Highlights of INSURE project WP 1 - Sustainable remediation of contaminated sites

Harri Talvenmäki

Niina Lallukka, Martin Romantschuk, Vili Saartama, Suvi Survo, Hannu Silvennoinen*, Tuomas Piepponen*, Peteris Birzgalis**

University of Helsinki, Faculty of Biological and Environmental Sciences

*Nordic Envicon oy

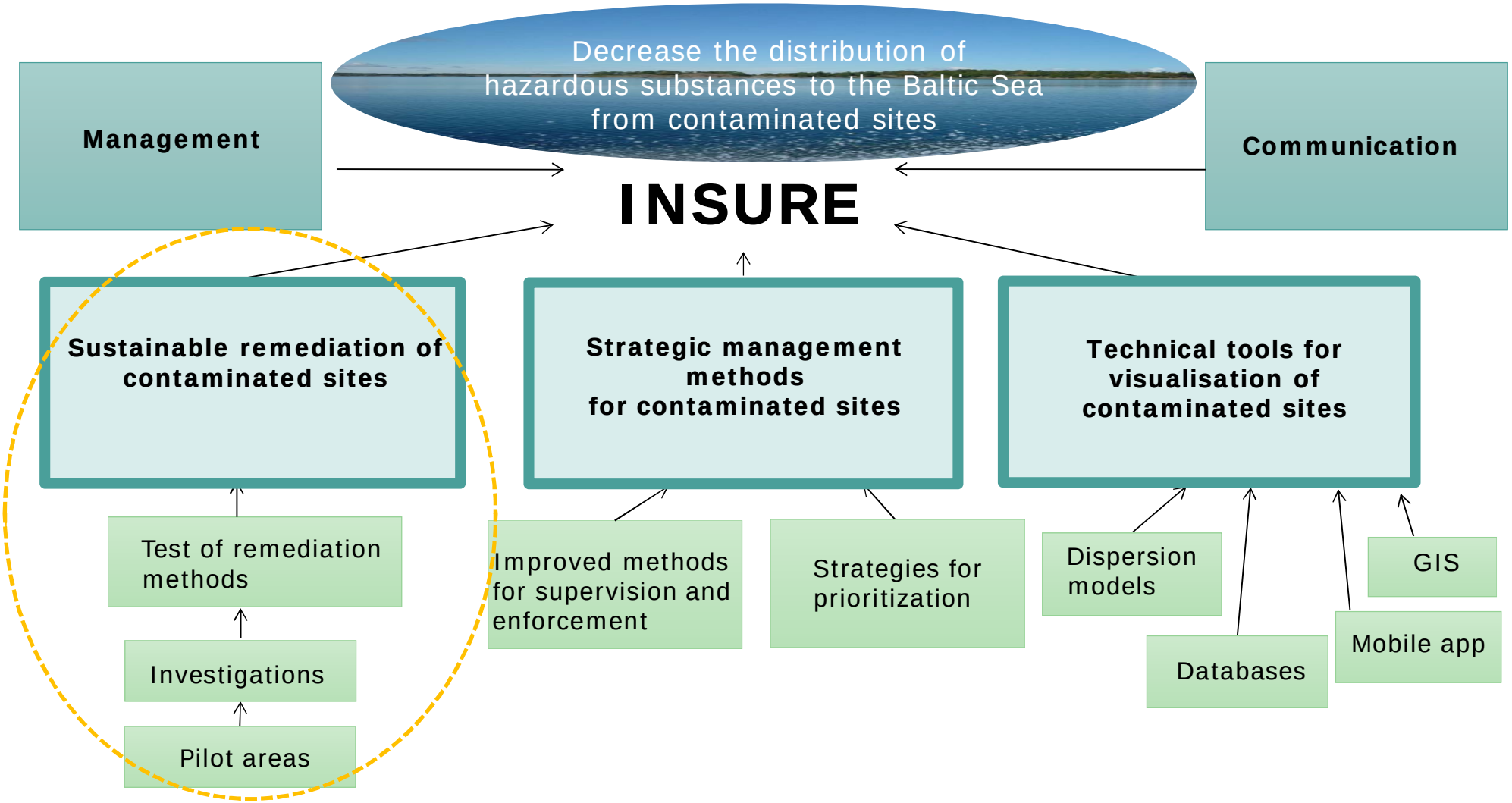
** SIA “Vides Konsultāciju Birojs”

28.5.2019

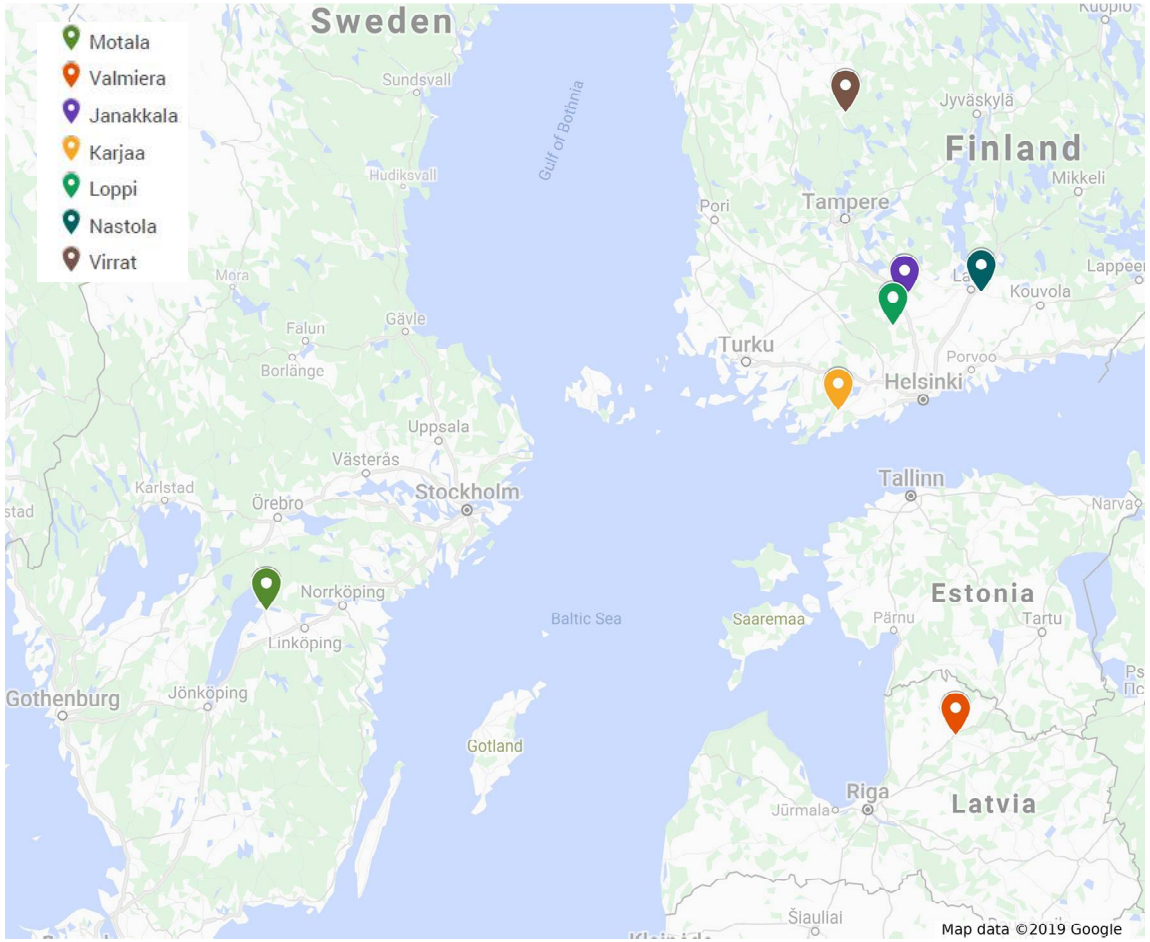
EUROPEAN UNION
European Regional Development Fund

Interreg
Central Baltic

INSURE

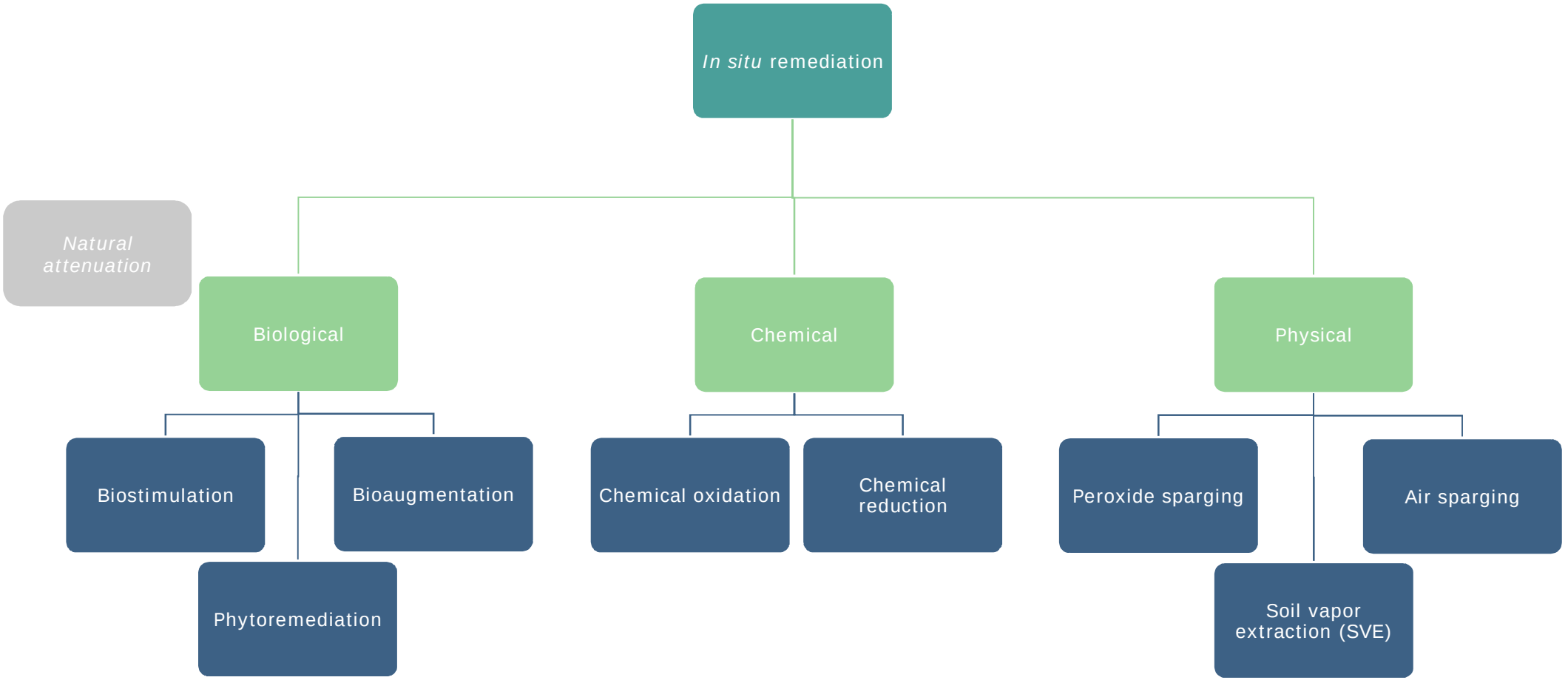

Decrease the distribution of hazardous substances to the Baltic Sea from contaminated sites
Management
Communication
INSURE
Sustainable remediation of contaminated sites
Strategic management methods for contaminated sites
Technical tools for visualisation of contaminated sites
Test of remediation methods
Investigations
Pilot areas
Improved methods for supervision and enforcement
Strategies for prioritization
Dispersion models
Databases
Mobile app
GIS

INSURE pilot sites



Background

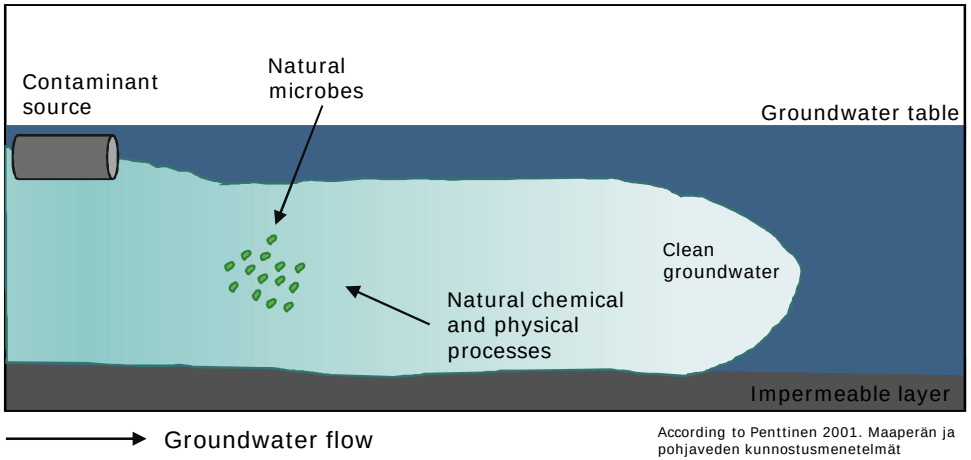
- The common way for treatment have been excavation and storage on landfills
- Will to reduce the use of landfills and move from “dig and dump” to alternative remediation methods


In situ remediation
Natural attenuation
Biological
Chemical
Physical
Biostimulation
Bioaugmentation
Phytoremediation
Chemical oxidation
Chemical reduction
Peroxide sparging
Air sparging
Soil vapor extraction (SVE)

BIOREMEDIATION: Natural attenuation bottlenecks

- Low temperature
- Lack of electron acceptors (O_2, NO_3^-, Fe_3^+, SO_4^-, ...)
- Lack of additional nutrients (N, P)
- Uneven distribution of contaminants and/or microbes
- Low bioavailability of oil (NAPL, adsorption to soil particles)

→ TASK FOR BIOSTIMULATION: TO REMOVE BOTTLENECKS



According to Penttinen 2001. Maaperän ja pohjaveden kunnostusmenetelmät

Kauppi, S., Sinkkonen, A., Romantschuk, M. 2011. International Biodeterioration and Bioremediation 65, 359-368

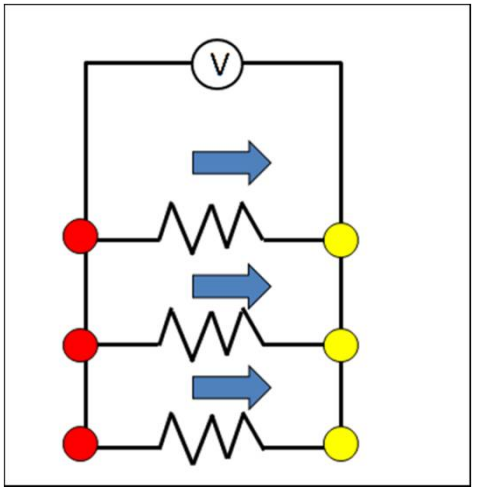
IN SITU REMEDIATION

INSTALLATIONS

a. Drillings across the contaminated zone

b. Installation of perforated plastic tubes (biological: for nutrient amended water)

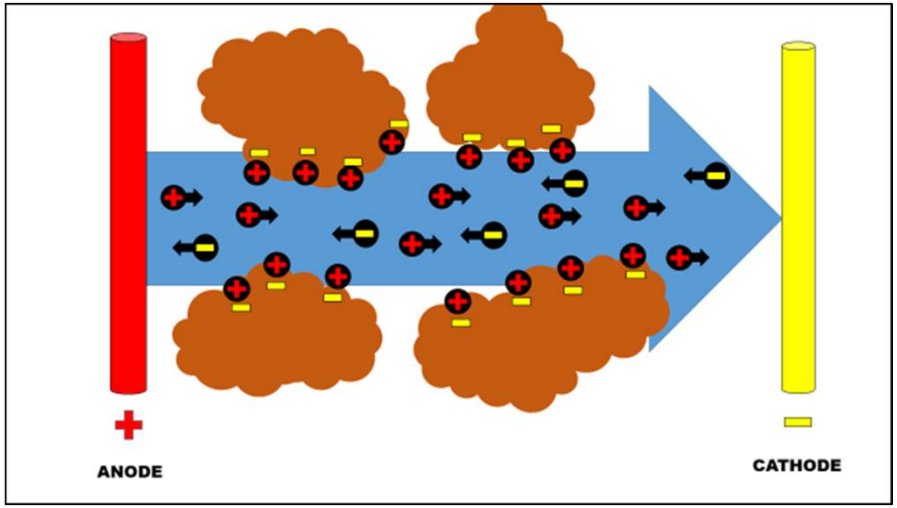
+ ELECTRO OSMOSIS



c. Installation of stainless steel rods

d. Attachment of electrodes to a transformer

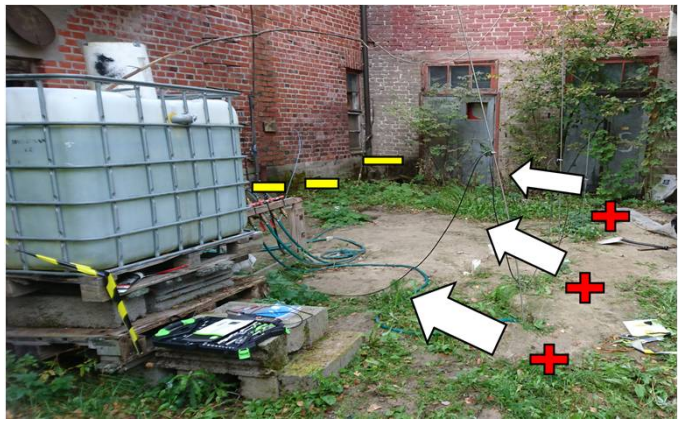
e. Parallel circuit (DC) is created into the contaminated zone with two rows of electrodes



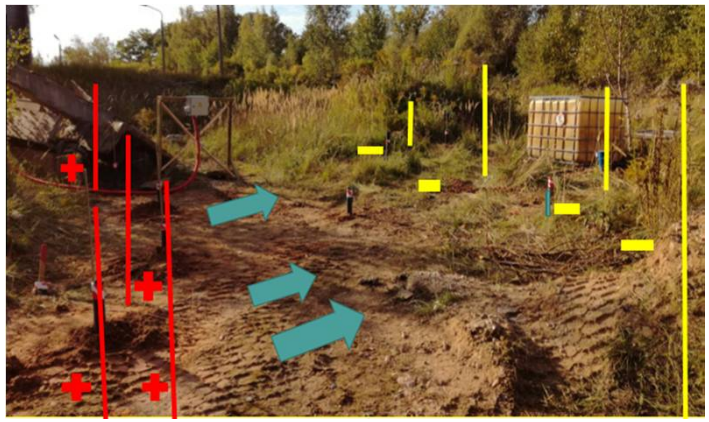
Due to the electric charge of soil particles, ions with opposite charge are bound to the soil and free ions travel towards electrodes according to their charge

Due to viscosity, water is being dragged from anode to cathode

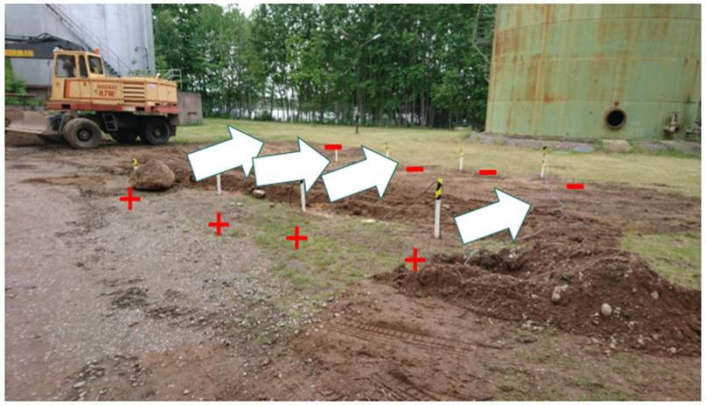
Heat is generated and nutrients distributed horizontally to stimulate bacterial digestion of organic contaminants



VILLÄHDE, Finland

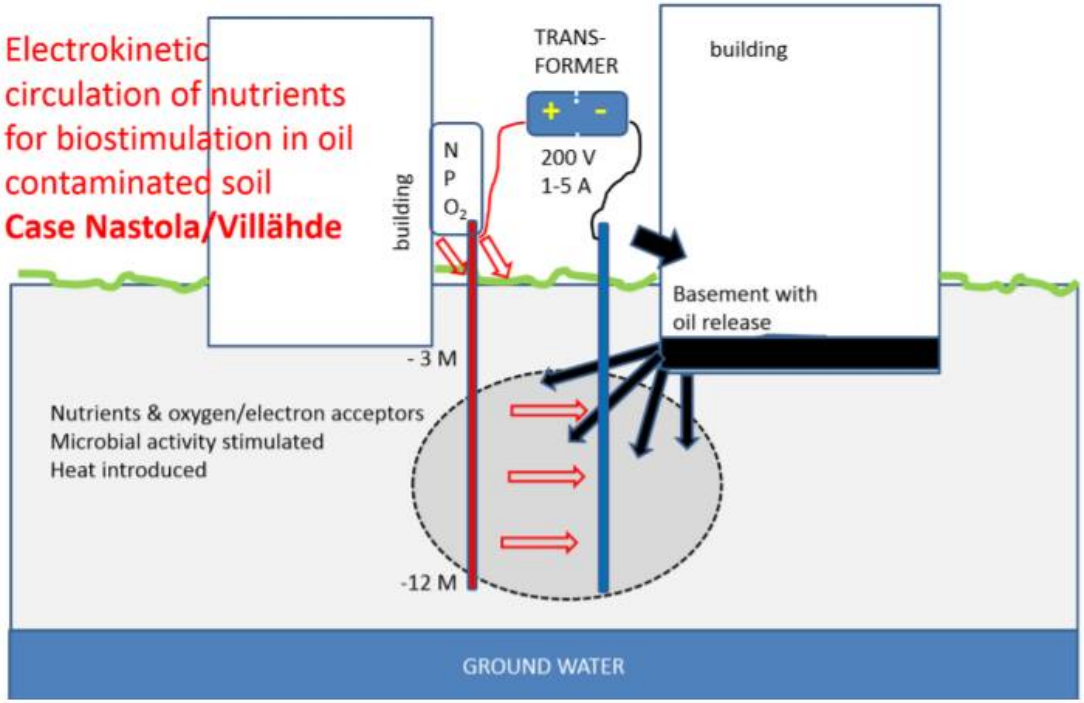


VALMIERA, Latvia

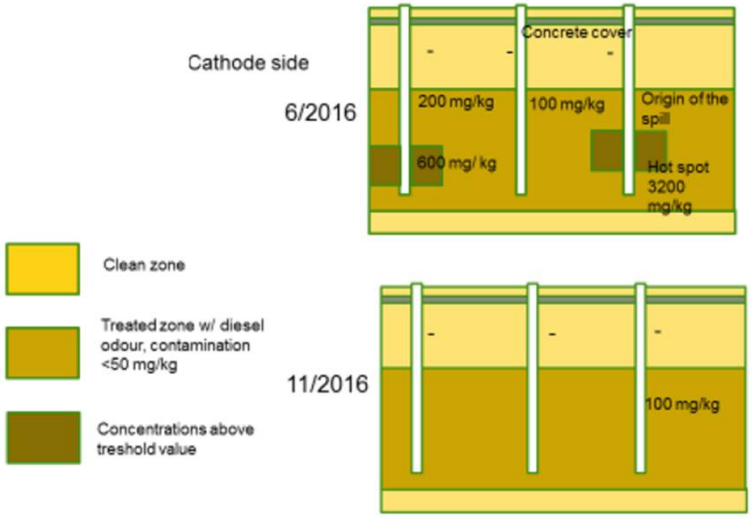


MOTALA, Sweden

Non-saturated zone application

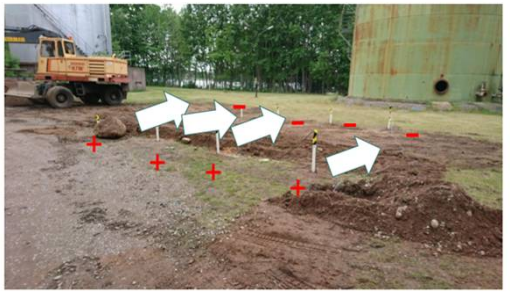


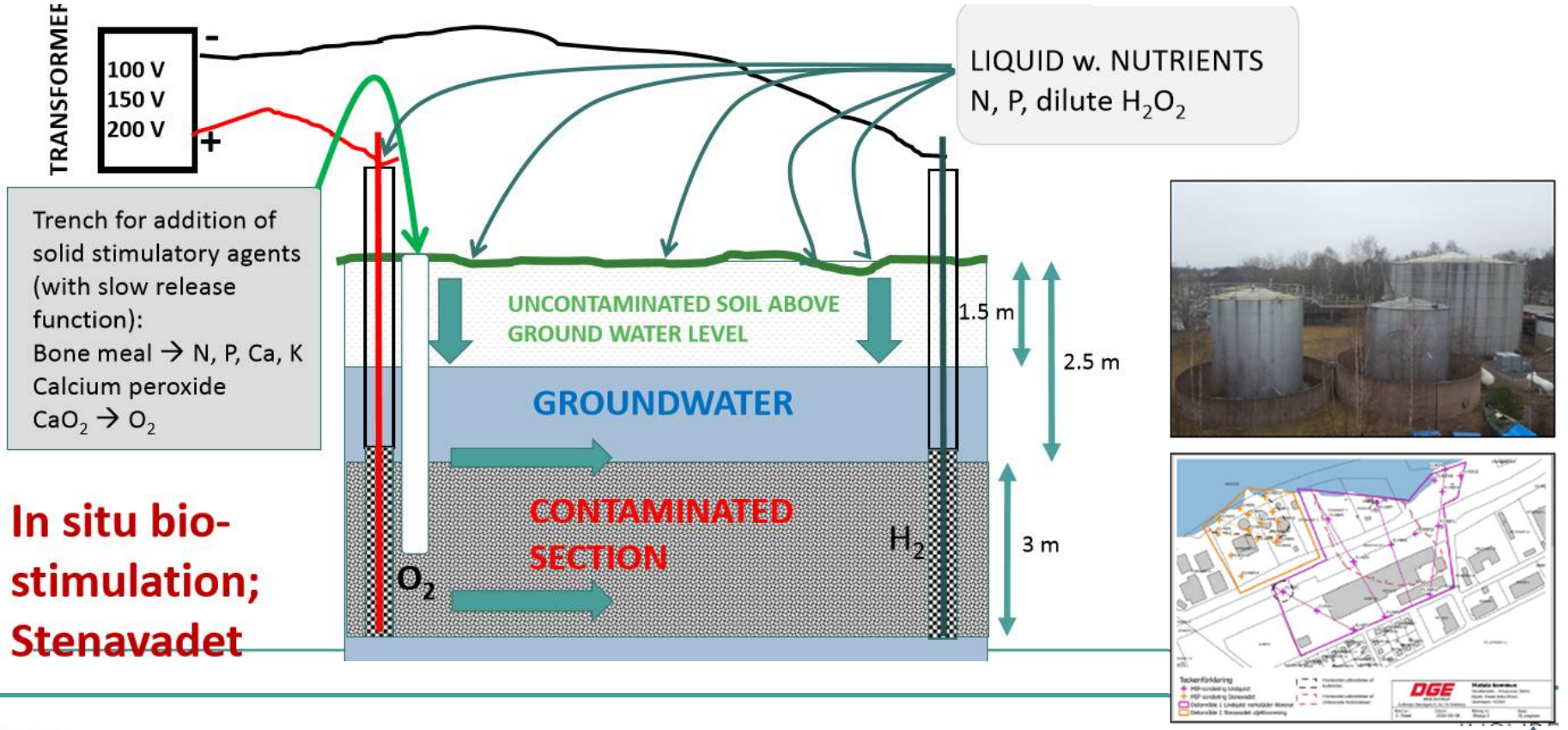
Site Villähde



- Two light fuel oil hotspots in 7-10 m depth. Area successfully treated in 4,5 months (2016)
- Injection of nutrient-amended water into the electrode channels

Below ground water level application





EUROPEAN UNION
European Regional Development Fund

Interreg
Central Baltic

INSURE

Bone meal

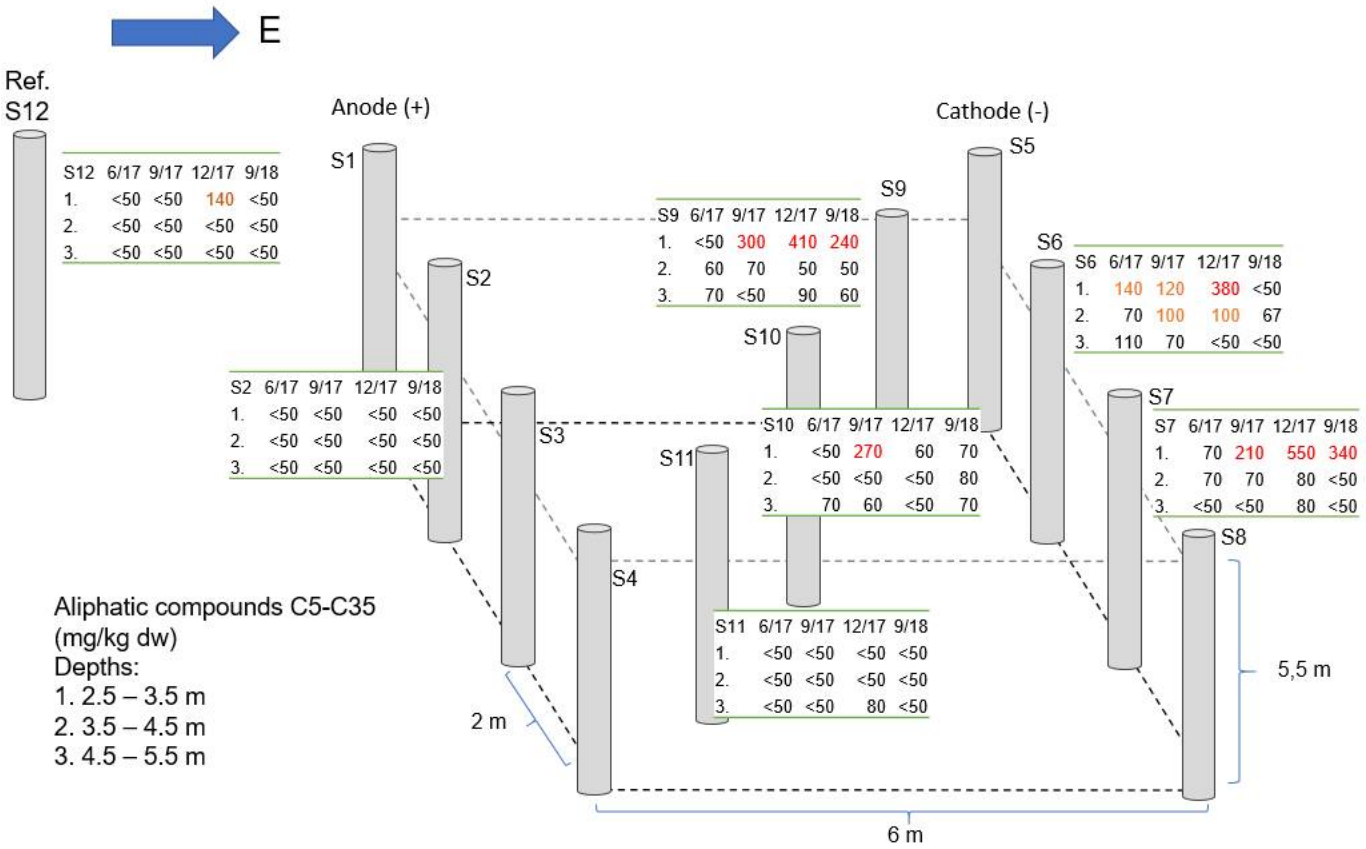
- Soil remediation with meat processing by-product (unhazardous, sterilized)
- REMSOIL® stimulates existing microbes
- Slow release of nutrients (N, P, K, Ca)
  - No leaching
  - Long-lasting stimulation
- Stimulates decomposition of organic contaminants (diesel, PAHs, etc.)
- No effect on soil pH

Motala results

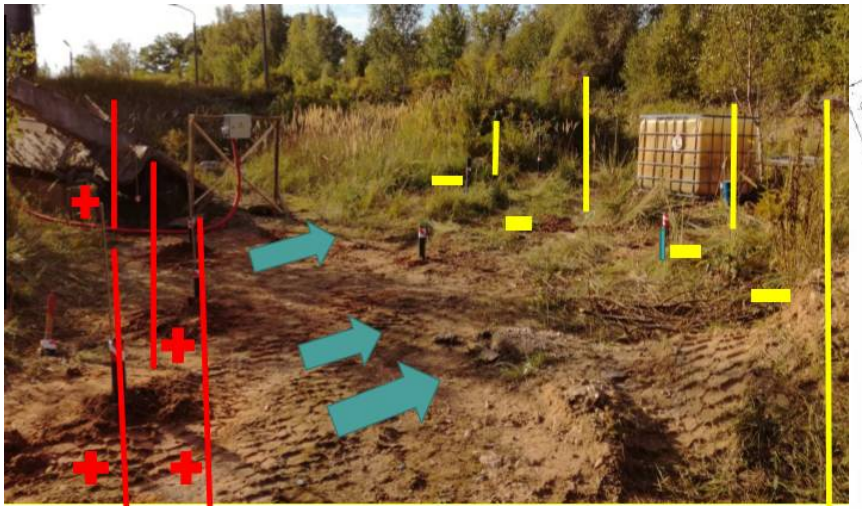
Only partial recovery with one year treatment

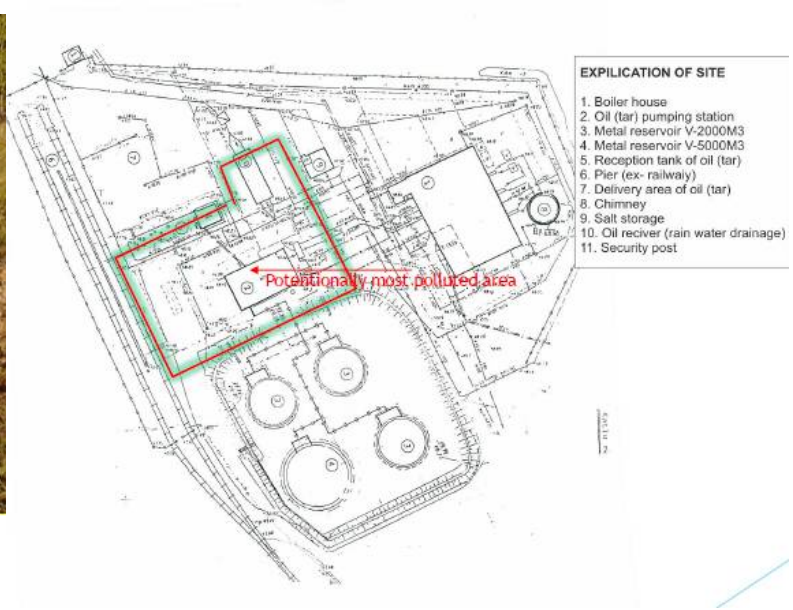
Biodegradation was considered insufficient

Mobilisation of oil towards the groundwater surface



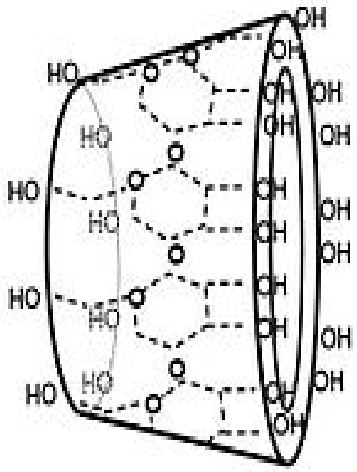
Site Valmiera, Latvia





Crude mazut oil contaminated site
treated with biostimulation enhanced with electro-osmosis and cyclodextrin. Treatment time 6 months (2018-2019)

Cyclodextrins –site Valmiera, site Janakkala, site Karjaa



Cyclic sugar produced from raw material containing starch,

- hydrophobic center attaching hydrophobic compounds (oils)
- quest-host complex formed through Van der Waals interaction
- hydrophilic exterior makes the complex soluble

-> Non water soluble compounds become soluble and hence more bioavailable

-> can decrease the treatment period but also increase the risks of contaminant mobilization

-> difficult to get permissions even for pilot tests

Valmiera Results

Aliphatic compounds
C10-C40 (mg/kg)
Depths:
1. 0.0 – 1.0 m
2. 1.0 – 2.0 m
3. 2.0 – 3.0 m
4. 3.0 – 4.0 m

Ref.
F2

F2	9/18	1/19	4/19	Change
1.	68	195	56	-12
2.	64	6.0	12.0	-52,0
3.	55	5.7	4.0	-51,0
4.	21	6.1	8.0	-13

Cathode (-)

Anode (+)

K1

K2

K3

K4

A1

A2

A3

A4

S1

S2

S3

S3	9/18	1/19	4/19	Change
1.	22	12	52	30
2.	2510	26	300	-2210
3.	530	1070	910	380
4.	68	1440	177	109

S2	9/18	1/19	4/19	Change
1.	52	5.0	87	35
2.	230	644	24	-206
3.	51	21	318	267
4.	15	15	103	88

S1	9/18	1/19	4/19	Change
1.	24	68	15	-9,2
2.	1210	22	1590	380
3.	1840	590	1530	-310
4.	61	81	27	-34,4

Ref.
F1

F1	9/18	1/19	4/19	Change 9/18–4/19
1.	161	13	47	-114
2.	1500	2100	122	-1378
3.	900	32	190	-710
4.	104	180	83	-21

2 m

4.0 m

6 m

EUROPEAN UNION
European Regional Development Fund

Interreg
Central Baltic

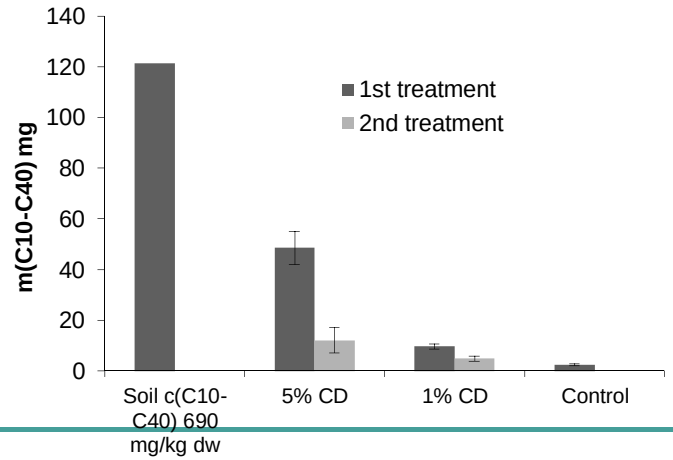
INSURE

Site Karjaa

- Oil contaminated residential area
  - Clay/silt soil type
- Soil flushing simulation to test the ability of methyl-b-cyclodextrin (CD) to enhance the bioavailability of oil hydrocarbons
  - Soil received from the site

→ The additive could be used either for more effective biological treatment or for soil flushing

	original concentration in soil	5 % cyclodextrin			1% cyclodextrin			control		
	(mg/kg dw)	1.	2.	total	1.	2.	total	1.	2.	total
Arom. C10-C12	< 30									
Arom. C12-C16	44	54 %	15 %	**61 %**	10 %	2 %	**12 %**	1 %	0 %	**1 %**
Arom. C16-C21	30	43 %	85 %	**91 %**	11 %	0 %	**11 %**	0 %	0 %	**1 %**
Arom.C21-C35	<30									
Aliph. C10-C12	84	48 %	-2 %	**47 %**	6 %	0 %	**5 %**	2 %	0 %	**2 %**
Aliph. C12-C16	290	64 %	10 %	**67 %**	12 %	3 %	**15 %**	2 %	0 %	**2 %**
Aliph. C16-C35	490	34 %	16 %	**45 %**	7 %	4 %	**11 %**	1 %	0 %	**1 %**
C10-C21	790	48 %	13 %	**55 %**	9 %	3 %	**12 %**	1 %	0 %	**1 %**
C21-C40	150	34 %	17 %	**45 %**	6 %	3 %	**8 %**	4 %	-1 %	**3 %**
C10-C40	950	45 %	12 %	**52 %**	9 %	3 %	**11 %**	2 %	0 %	**1 %**



Results from site Karjaa:

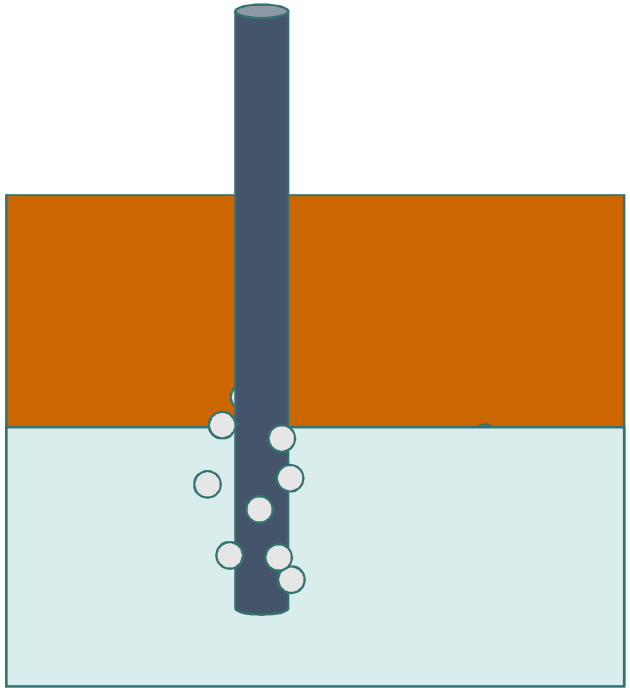
Amount of oil (mg) dissolved in water. On the left is shown the amount of oil in homogenized soil (multiplied with soil dry weight 0.18 kg)

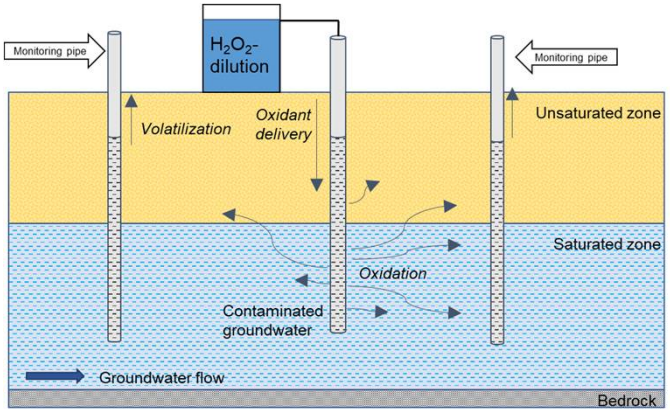
Hydrogen peroxide in biological, chemical and physical remediation

- **Chemical** – Contaminant is degraded by chemicals
  - **H_2O_2:** breaks into reactive radicals when catalyzed by iron, radicals destroy organic oil hydrocarbons.
- **Physical** – Contaminant is physically removed from the media
  - **H_2O_2:** bubbling and volatilization caused by peroxide breakdown reactions produce an effect comparable to air sparging, could be used to volatize VOCs from groundwater
- **Biological**: Contaminant is degraded by microbes
  - **H_2O_2**: used as the oxygen source for microbes in low concentrations. Toxic in higher doses.

COULD PEROXIDE SPARGING BE USED AS AN ALTERNATIVE FOR AIRSPARGING FOR VOLATILE COMPOUNDS?

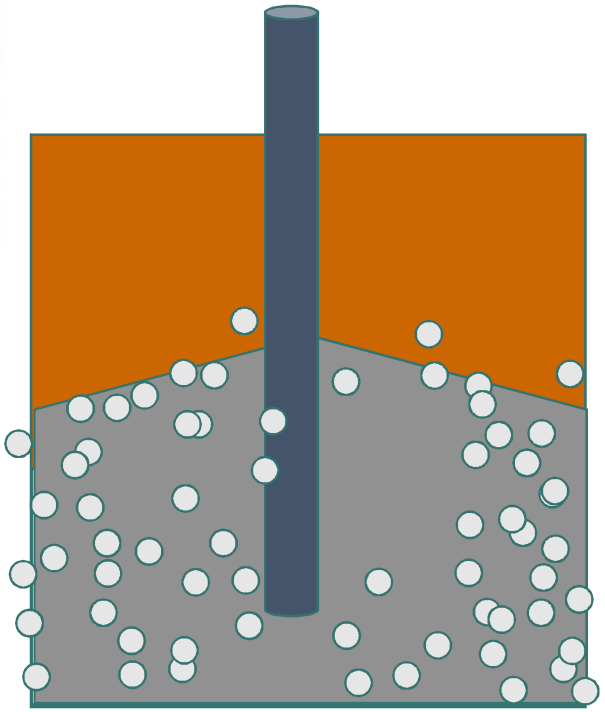
Air Sparging





Air escapes from soil via the route of least resistance, liquids should be easier to inject. The peroxide sparging stars after a lag period.

Peroxide Sparging



- In acidic soil pH, chemical oxidation dominates,
- Closer to neutral pH, volatilization becomes a factor

-> peroxide treatment should work for volatile compounds near neutral pH

(- possible rebound concentrations from the gaseous phase for VOCs)

-> treating non-volatile compounds may result in mobilisation -> Not a multipurpose treatment for old fuel stations.

-> Since the rebounds need to monitored for several months, and peroxide is diluted to sufficient levels for biological remediation in the soil, biological mechanism is also a factor.

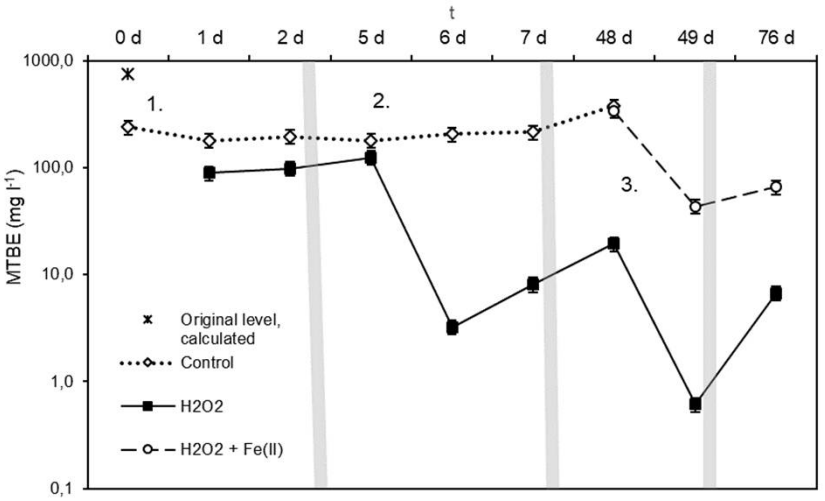
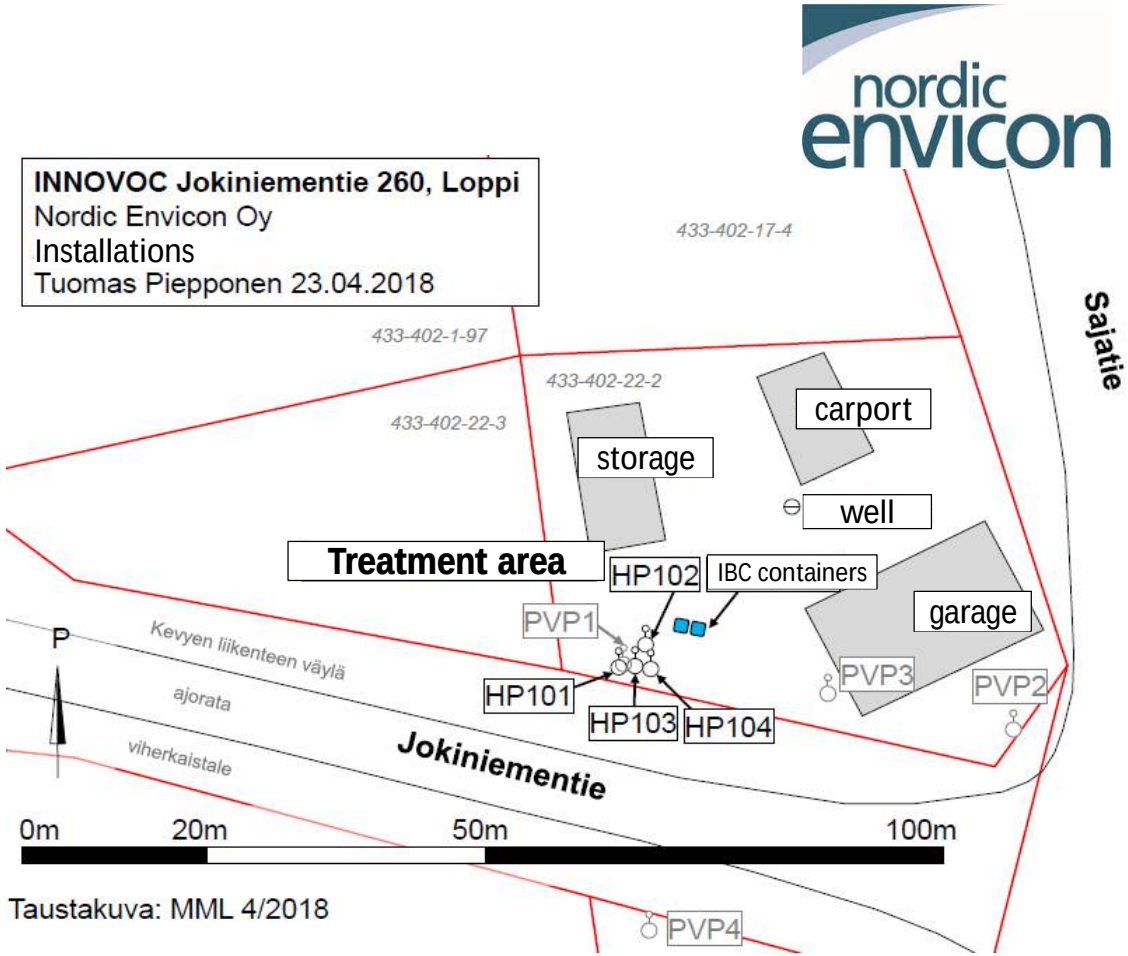


Fig The effect of treatment on MTBE-concentrations in pore water in relation to time after the initial addition. Results show average ± 85 % confidence intervals. Grey vertical lines indicate non-uniform timeline. Log10 transformed y-axis. The treatment numbers correspond to those in table 2.

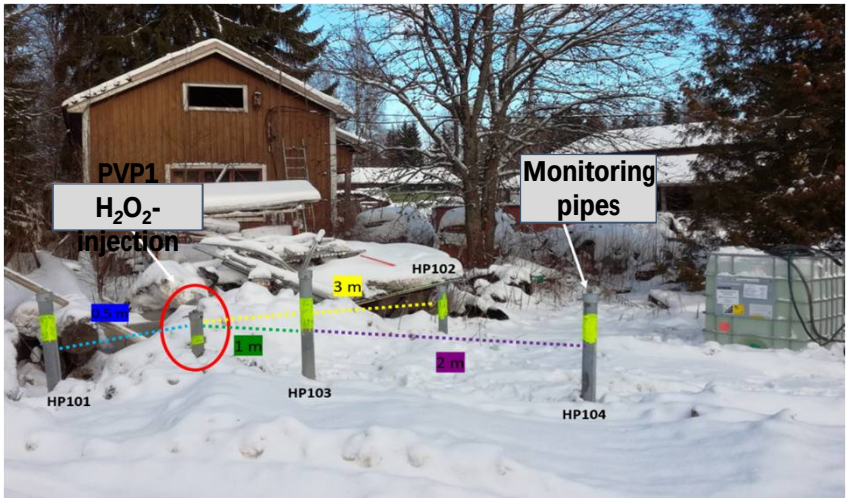
Site Loppi

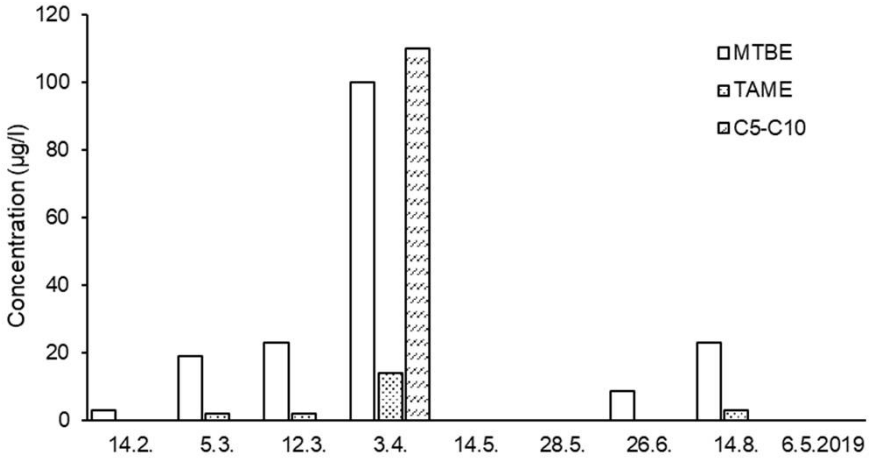
- Former gas station, activity ended around 2002
- Soil contaminated with gasoline, diesel and BTEX
- Groundwater contaminated with gasoline and BTEX
  - Groundwater at depth of 3-4 m

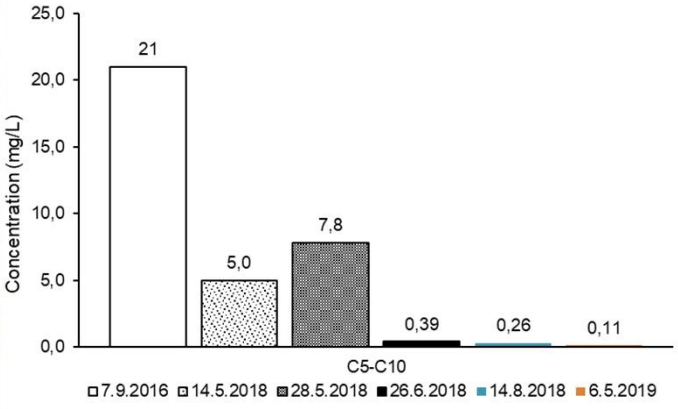
- Feb-March 2018 1st treatment
- May-July 2018 2nd treatment (larger area)
- Last control visit in May 2019



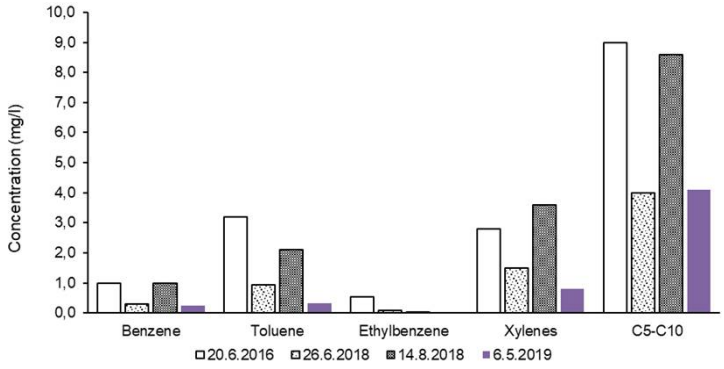
Loppi results







Mobilisation to PVP 2?



EUROPEAN UNION
European Regional Development Fund

Interreg
Central Baltic

INSURE

Site Janakkala

Phase 1: Chemical treatment Fenton (2016)

Phase 2: Biostimulation/-augmentation

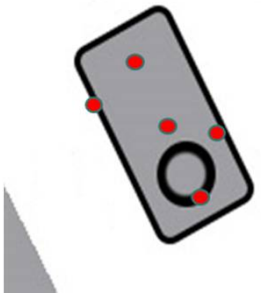
- Soil from previously cleaned site used as inoculum
- Calcium peroxide and nitrate-ammonium fertilizer

Phase 3. biostimulation

- Meat industry waste bone meal used as a slow release fertilizer

Phase 4. Biostimulation, use of biosoap

- Addition of cyclodextrin



		c(C10-C40) (mg/kg dw)	total reduction
phase	original level	25000	
1	1st chemical treatment	7000	72 %
1	2nd chemical treatment	9000	64 %
2	biostimulation 2,5 months	6000	76 %
2	biostimulation 4 months	2500	90 %
2	biostimulation 10 months	1600	94 %
3	bistimulation 16 months	2000	92 %
4	biostimulation 28 months	400	98 %

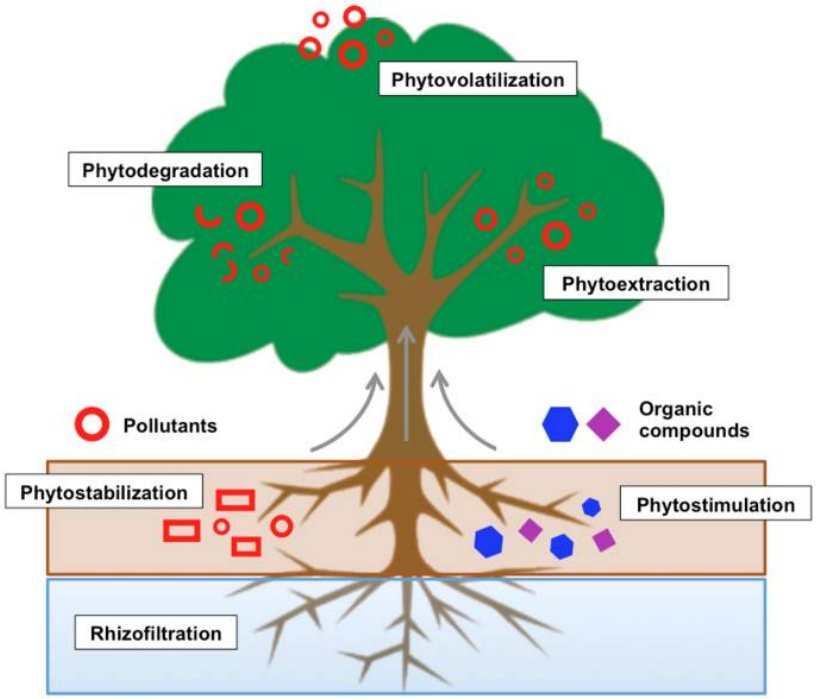
FINAL INVESTIGATIONS OF A LARGER AREA:

Phytoremediation

- Based on the ability of plants to take up, accumulate and/or degrade contaminants that are present in soil and water environments

+ Low costs
+ Minimal environmental disturbance
+ Esthetically pleasant
+ Prevents erosion
+ May enhance soil properties such as soil structure
+ Possibility to recover metals

– Slow process
– Toxicity of contaminants may affect the survival of the plants
– Not suitable for contaminants located deep under the soil
– Contaminants may enter the food chain



https://commons.wikimedia.org/w/index.php?curid=45235505

Site Virrat

- Old industrial site, contaminated with oil hydrocarbons and heavy metals
- In 2017 two spots on the site were still found to have very high concentrations of hydrocarbons and heavy metals respectively, and they had to be removed by excavation before starting the planting.
- 1200 aspen seedlings in 17 planting blocks planted during 2017
- DNA samples for identification of microbes and bioinformatic analysis to figure out the microbial communities in the contaminated soil
- The site was photographed using a drone in October 2017
- The next sampling in the fall, the treatment will continue until 2028

Conclusions

- Efficiency of *in situ* treatment is highly site and compound specific
- Combination of different methods may, and is often be needed, especially with multiple contaminants
  → Requires time
- In some cases, in challenging conditions, sites have been successfully and cost-efficiently remediated
- When risks are low and excavation is impractical, *in situ* is a good choice
- Combination of *in situ* with *ex situ*/on site methods is also worth considering
- Inherent trade off between sustainability and low risk level in some cases (bioavailability issues), permissions are therefore difficult to get.

Thank you!