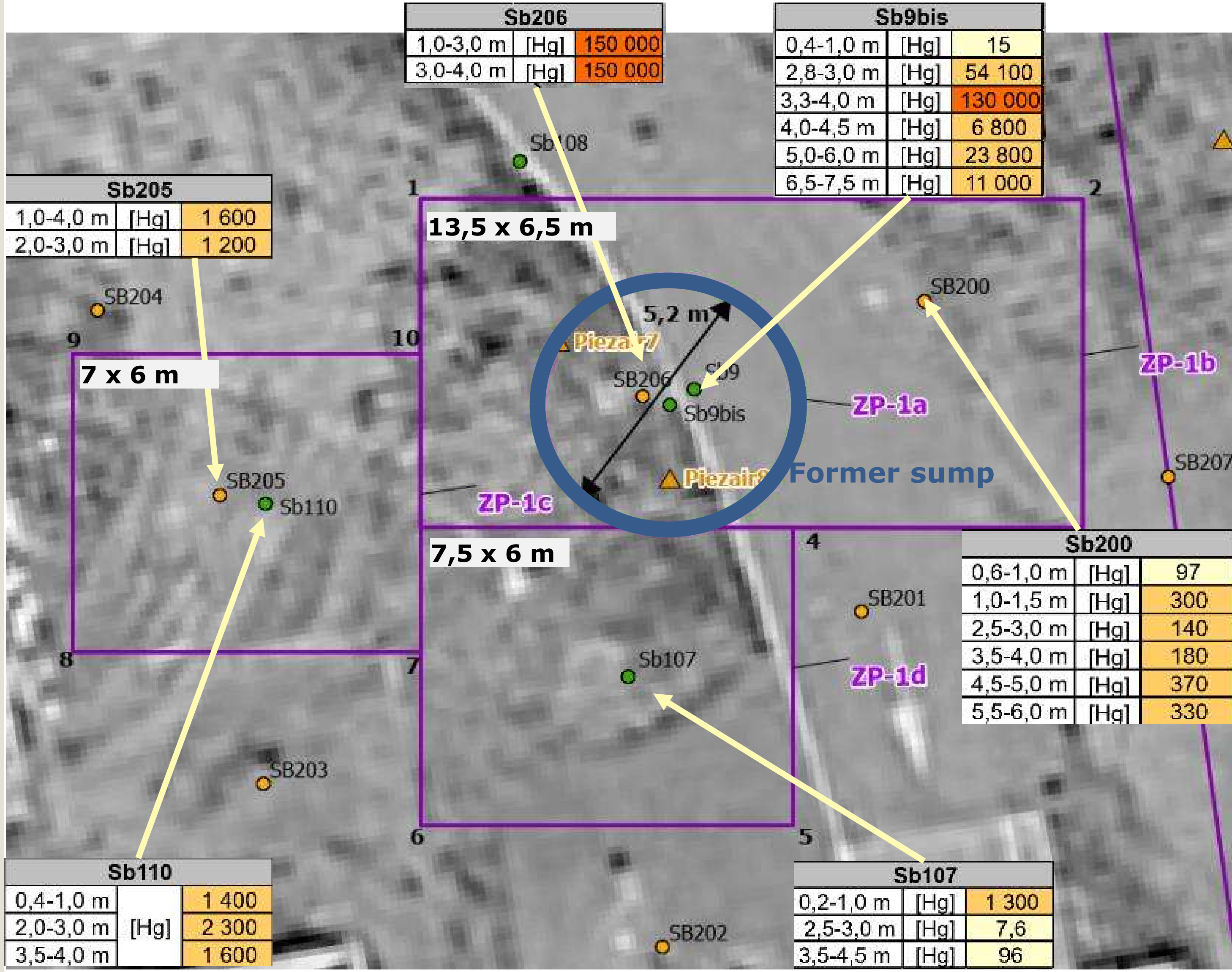
Site conditions

Context : Site Closure

3 phases of investigations between 2020 and 2022

Main findings at the sump area

- Elevated impact of mercury in soil (max = 150,000 mg/kg)
- Presence of mercury beads
- Impact depth (7m or more)
- Limited extension (150 m²)
- 2 tons of mercury estimated in this hotspot (95 % of total mass of mercury on site)
- Groundwater not impacted



Sb206		
1,0-3,0 m	[Hg]	150 000
3,0-4,0 m	[Hg]	150 000

Sb9bis		
0,4-1,0 m	[Hg]	15
2,8-3,0 m	[Hg]	54 100
3,3-4,0 m	[Hg]	130 000
4,0-4,5 m	[Hg]	6 800
5,0-6,0 m	[Hg]	23 800
6,5-7,5 m	[Hg]	11 000

Sb205		
1,0-4,0 m	[Hg]	1 600
2,0-3,0 m	[Hg]	1 200

Sb200		
0,6-1,0 m	[Hg]	97
1,0-1,5 m	[Hg]	300
2,5-3,0 m	[Hg]	140
3,5-4,0 m	[Hg]	180
4,5-5,0 m	[Hg]	370
5,5-6,0 m	[Hg]	330

Sb110		
0,4-1,0 m	[Hg]	1 400
2,0-3,0 m		2 300
3,5-4,0 m		1 600

Sb107		
0,2-1,0 m	[Hg]	1 300
2,5-3,0 m	[Hg]	7,6
3,5-4,5 m	[Hg]	96

Concentration in mg/kg

Soil conditions

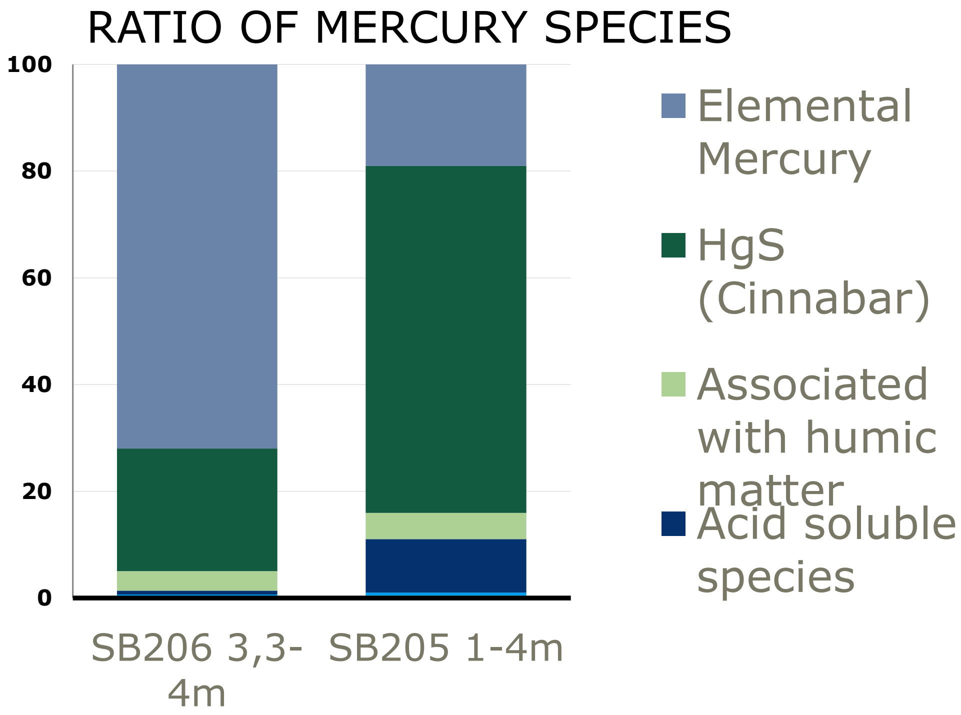
Sandy soil

75 to 90 % of dry matter

Mainly elemental mercury and Cinnabar (HgS)

Rather insoluble mercury

Negligeable concentration of organic mercury



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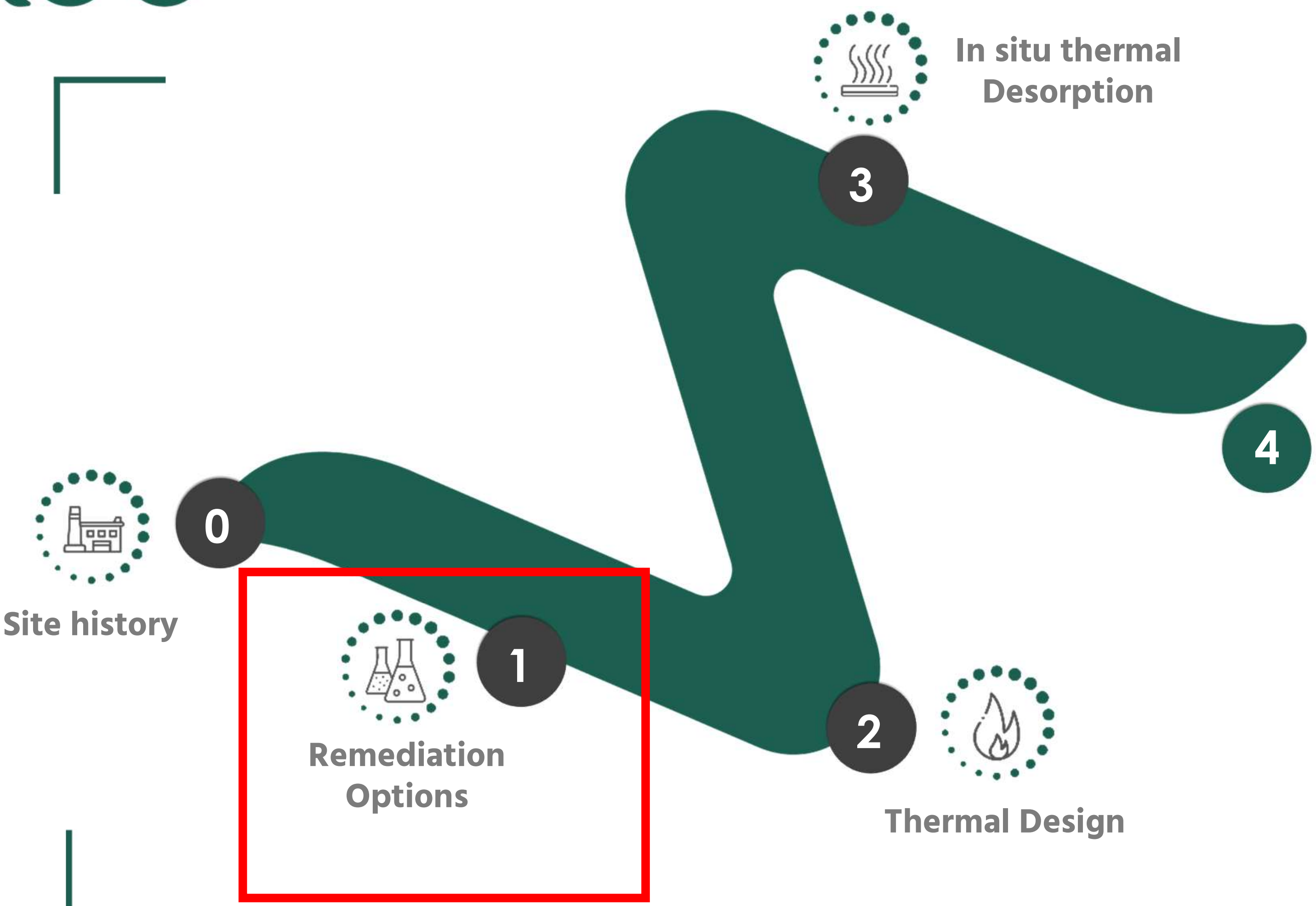
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Remedial action plan

French methodology requirement

→ Removal of the main hotspot

2 remedial options

- In-situ thermal desorption + venting + condensation of elemental mercury + off-site disposal (salt mine)
- Excavation at 10m depth (sheetpile) + on-site pre-treatment (stabilisation) + off-site disposal

Feasibility studies in order to validate these 2 options

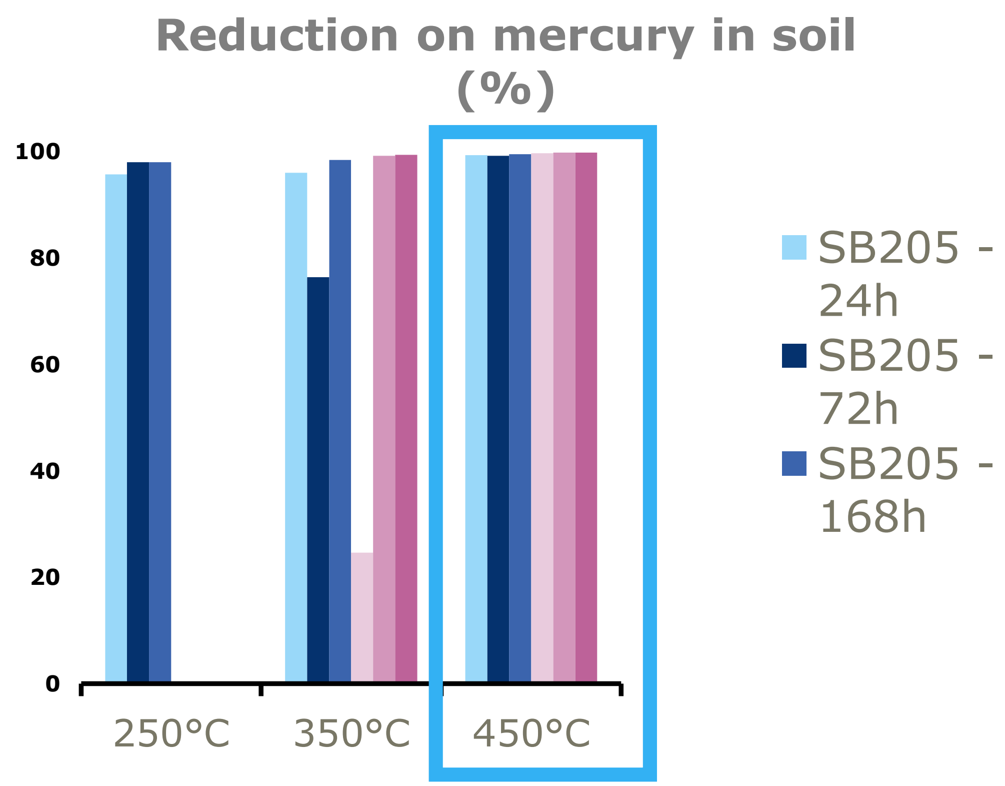
Thermal treatment pilot test results (lab test)

Low soil thermal capacity: between 0.7 and 1.1 kJ/kg/°C
➔ less energy consumption than with standard soil

Great efficiency at 450°C → up to 99.8% of reduction of mercury in soil with only 24h treatment

Equivalent efficiency at 350°C with 7 days of treatment

Nearly 100% of mercury were condensed as elemental mercury, thus almost no additional costs for the treatment of gas emission or water



Why was In-Situ Thermal Desorption chosen?

Favorable site conditions (homogenous sandy soil + restricted area)

Great reduction of hazardous waste in volume (2 t Vs 2,000 t)

Only **few contaminated soil mouvement** during the process → reduction of human exposition and risk of dispersion

Nearly **no need for backfilling material**

How will the project contribute to the UN SDGs

Responsible consumption and production

- low quantity of waste
- low need for backfilling materials and reduced transportation

Good Health and Well-being

- Reduced potential exposure to volatile mercury during the treatment process

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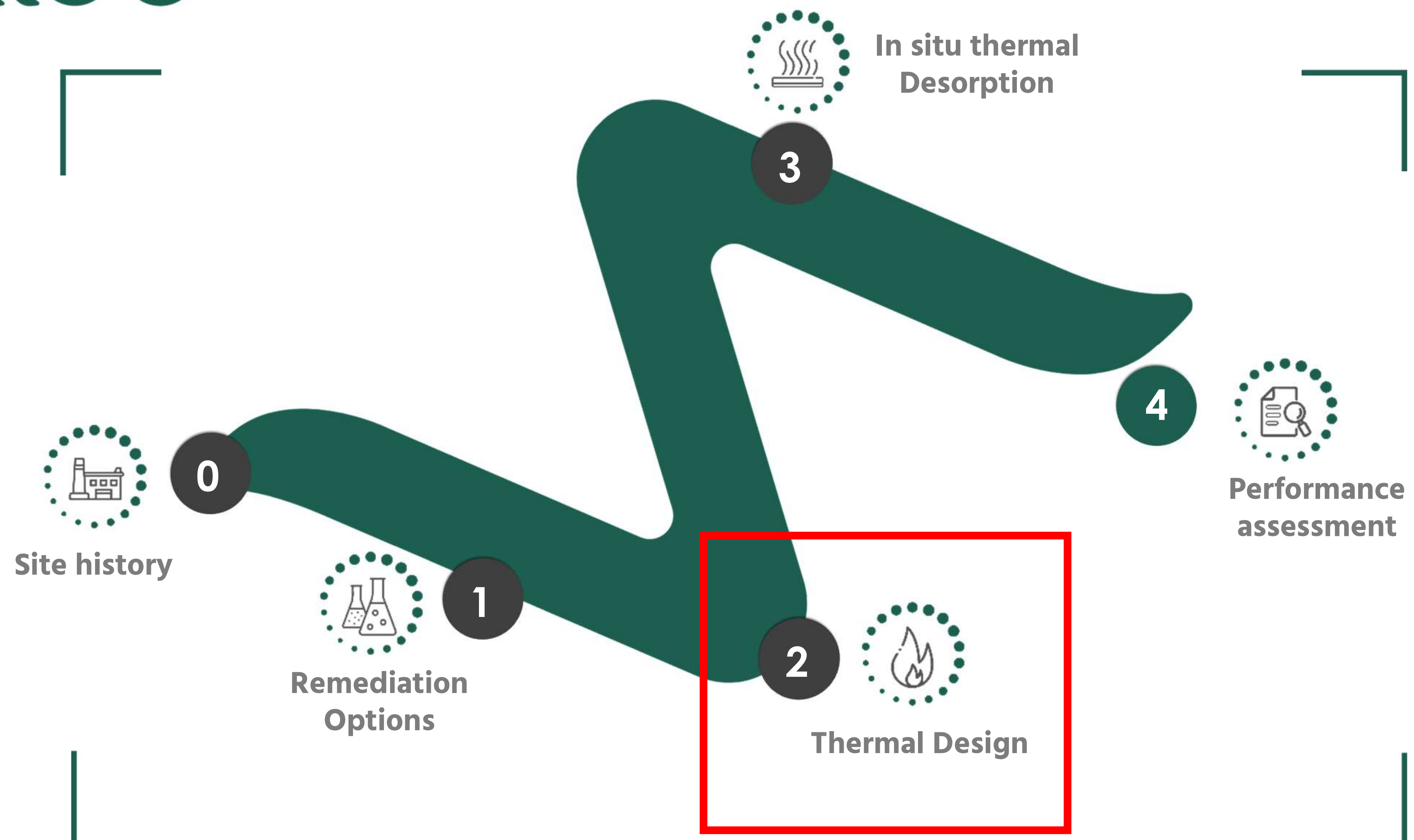
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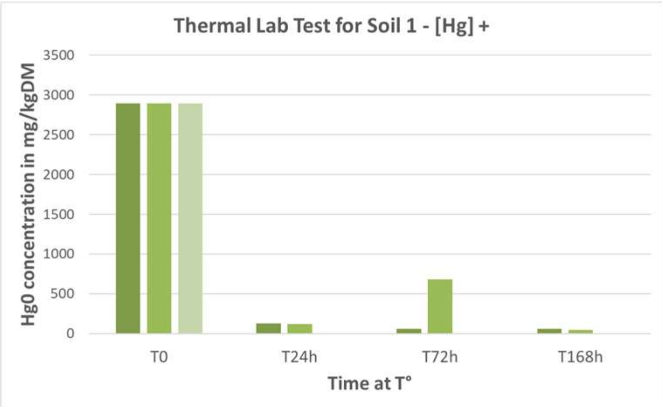
Thermal design : 1st step → Lab Test

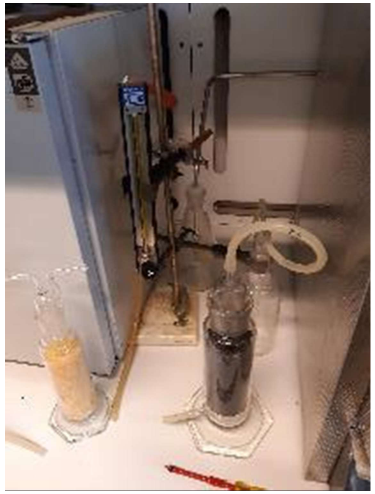
Several couples Temperature / Time are tested (Reminder Hg boiling point (BP) = 356,62 °C)



<u>Medium concentrations</u>:

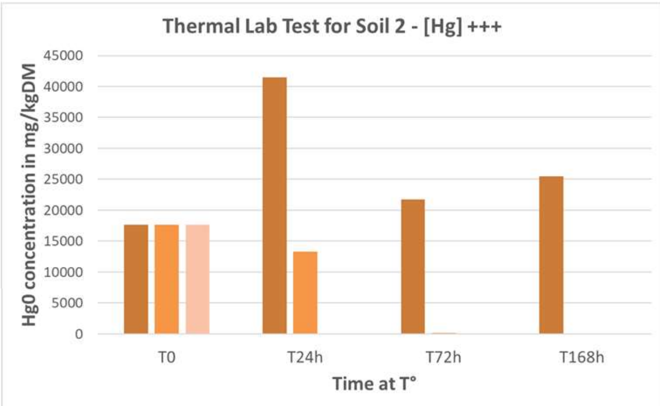
good results even at T°<BP.

At 450°C [Hg] < 15 mg/kgDM after a week.



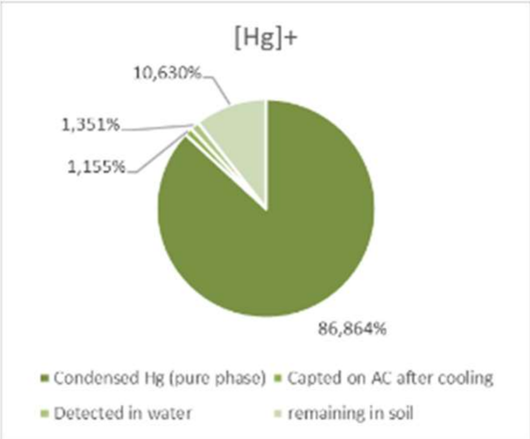
<u>High concentrations</u>:

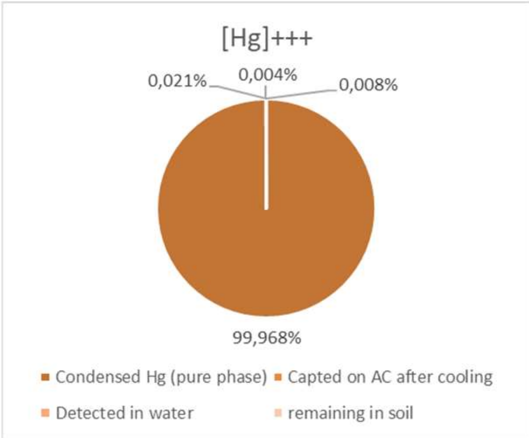
Best results at 450 °C ([Hg]<36 mg/kgDM) but still good results at 350 °C.



Thermal design : 1st step → Lab Test

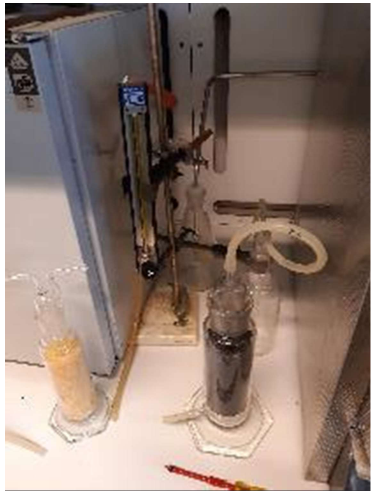
Partionning of Mercury recovery





Nearly 100% of Mercury is condensed. Some heterogeneity due to Mercury form;

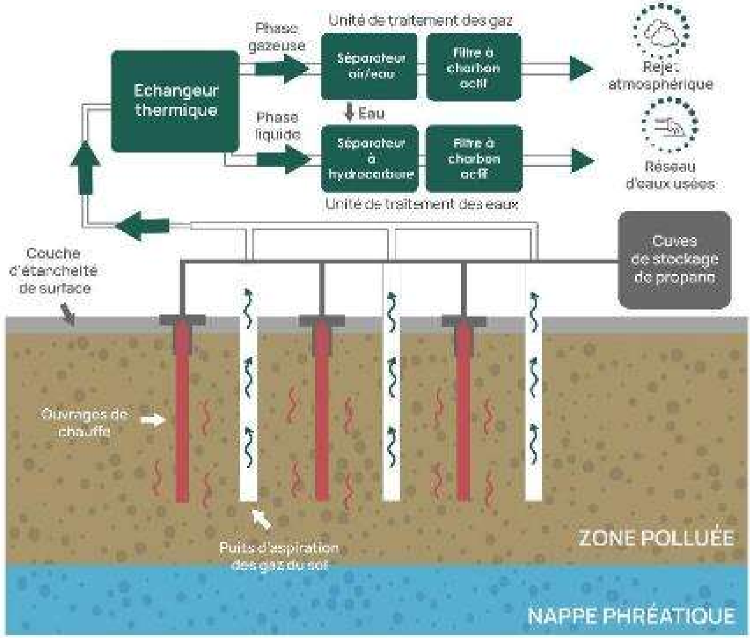
Low AC consumption for fullscale



Thermal design : Heating system

- Primary energy = Propane
- T°C aimed = 450°C

- Mass of soil to Treat = 2 421 T
- Mass of water in soil = 242 T

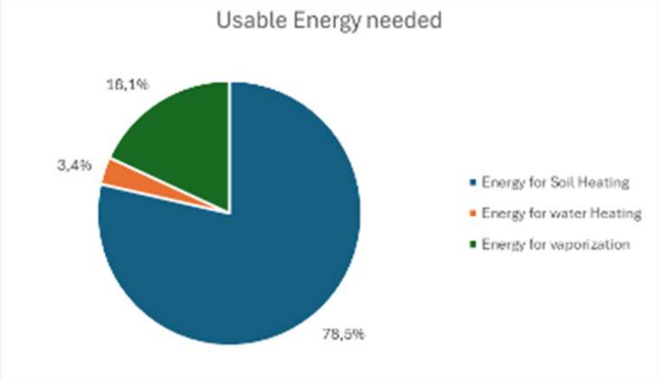


<u>Calculation for:</u>

1- elevation of T° to 450 °C of soil;

2- elevation of T° to 100°C of H_2O;

3- evaporation of H_2O;



<u>Efficiency led Strategy:</u>

- Minimizing energy loss by insulation, by air flow AND by combustion air;

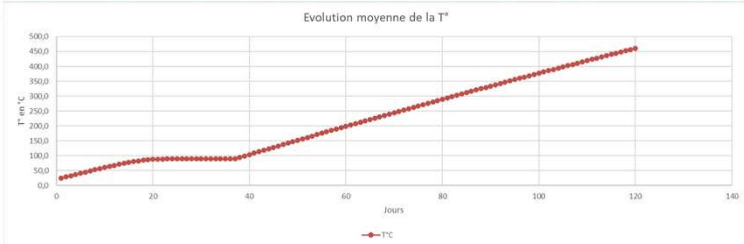
<u>Comparison between 2 strategies For 500 mW.h</u>:

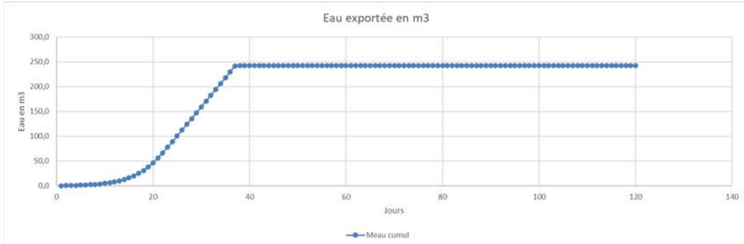
<u>Case 1</u>

- 45 days → 463 kW;
- 23 burners ~20 kW;
- Mean T°C at Exhaust air ~500°C
- Energy loss = **40 %**

<u>Case 2</u>

- 120 days → 174 kW;
- 9 burners ~20 kW;
- Mean T°C at Exhaust air ~300°C
- Energy loss = **24 %**





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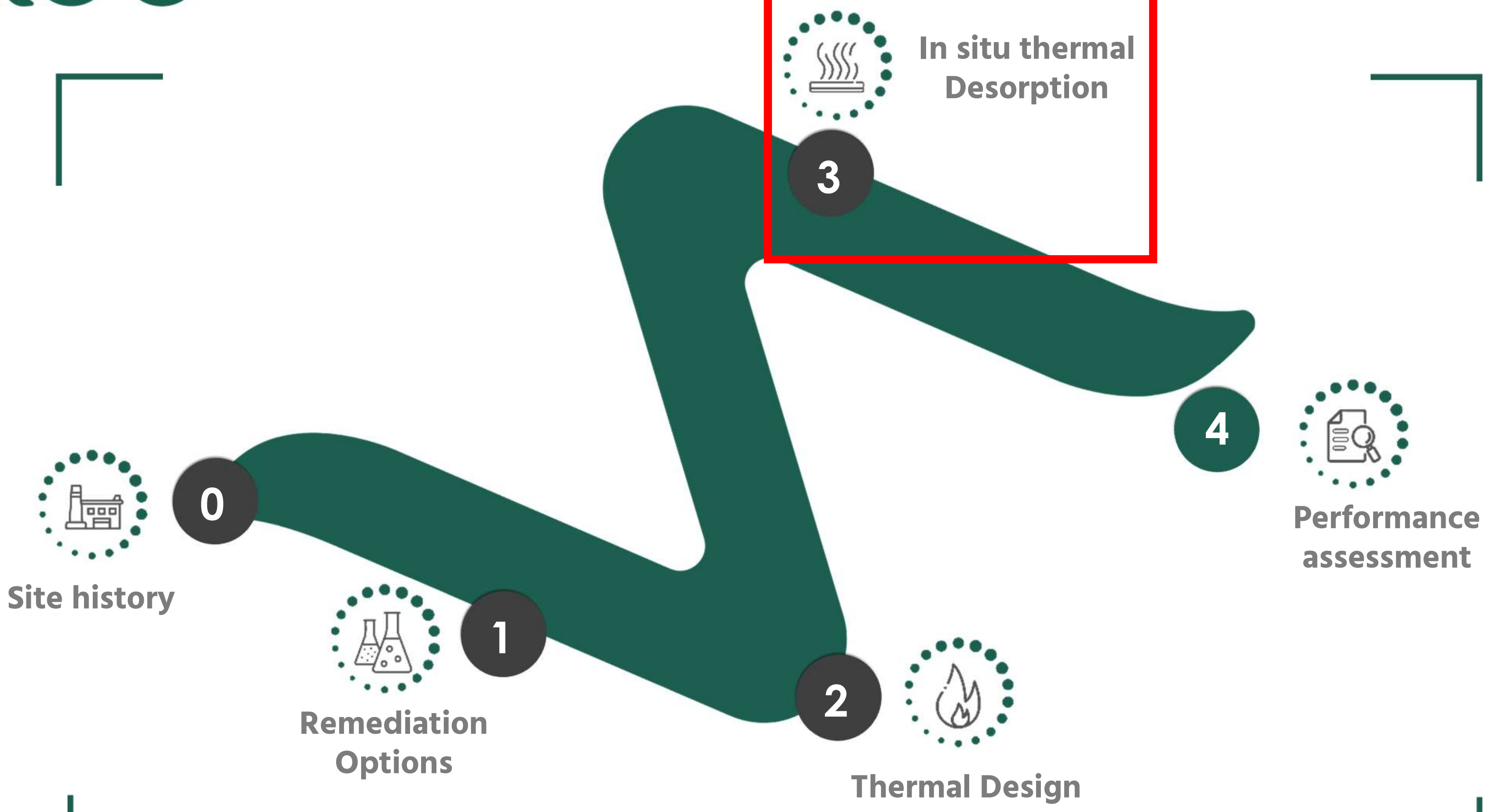

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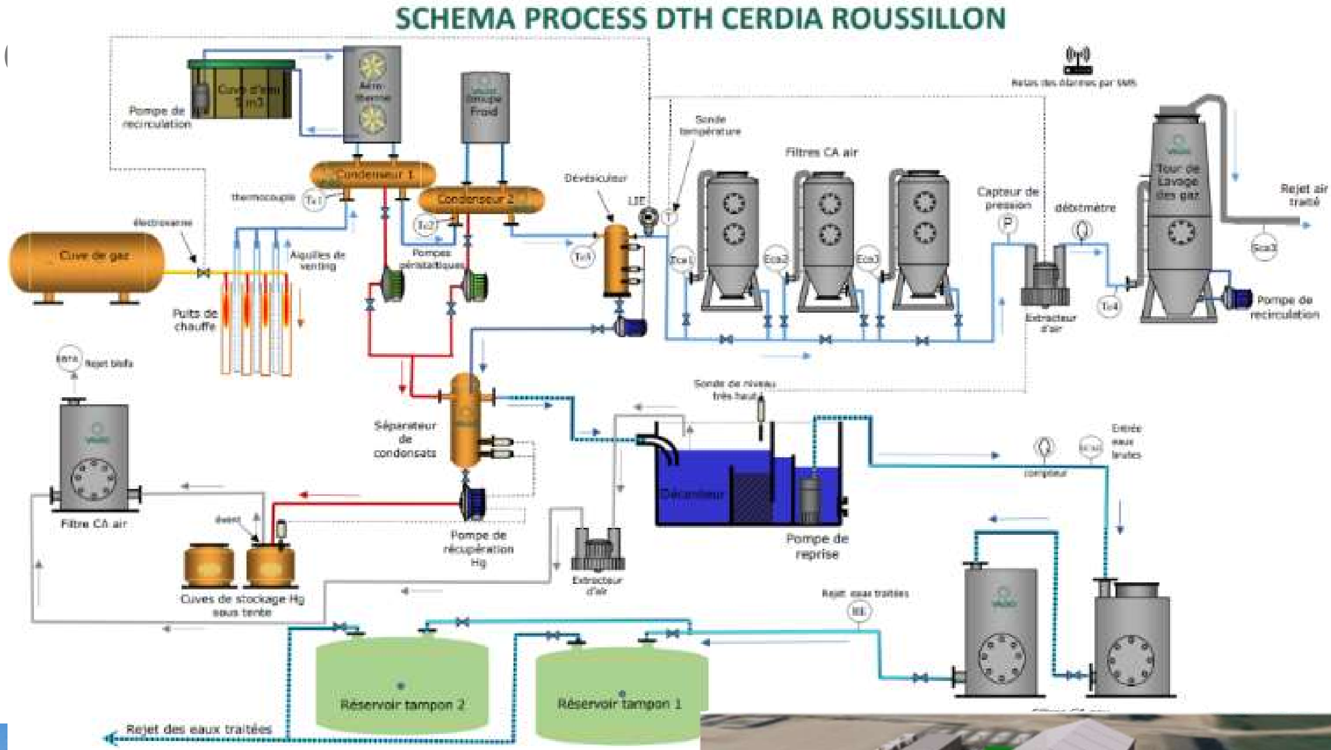
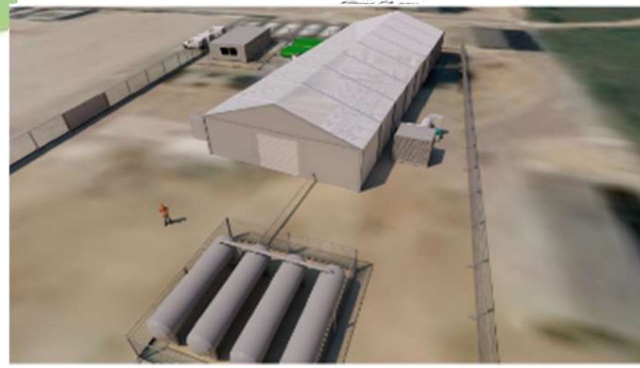
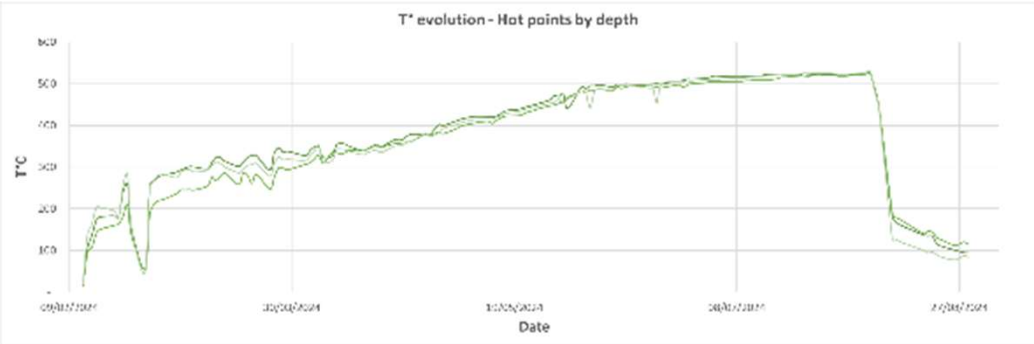
Thermal Desorption syst

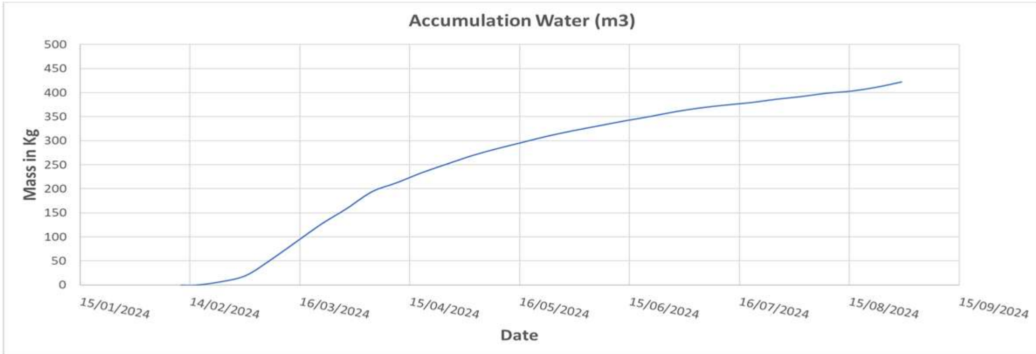
- 40 burners;
- 15 SVE wells;
- SVE systems ~700 m3/h
- 2 tubular exchangers
- 1 Chiller + 1 aerotherms
- 3 AC filters
- 1 washing tower

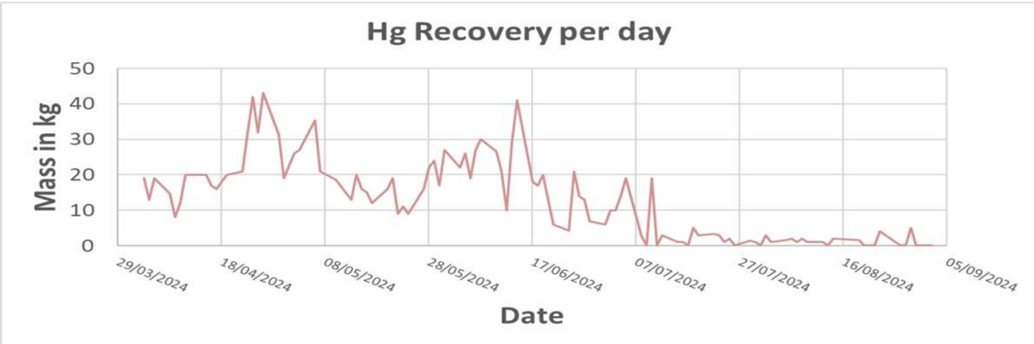




Thermal Desorption Exploitation







- Water is extracted after 10 days;
- Hg is recovered after 50 days;
- Slow increase of T°C on hot spots → energy savings;
- Nearly 2T of Hg is collected;
- 185 T of Propane consumed
- Max mean T° = 491 °C and 450 °C in cold points

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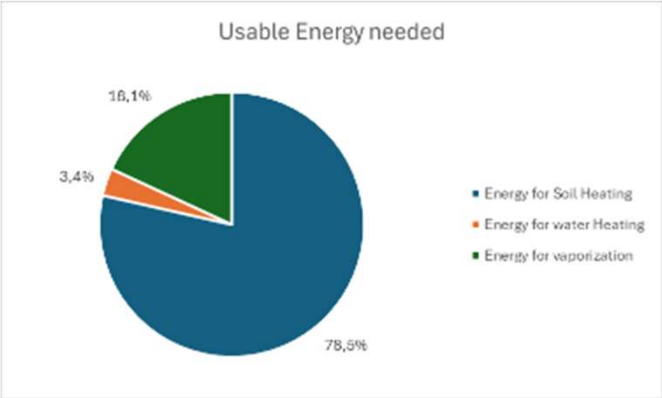
Thermal Desorption Comparison to model



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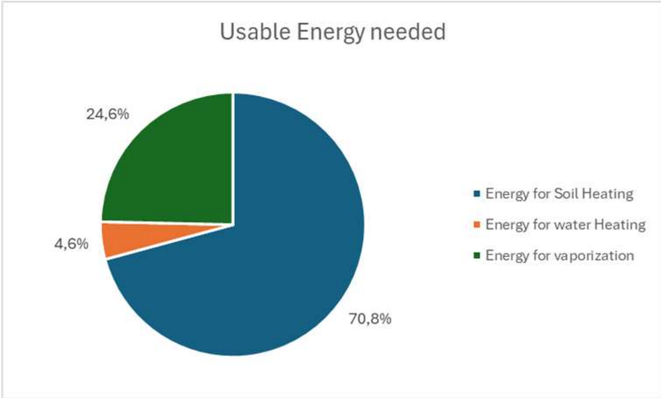
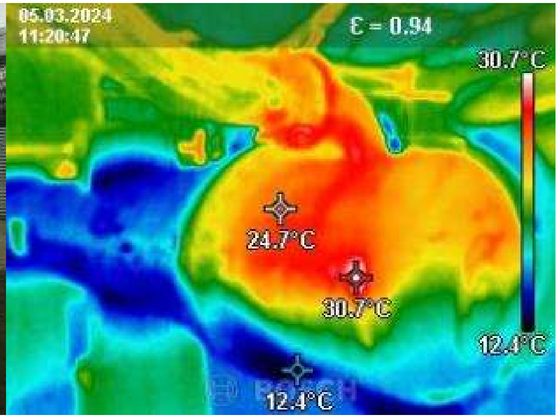


Realized

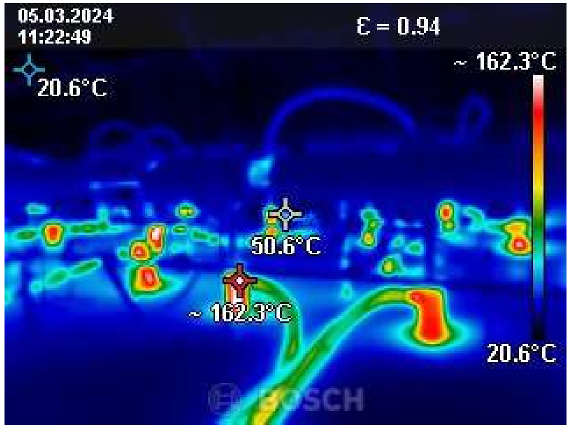
- Much more water than expected (+ 62 %)
- Hg is recovered after 50 days;
- Slow increase of T°C on hot spots → energy savings;
- Nearly 2T of Hg is collected in 140 days;
- 185 T of Propane consumed
- Max mean T° = 491 °C and 450 °C in cold points



-SVE air treated at 12 °C

→ Optimizing Ac performances;

-Control of insulation



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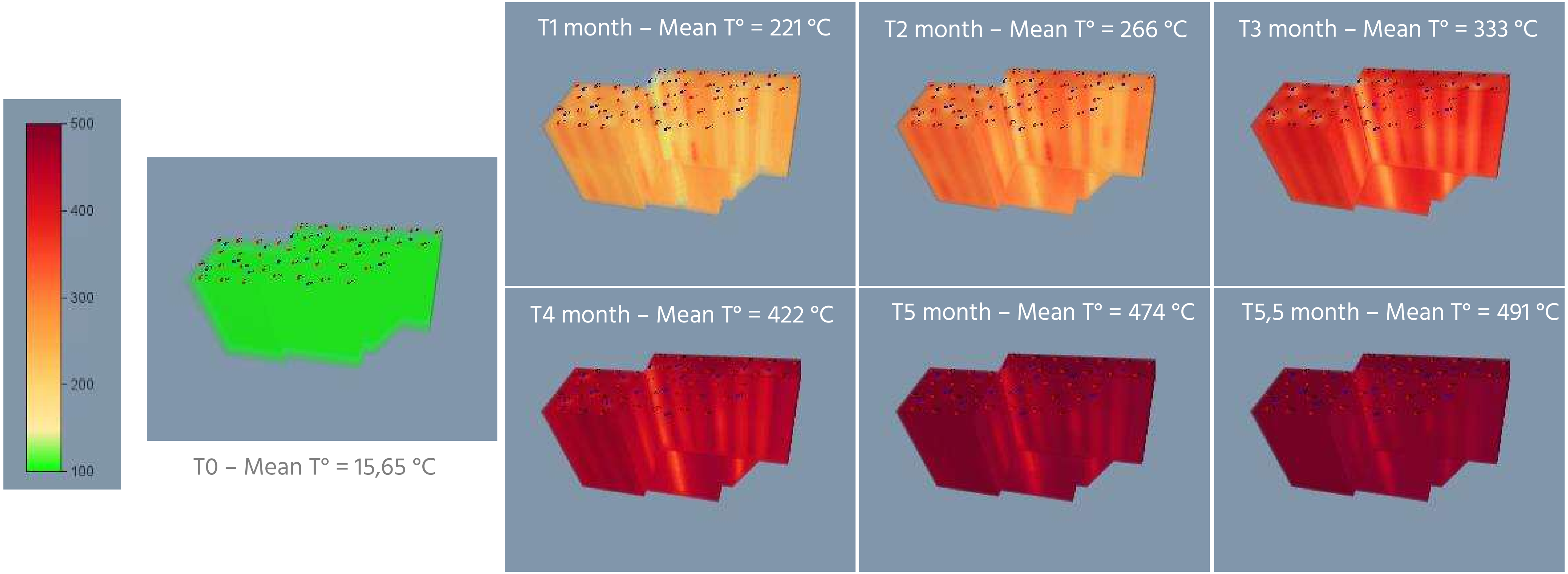

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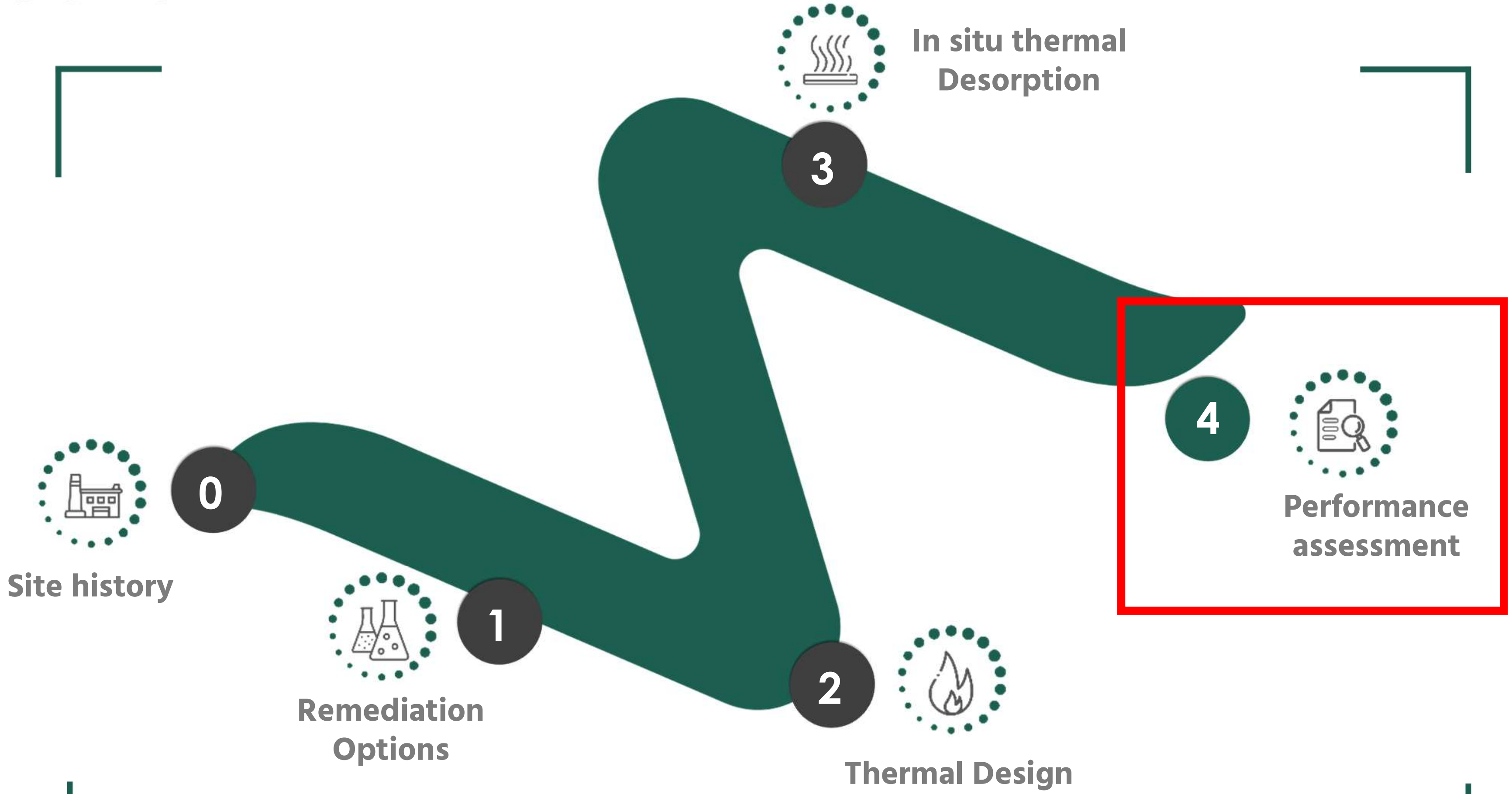
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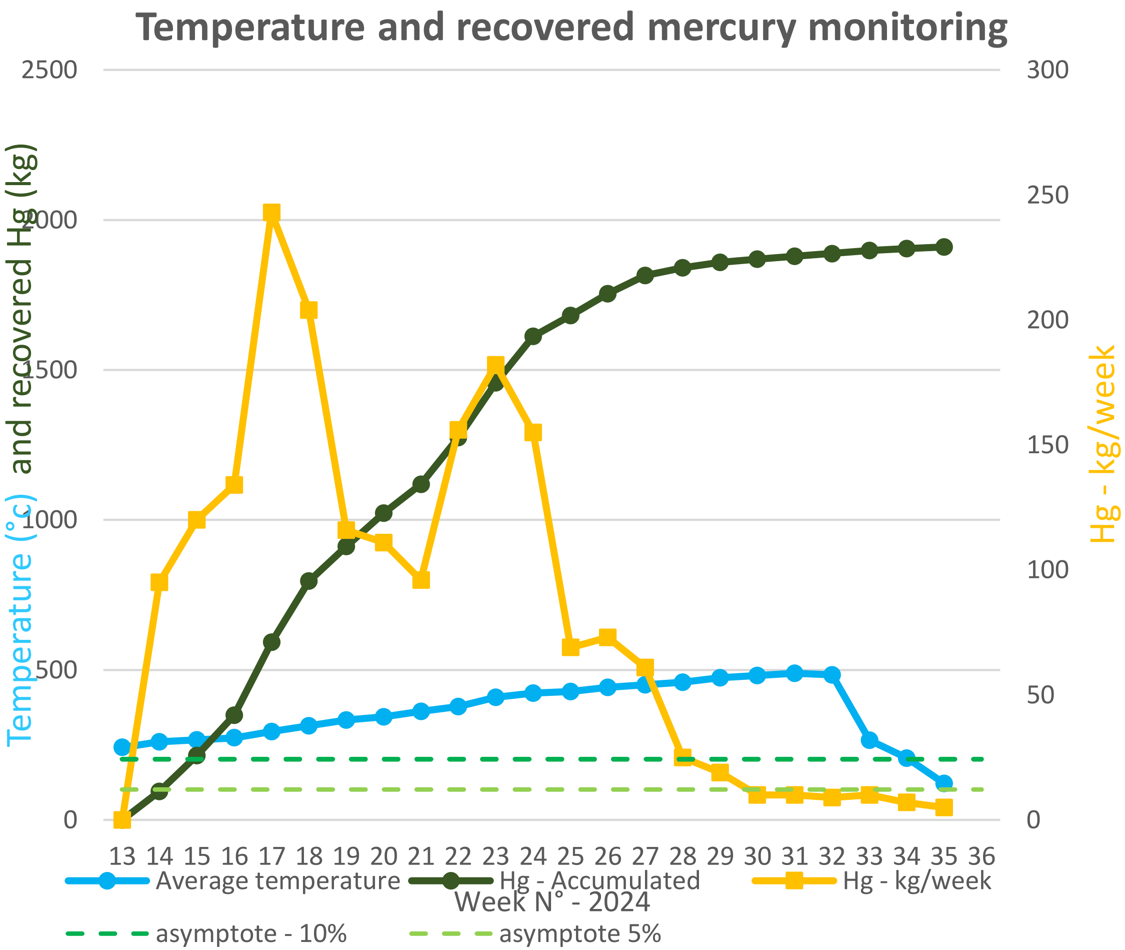
Objectives and monitoring of the ISTD

Objectives

Reaching and maintaining 450°C on 95% of the sensors at the cold points, up to an asymptote for Hg recovery

Asymptote

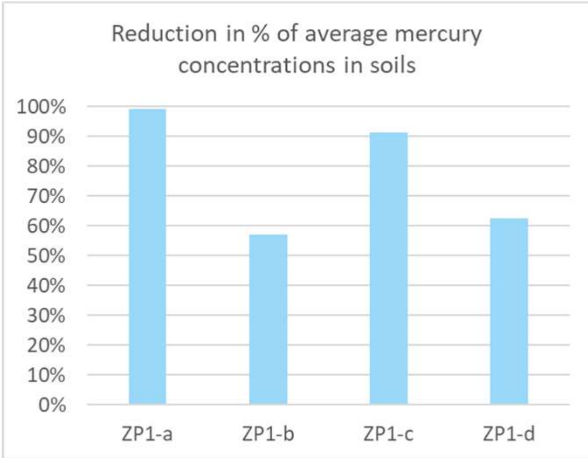
- Reached when recovered Hg <10% of Qmax Hg
- Treatment stopped when Hg recovered <5% of Qmax Hg over 14 consecutive days



Mass balance and Concentration reduction

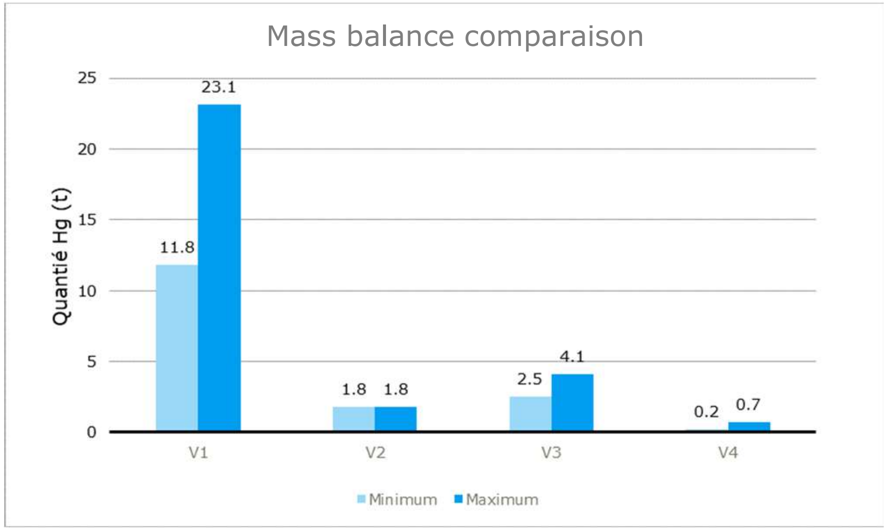
	Mercury concentration in the soil before treatment			
[Hg] en mg/kg	**ZP1-a**	**ZP1-b**	**ZP1-c**	**ZP1-d**
[Hg]min	15	2	221	4
[Hg]moy	63 540	559	1 105	461
[Hg]max	150 000	6 377	3 770	1 841

	Mercury concentration in the soil after treatment			
[Hg] en mg/kg	**ZP1-a**	**ZP1-b**	**ZP1-c**	**ZP1-d**
[Hg]min	182	8	8	36
[Hg]moy	561	241	96	172
[Hg]max	784	873	348	722

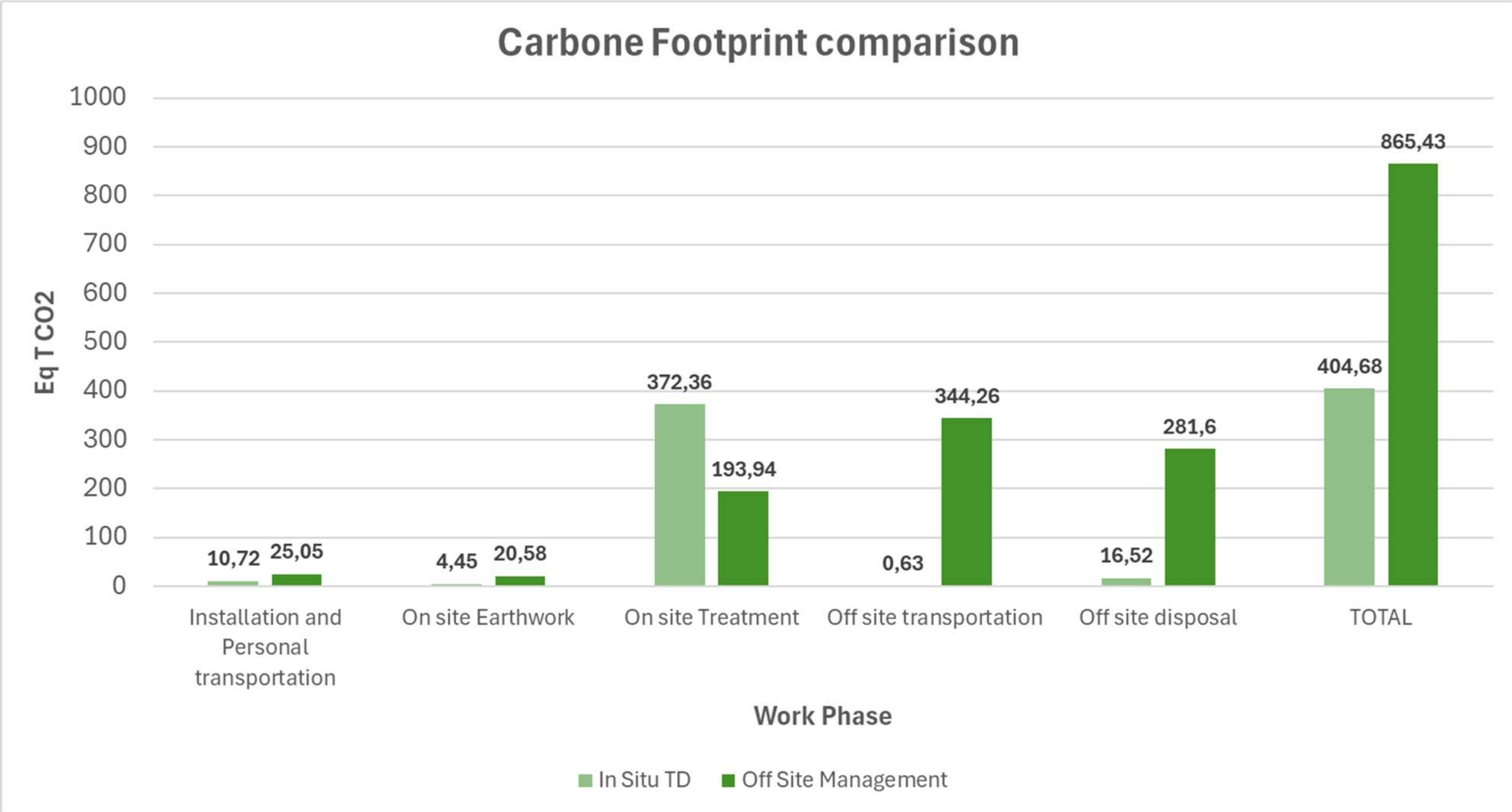


The mass balance of mercury present in the soil was evaluated and adjusted during the works:

- **V1** : 6 boreholes (diag.) – overestimation due to the presence of mercury beads
- **V2** : 10 boreholes (initial state before works) including homogenization of samples
- **V3** : 16 boreholes (V1 + V2), applying the % of mercury that can be mobilized (mercury speciation)
- **V4**: 6 post-work boreholes (final state), applying the % of mercury that can be mobilized.



Carbon footprint assessment



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