Groundwater Sanitation

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Groundwater Sanitation:

- About 75% of German drinking water is extracted from groundwater
- Large sections of groundwater polluted (especially area of former GDR)
- Pollutants must be removed
- New contamination has to be prevented
- Chosen method depending on type of contamination and situation on site
- Can be done *in-situ* oder *ex-situ* using
  - biological,
  - physico-chemical methods or
  - a combination of both
Possible sources of groundwater pollution:

- Industrial processes
- Mining
- Dry-cleaning
- Environmental accidents

Most common contaminants:
- BTEX, PAHs, haloginated compounds
- Heavy metals
- Nitrate
- Often complex combination of many different substances
Biological methods:

- **Bioreactors**
  - Aerobic conditions (e.g. for volatile chlorinated hydrocarbons)
  - Anaerobic conditions (e.g. for BTEX)
  - Active sludge basins, fluidized/fixed bed reactors (biofilm reactors)

- **Stimulation of microbial activity *in-situ***
  - Addition of electron-acceptors/-donors
  - Aeration
  - Addition of nutrients
Physico-chemical methods:

- Oxidation / reduction (e.g. by $O_2$ or $H_2O_2$)
- Sedimentation
- Ion-exchange
- Filtration (slow sand filter, deep)
- Adsorption (activated carbon)
- Stripping (removal of volatile compound by aeration / suction)
- Catalytic processes (e.g. dechlorination of halogenated hydrocarbons)
The integrated approach

- Three steps:
  1. Removal of contaminated soil
  2. Sanitation of aquifer and groundwater (combined biological and physico-chemical)
  3. Prevention of re-contamination (e.g. by sealing the ground and preventing pollutants from entering the aquifer)
Example: Former gasworks Flingern
The gasworks between 1890 and 1968:

- Benzene factory
- Fuel depot
- Cracker
Example: Former gasworks Flingern

- Was used as cokery for production of coke, tar, ammonia and gas
- Contamination with aromatic hydrocarbons caused by
  - Leakages (tanks, pipes)
  - Losses during decanting benzene
  - Bombardment in WW2
- Today:
  - used mainly by Stadtwerke Düsseldorf AG
  - Amongst others: Incineration plant and coal-fired power plant
  - Some parts of the site are not usable due to the contamination with BTEX
Example: Former gasworks Flingern

Spread of contamination:
Sanitation:

Aim:
- < 10 µg/L BTEX in groundwater

Conditions:
- Anaerobic groundwater

Concept:
- Combination of off-site, on-site and *in-situ* techniques
  - Off-site: contaminated soil is dredged out and thermically treated
  - On-site: the groundwater is pumped into a bioreactor; the treated water is then reinfiltrated upstream to the contamination source
  - *In-situ*: Addition of electron-acceptors to infiltration water to stimulate microbiological activity in the aquifer
Anaerobic degradation of Ethylbenzene:

Improved BTEX-biodegradation:
SO$_4^{2-}$-addition → fast degradation of Ethylbenzene, Toluene, Benzene and Xylol (in this order)

Best biodegradation under sulfate-reducing conditions
Reactions in the aquifer:

BTEX-degradation under sulfate-reducing conditions
Limiting factor: Sulfate
Schematic view of the treatment plant:
Results:

![Graph showing BTEX, Naphthalene, and Sulphate concentrations over time.](image)

- **BTEX**: 10 µg/L
- **Naphtha**: 2 µg/L

**Example:** Former gasworks Flingern
Example: The SAFIRA project
Example: The SAFIRA project

- Located in Bitterfeld
- Bitterfeld former place of leaching mining and chemical industry (in GDR)
- Well-known example for multiple contaminations (no environmental protection in the GDR)
- Abandoned polluted areas still big problem
• SAFIRA (Sanierungsforschung in regional kontaminierten Aquiferen)
  – Interdisciplinary approach to develop cheap in-situ remediation techniques to clean complexely contaminated groundwaters
  – Based on biological and physico-chemical methods
Cleaning concept:

1. Microbial colonisation of subsurface at test site:
   Target: degradation of chlorobenzenes using SRBs and denitrifyers

2. Elimination of volatile compounds by adsorption (activated carbon) – MO cover activated carbon as biofilm and degrade adsorbed pollutants – continuous regeneration of AC

3. Dechlorination of chlorohydrocarbons (electrochemical and catalytic) – Catalyst: Pd on activated carbon
Model of the pilot plant:
Results (from 2000):

- The in-situ plants promise cheap and effective groundwater decontamination
- Large areas can be remediated
- Combination of different methods provides relatively fast degradation of pollutants
- Although: remediation of the test site will last > 10 years

Still to be researched:

- Best combination of reactors, actual process is not optimal