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Chemical oxidation of chlorinated hydrocarbons in soil utilising peroxygen chemicals, different activation aids and biosurfactant

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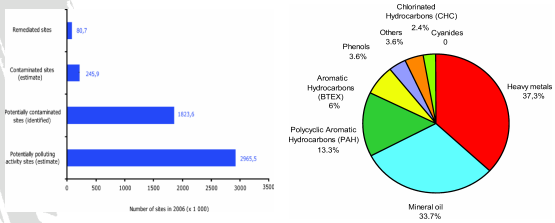
It has been estimated that 3.5 million sites only in the EU may be potentially contaminated, with 0.5 million sites being really contaminated and needing remediation.



Source:European Environmental Agency *Overview of progress in the management of contaminated sites in Europe* **(published Aug 1, 2007, last modified Jul 7, 2011)**

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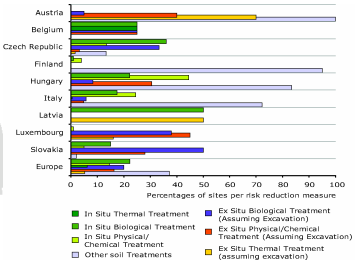
Remediation technologies: the graph shows remediation technologies applied in the surveyed countries as percentages of number of sites per type of treatment



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Chemical oxidation

- Chemical oxidation is a proven technology for remediation of contaminated soil.
- Since the reaction is almost immediate, such treatment is far more rapid than biological techniques, and can be faster than thermal or vapour recovery technologies.
- **A realistic conceptual model could be the use of chemical oxidation as a mass removal and biodegradation as a polishing step.**
- Matching the remedial chemical and technology of delivery to the contaminant of concern and site conditions is an extremely important step in the successful remediation of contaminated soil.

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Types of organic contaminants

Volatile Organic Compounds (VOCs)
-benzene, toluene, ethylbenzene, xylenes (BTEX)
-chlorinated solvents (perchlorethylene)
-some oxygenated VOCs (acetone)
- **Semi-Volatile Organic Compounds**

-total petroleum hydrocarbons (TPH)
-polycyclic aromatic compounds (PAH)
-phenols
-phthalates
-some oxygenated SVOCs (>C_3 alcohols, aldehydes)
- **Pesticides, e.g., DDT, toxaphene**
- **Other chlorinated aromatics, e.g., PCBs, PCDD/PCDFs**
- **Other**

-oils
-tars

Soil characteristics that influance the application of the chemical oxidation

- **Heterogeneity** - the variability of the soil types at a site, such as sandy, clayey, gravel, the presence of sand or clay lenses or fractures
- **Permeability**, the ability to move air and water through the soil
- **Humus content** – the natural organic matter present in soils

Lab-scale studies are necessary.

Lab-scale treatability studies (aims)

- to assess the effect of **contaminants' aging** on the feasibility of treatment processes;
- to optimize **treatment conditions** (influence of treatment time, manner of remedies addition, etc);
- to find the optimal treatment conditions in order to minimize stress on soil bacteria after the application of strong oxidants and to **support the following biodegradation** of contaminants;
- to estimate possible secondary effects of the treatment on soil quality by **ecotoxicological responses**;
- to **estimate treatment cost**s;
- **to establish the effective treatment methods.**

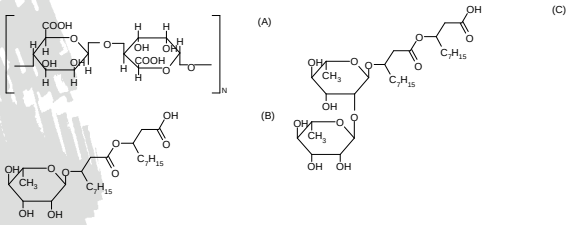
Chemicals applied in the present lab-scale study

- hydrogen peroxide (liquid carrier);
- sodium peroxodisulfate (persulfate);
- calcium and magnesium peroxides (solid carriers of hydrogen peroxide)

Activation aids

- supplemental ferrous iron, ferric iron;
- EDTA chelated ferrous iron;
- natural transition metals and minerals;
- EDTA chelated natural transition metals of soil;
- combined application of persulfate and hydrogen peroxide;
- base activation of persulfate;
- application of acidic pH to sustain the persulfate and hydrogen peroxide activation processes

Biosurfactant (BS) - rhamnolipid-alginate complex obtained by biosynthesis of strain *Pseudomonas* sp. PS-17



- Structures of the BS components: (A) polysaccharide alginate, (B) monorhamnolipid, (C) dirhamnolipid.

Aims of the study

To evaluate and compare the individual chemical impact on HCH-contaminated soil treatment.

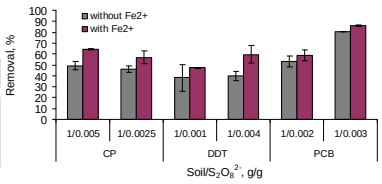
To test different activation aids as the selection of that depends not only on the remedial chemical used, but also on the target contaminant.

To resolve the benefits of the treatment with combined application of biosurfactant and the chemicals.

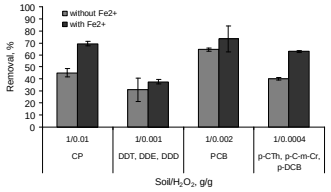
Several characteristics of the soil

Property	Value
Soil texture	**sandy silt**
pH	**5.2**
Ferrous iron fraction, g/kg of soil	1.9±0.5
Total extractable iron, g/kg of soil	**12.1±0.9**
Ion-exchangeable Fe(II) fraction, mg/kg of soil	2.0±0.3
Organic carbon, mg/kg of soil	**460±30**

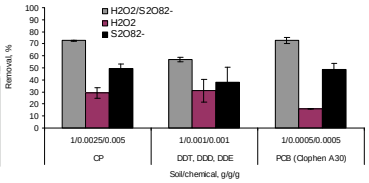
Contaminants removal in soil slurry at natural soil pH by 1-d persulfate treatment with different w/w ratios of soil/persulfate ($S_2O_8^{2-}$/Fe^{2+}=10/1, g/g).



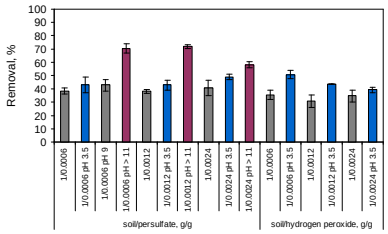
Contaminants removal in soil slurry at natural soil pH by 1-d hydrogen peroxide treatment with different w/w ratios of soil/hydrogen peroxide (H_2O_2/Fe^{2+}=10/1, g/g).



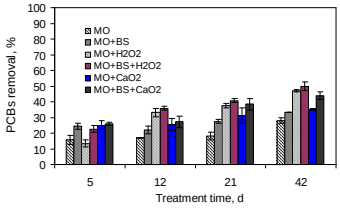
Contaminants removal in soil slurry at natural soil pH by 1-d persulfate, hydrogen peroxide and combined hydrogen peroxide and persulfate treatment with different w/w ratios of soil/persulfate.



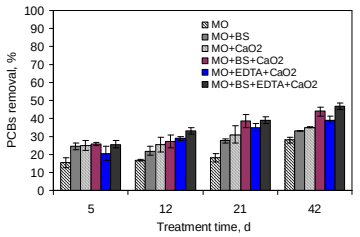
Total DDT removal (% of initial, mean ± standard deviation) by a 24-h treatment of soil with persulfate or hydrogen peroxide at different initial values of pH and weight ratios of soil/chemical.



PCB-containing oil removal by combined chemical–biological treatment system utilizing liquid H_2O_2 and CaO_2 (soil/H_2O_2 of 1/0.0005 w/w, 0.025 g EDTA kg^{-1} of soil and 0.4 g BS kg^{-1} of soil).



PCB-containing oil removal by combined chemical–biological treatment system utilizing CaO_2 (soil/CaO_2 of 1/0.0005 w/w, 0.025 g EDTA kg^{-1} of soil and 0.4 g BS kg^{-1} of soil).



- Summarizing the results of the present study it can be concluded that the **process integration achieved by joint application of biosurfactant, oxidizing chemical in moderate dosages and microbial consortium could be a promising option** for soil decontamination resulting in improved treatment efficacy.
- **The utilization of a pro-longed treatment time with moderate addition of the remedial chemical could be recommended** in order to reduce the non-productive oxidant decomposition and to promote the co-existence of chemical and biological oxidation of the contaminants.

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