In-situ chemical oxidation

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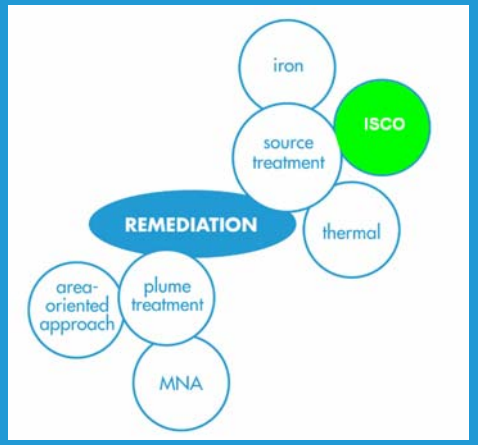
INTERREG IVB

Introduction ISCO

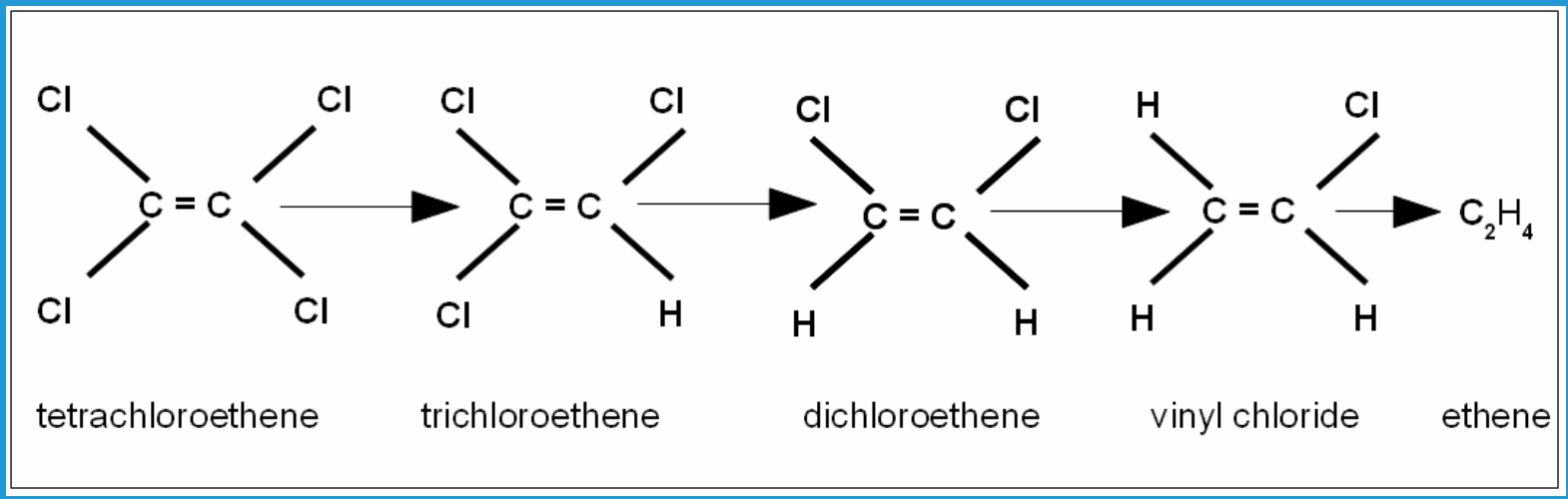


- Relative new technique for the remediaton of the source

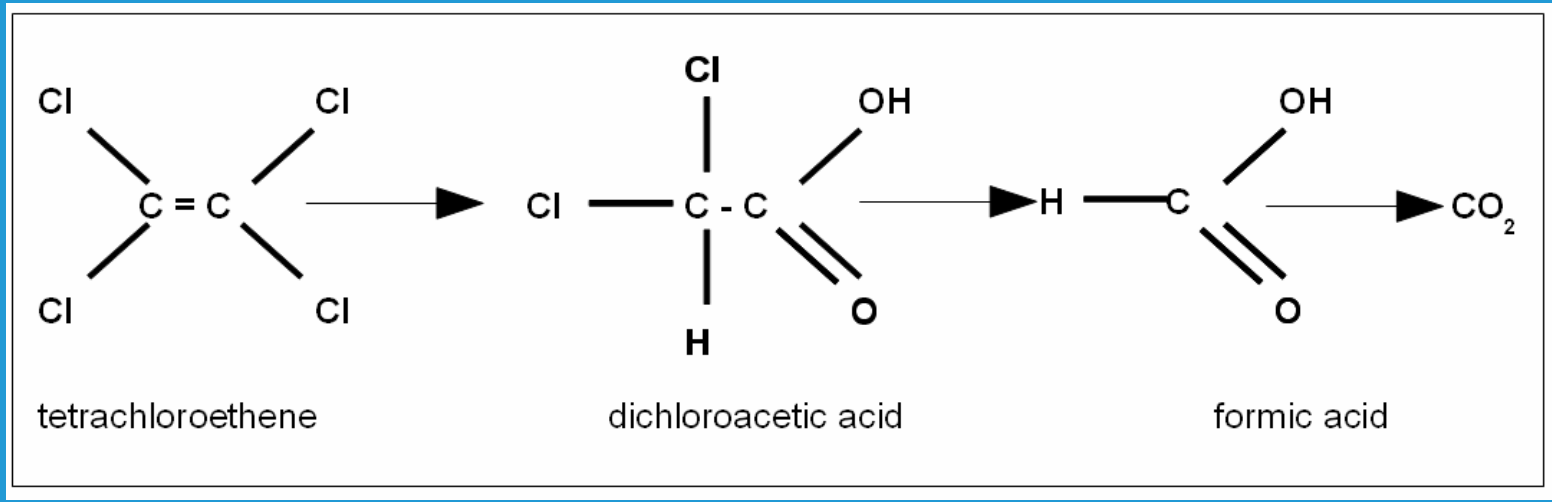
  <u>Principle</u>: the injection of a strong oxidant in the soil that breaks down the pollution chemically

- **Advantages:**
  - **No excavation necessary**
  - **Limited duration**
  - **No accumulation of toxic products**

No accumulation of toxic products



Anaerobic biological degradation



Chemical oxidation

Oxidants

The products used for ISCO are the following oxidants or are based on the following oxidants, often combined with auxiliary products (iron, acids, chelator,...)

1. **Hydrogen peroxide (H_2O_2)**
2. **Sodium and potassium permanganate (MnO_4^-)**
3. **Sodium persulphate ($Na_2S_2O_8$)**
4. **Ozone (O_3)**

1. Hydrogen peroxide

- Must be catalysed to form radicals (e.g. iron: Fenton's reagens)
  - Classical acid Fenton's reaction: pH between 3.5 – 5
  - Modified Fenton's reaction: organic chelator
- Complex and different chemical chain reactions
- Applied in concentrations between 5 – 10 % (vol)

1. Hydrogen peroxide

Pro

- Powerful oxidant
- Low cost per oxidizing equivalent
- Attacks DNAPL
- Heat production (enhances desorption)

Contra

- Challenging to apply
  - Activator necessary (iron – pH)
- Short lifetime (< day)
- Heat and gas production can limit applicability
- Possible mobilisation of metals
- Not suitable for soils rich in carbonates

2. Permanganate

- <u>Sodium permanganate</u> (liquid) or Potassium permangante (solid)
- Simple stoichiometric reaction (no radicals)

$$C_2HCL_3 + 2\ MNO^{4-} \rightarrow 2\ MnO_2 + 2\ CO_2 + 3\ Cl^- + H^+$$

- Temporary coloring of the groundwater (purple)

2. Permanganate

Pro

- Easy to apply
- Long lifetime (weeks to months)
  - ➢ Diffusion is possible
- Mild reaction

Contra

- Less powerful, but suitable for chloroethenes
- Not suitable for DNAPL
- MnO_2 deposition, reduce permeability

3. Sodium persulphate

- Must be catalysed to form radicals
  - Iron
  - Heat (temperature above 30°C)
  - Hydrogen peroxide
  - pH > 10.5
- Complex and different chemical chain reactions
- Applied in concentrations to approx. 5 % (vol)

3. Sodium persulphate

Pro

- Powerful oxidant
- Long lifetime
- No production of heat, gas

Contra

- Highest oxidant cost
- Activator necessary
- High resultant sulphate concentration (> 1000 mg/l)
  - Negative impact on anaerobic biological remediation
- Less experience

4. Ozone

- Gas
- Complex and different chemical chain reactions
- not suited for DNAPL’s
- Often combined with hydrogen peroxide

4. Ozone

Pro

- **Harmless reaction products**
- **Production of O_2, stimulation of aerobic degradation**

Contra

- **Toxic gas**
- **Limited supply, longer duration**
- **Must be generated on-site**
- **High production cost, cooling necessary**

Injection techniques

1. Direct push

Pro

- **Relatively simple to treat specific areas at certain depth**

Contra

- **If a second injection is required, a new mobilisation is necessary, which strongly increases the costs**

Injection techniques

2. Fixed filters

Pro

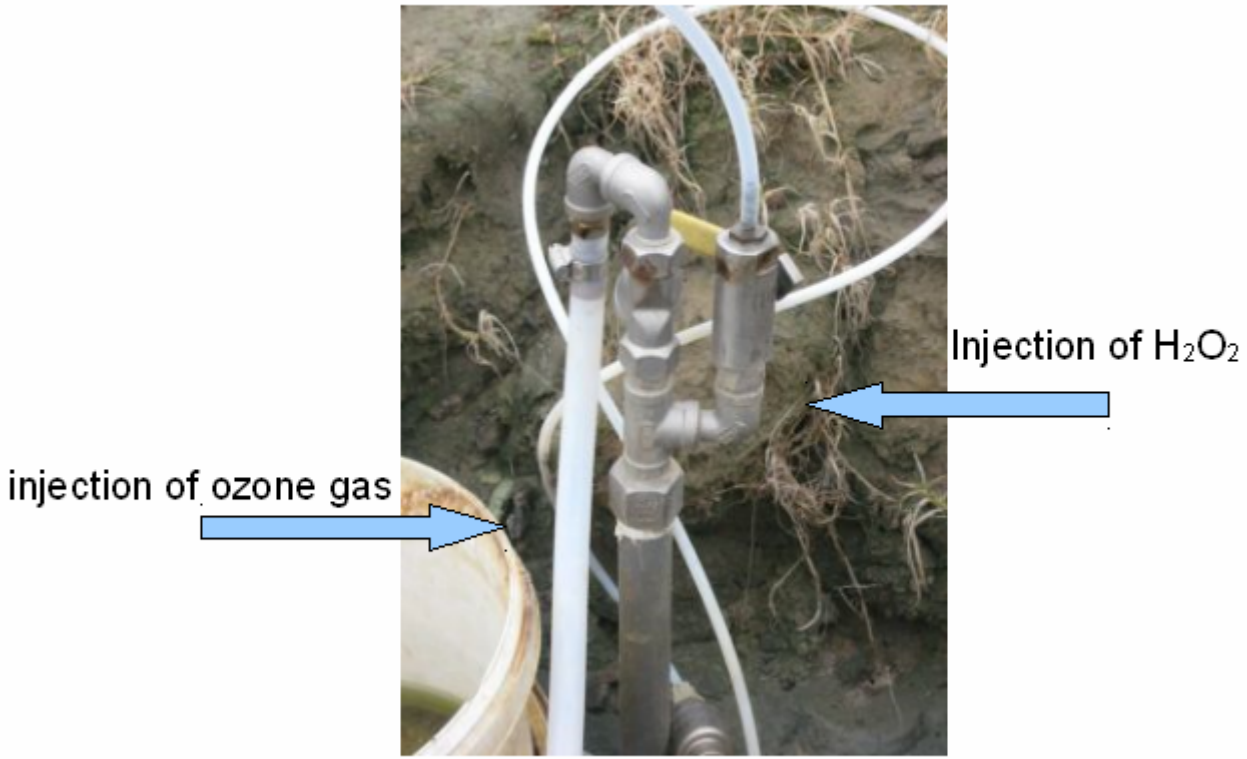
- **A second injection is very simple (rebound)**
- **Easy to follow up**

Contra

- **Cost of the material**
- **Time to install**

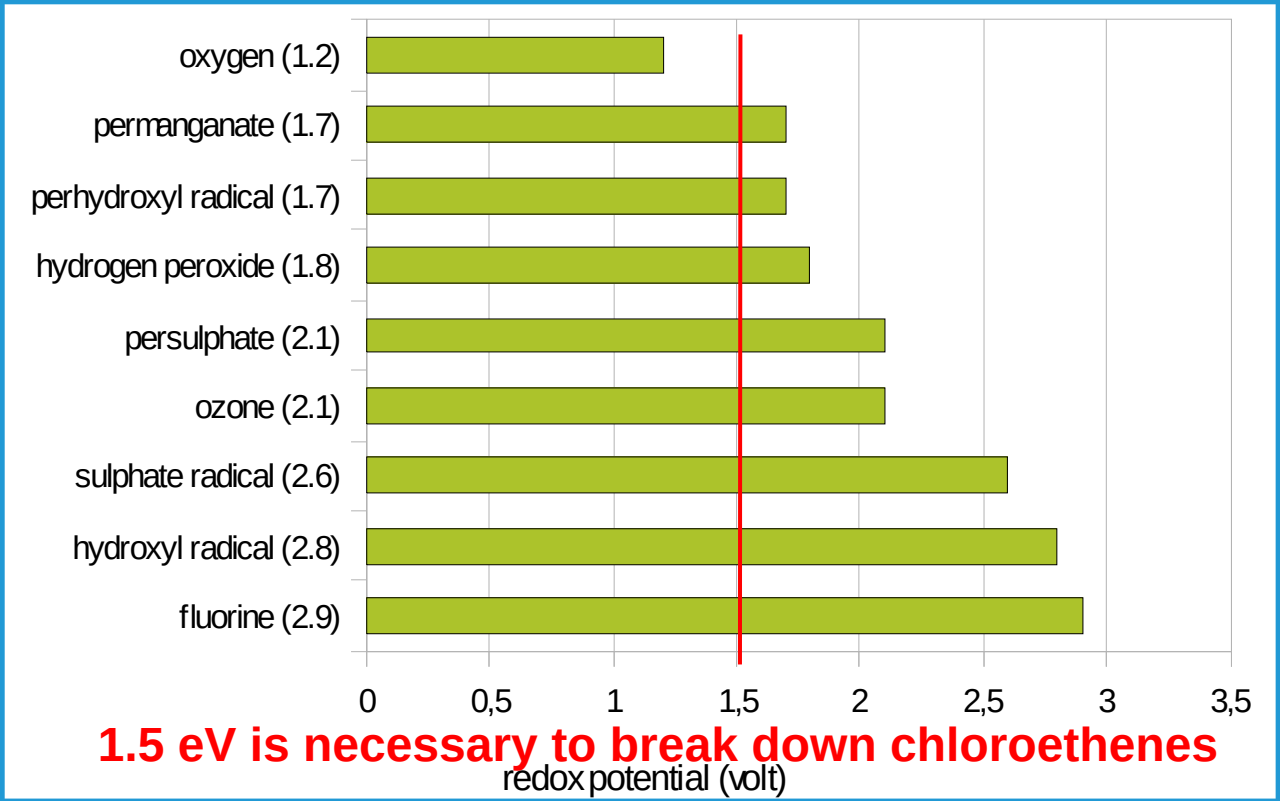
Injection techniques

3. Ozone sparging



Points of attention

. **The oxidizability of the soil contaminants**



1.5 eV is necessary to break down chloroethenes

Chlorinated ethenes are very well oxidizable with different oxidants, chlorinated ethanes are slightly harder oxidizable

Points of attention

2. **The concentration of the soil contaminants**

   ISCO is especially interesting for the remediation of zones with high contaminant concentrations (source), not possible to remediate with NA

3. **The local geology and hydrogeology – Good CSM**

   Knowledge about the permeability and homogeneity of the formation, spreading of the pollution (source zone and plume), pollution load (ground and groundwater), presence of preferential channels, groundwater flow,...
   Pilot test is recommended

4. **The stability of the oxidant**

   The use of a stable oxidant (permanganate) is advisable in less permeable soils

Points of attention

5. The soil oxidant demand

$$SOD = (Effective\ oxidant\ use - oxidant\ used\ by\ pollution)$$

- The amount of oxidant consumed by the oxidation of the soil material, excluding the soil contaminants (e.g. organic matter).
- Based on lab test: ISCO (economically) feasible

6. The cost (of the oxidant)

Depends of the unit price and the consumption of the oxidant but more important factors are: injection method, injection time, number of injections required

Points of attention

7. Safety and health aspects

In addition to the general safety and health requirements, there are extra aspects to take into account:

- Handling and storage of chemicals
- Thermodynamic aspects of ISCO

8. Rebound

just like with other in-situ techniques there is always a rebound effect

- Discharge into the groundwater due to remaining DNAPL
- Diffusion from less permeable layers
- Oxidation of organic material to which the contaminants were absorbed

Solution: second injection of combination with stimulated NA

Recommendations

1. Hydrogen peroxide

- Fenton’s reagens is best injected in very permeable soils, in less very permeable soils modified Fenton’s can be used
- Not suited for soils with high organic matter (peat) because of high SOD, potentially heavy reactions, setting of peat
- If necessary combined with soil vapour extraction

Recommendations

1. Hydrogen peroxide

- Always fixed injection filters
- The injection with catalyst always precedes the injection with oxidant (no above ground mixture)
- Preferably discontinuously injected

Recommendations

2. Permanganate
    - Can be applied in less permeable soils, considering it is a stable oxidant with long after effect
    - Weak oxidant and is preferably used in plume area's or as after treatment (polishing step) of a source remediation
    - Not recommended for DNAPL's because of crust formation of MnO_2 around the pure product
    - Sodium permanganate (fluid) is easier manageable than Potassium permanganate (powder)
    - Fixed injection, direct push or soil mixing

Recommendations

3. **Persulphate**
    - **Can be applied in less permeable soils, considering it is a stable oxidant with long after effect (shorter than permanganate)**
    - **Can be used for oxidizing DNAPL's, but taking into account the cost it's better to use as a polishing step after, for example, an injection with peroxide**
    - **Injection near concrete constructions is not recommended due to possible impact on the concrete**
    - **Fixed injection or direct push**

Conclusions ISCO

- Frequently and successfully used in different soils
- Cost-effective to quickly reduce pollutant load
- To obtain very low concentration, ISCO must be combined with other techniques:

  very well combinable with stimulated NA !!

- Complex technique: to be successful the soil expert and contractor must have the necessary knowledge and practical experience

More information :

Code of good practice
In-situ chemical oxidation

www.CityChlor.eu

www.youtube.com/user/citychlor

linkedIn