

Sustainable management of contaminated sites

Presentation 2.1

Phase 2 – PCB Contaminant behavior

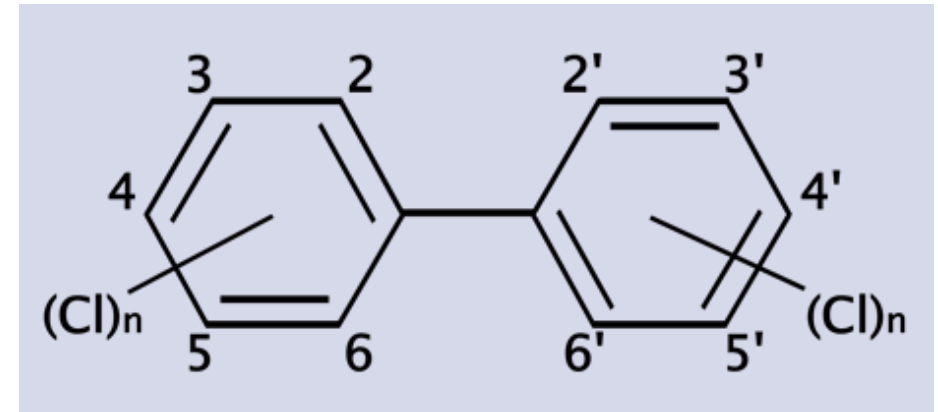
Charles Pijls

Summarized & presented by Boudewijn Fokke

October 2021

Contents

- PCB chemical and physical properties
- Contaminant behavior in soil and groundwater
- Examples CSM
- Questions ?



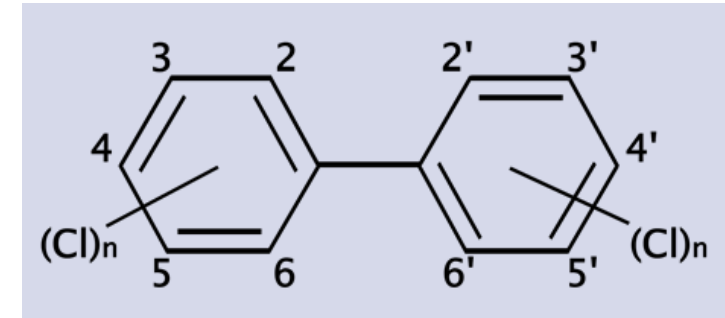
Dutch PCB reference framework for soil

- Limit value PCB total = 0.02 mg/kg dw or ppm
- Remediation value PCB total = 1 mg/kg dw or ppm
- PCB total are PCB 28, 52, 101, 118, 138, 153 and 180

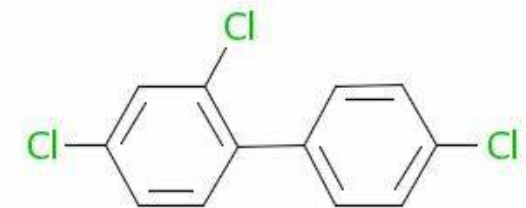
PCB chemical and physical properties

PCB - Polychlorinated biphenyl - $C_{12}H_{10-x}Cl_x$

- Man-made organic chemicals
- Classified as a POP (Persistent Organic Pollutant)
- Annex 1 of the Stockholm Convention,
- By 2025 elimination of the use in equipment
- 209 PCB congeners with similar organic structure but varying number of chlorine
- The positions of chlorine atoms on the benzene rings are indicated by numbers assigned to the carbon atoms
- PCB total are PCB 28, 52, 101, 118, 138, 153 and 180



PCB No 28



2,4,4'-PCB / $C_{12}H_7Cl_3$ is number 28 in the list

PCB chemical and physical properties

Properties

- High heat stability
- Hardly inflammable (complete combustion only at $> 1000\text{ }^{\circ}\text{C}$)
- Relatively good acid, alkali and chemical resistance
- Stable against oxidation and hydrolyze
- Only poorly soluble in water (polar fluid)
- Soluble in organic fluids / fat / oil (a polar fluid)
- Good heat conductivity
- Low vapor pressure
- Very small electrical conductivity (good insulator)



PCB applications

PCB in closed applications

- Insulation and/or cooling fluid in transformers
- Dielectric fluid in capacitors
- Hydraulic fluid in lifting equipment, trucks and high-pressure pumps (mining industry especially)

PCB in partially open applications

- Heat transfer fluids
- Hydraulic fluid
- Vacuum Pumps
- Switches
- Voltage Regulators
- Liquid Files Electrical Cables
- Liquid Files Circuit Breakers



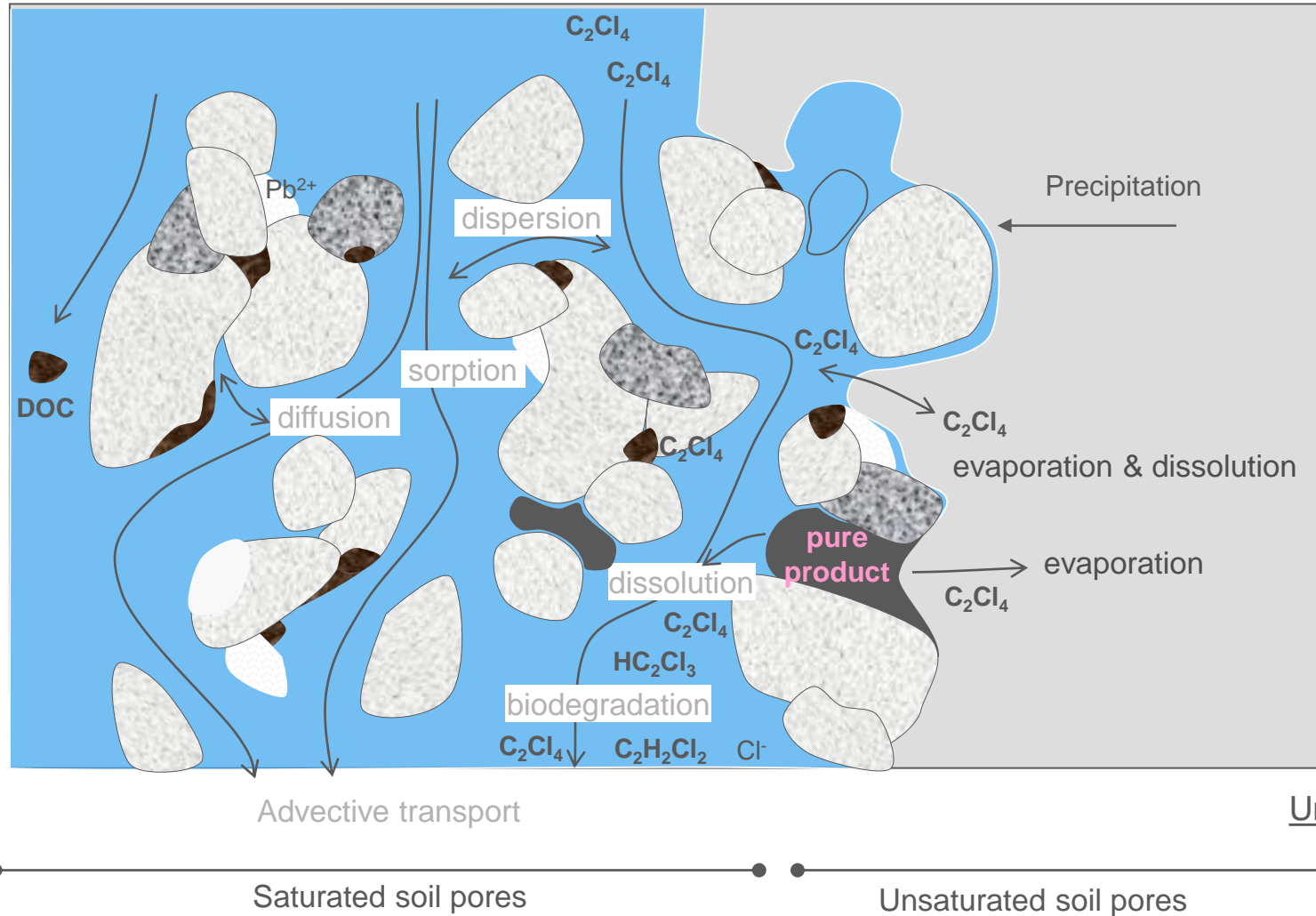
PCB Application in Open Systems

- Building materials
 - ✓ Sealants
 - ✓ Oil-based paint
 - ✓ Plaster
 - ✓ Ceiling components
 - ✓ Etc.
- Lubricating fluid in oils and grease
- Water-repellent impregnating agent
- Fire retardant for wood, paper, fabric and leather
- Laminating agent in paper production
- Additive in glues, sealants and corrosion protection coatings
- Carrier for insecticides
- Polymerisation catalyst support for petrochemicals
- Cable coatings/casings



Contaminant behavior in soil and groundwater

Distribution in soil compartments



Physical process

- Sorption
- Dispersion
- Diffusion
- Evaporation
- Precipitation

Chemical process

- Dissolution
- Complexation

Biological process

- Biodegradation

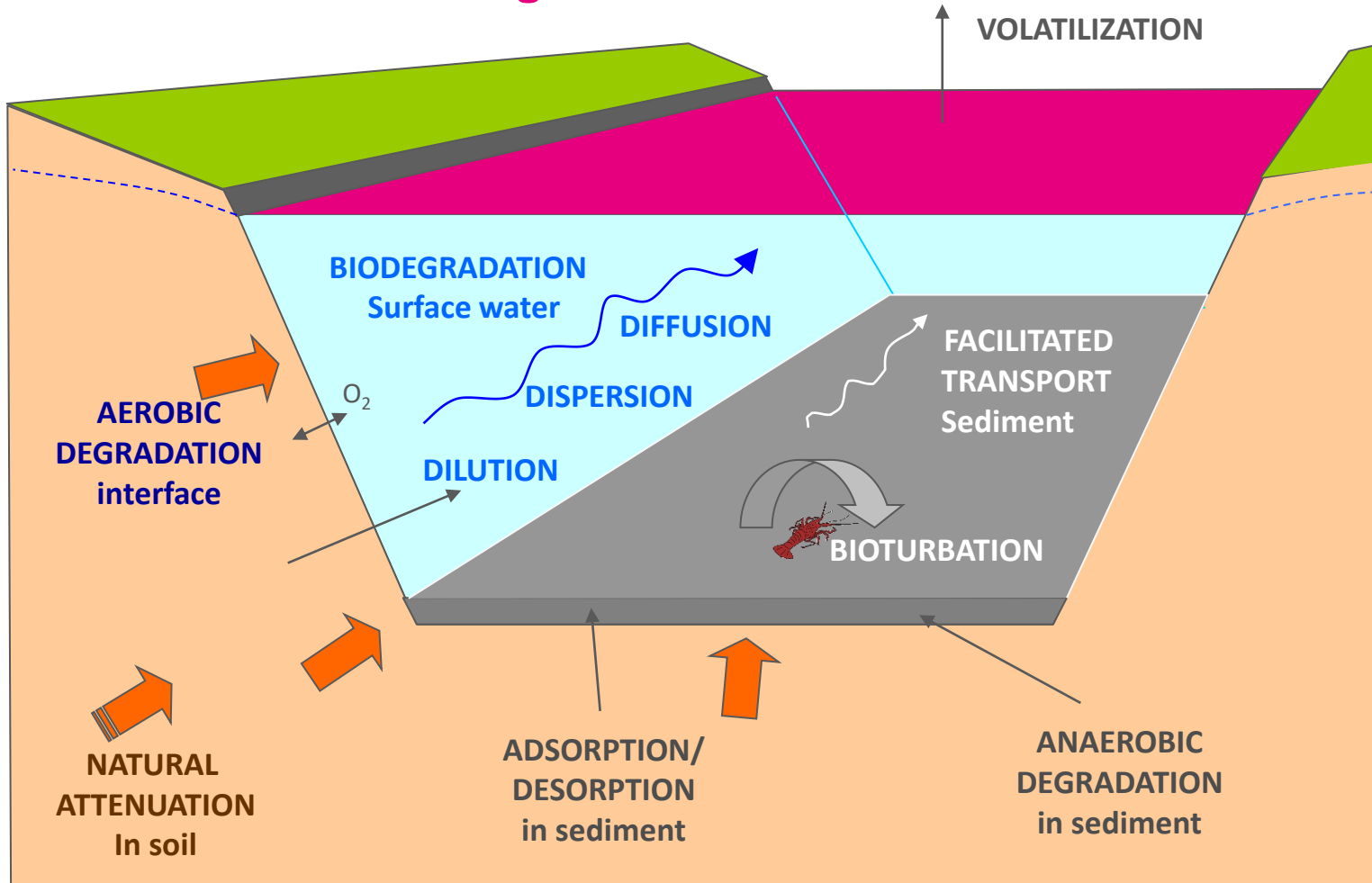
Underlined processes are most relevant for PCB



Contaminant behavior in soil and groundwater

Processes in the hyporheic zone

Hyporheic zone- the interface of groundwater & surface water



Contaminant behavior in soil and groundwater

Important contaminant properties

- Melting point
- Density
- Solubility
- Viscosity
- Residual saturation
- Biodegradability



Contaminant behavior in soil and groundwater Migration

- **Migration of solids**
 - By wind erosion
 - By run-off
 - Dissolution
 - Degradation (bio/photo-chemical)
- **Migration of liquids**
 - Infiltration in soil
 - Dissolution
 - Volatilization
 - Degradation (bio/photo-chemical)
- **Attention**
 - **Cosolvents** (PCB in oil)
 - **Facilitated transport** (e.g. dioxins and organic matter)

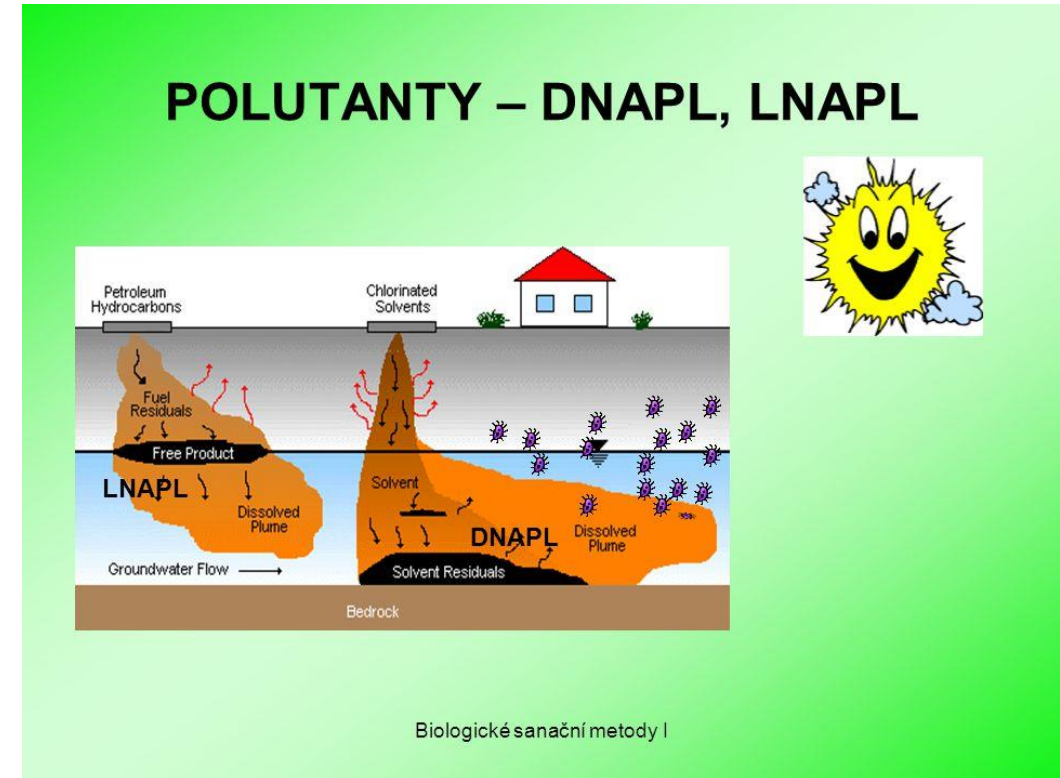


Contaminant behavior in soil and groundwater

Density

Density with respect to water

- Density $< 1 \text{ kg/dm}^3$
 - ✓ Light Non-Aqueous Phase Liquids or **LNAPL**
 - ✓ Petroleum- en aromatic hydrocarbons
 - ✓ Free phase in monitoring wells
- Density $> 1 \text{ kg/dm}^3$
 - ✓ Dense Non-Aqueous Phase Liquids or **DNAPL**
 - ✓ (Volatile) chlorinated solvents (e.g. Tri, Per, Tetra)
 - ✓ DNAPL in monitoring wells
 - ✓ Salt solutions
- Density $> 5 \text{ kg/dm}^3$
 - ✓ Heavy metals

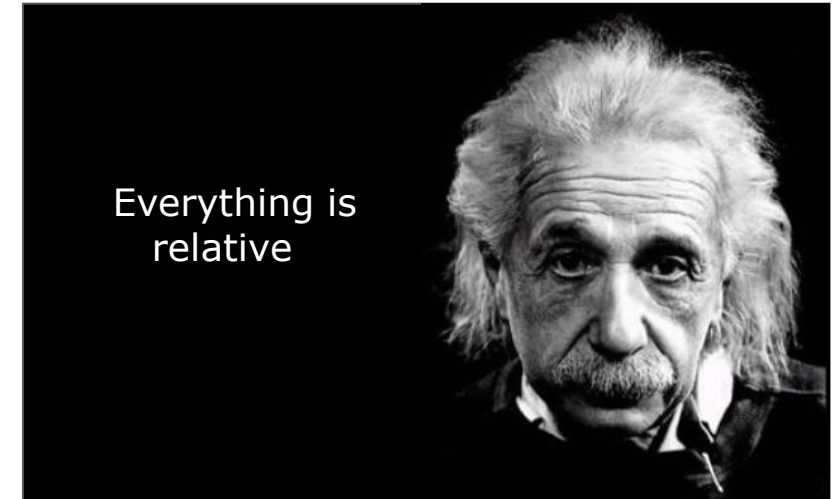


PCB1 density varies from 1.182 to 1.566 kg/dm^3

Contaminant behavior in soil and groundwater

Solubility

- Solubility is a relative concept
- High water solubility
 - ✓ Salts
 - ✓ Aromatic and chlorinated solvents
- Low water solubility
 - ✓ Poly-Aromatic Hydrocarbons
 - ✓ Petroleum Hydrocarbons
 - ✓ Metals
 - ✓ PCB (but good soluble in fats, oils and organic solvents)



PCB is low water soluble: 0.0027–0.42 ng/L

Contaminant behavior in soil and groundwater

Diffusion

Diffusion:

Contaminant transport resulting from concentration gradients

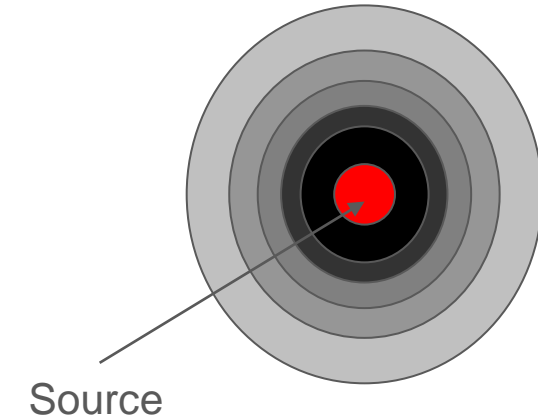


Not Diffusion resistant tank



Diffusion resistant piping

Migration in time



Contaminant behavior in soil and groundwater

Viscosity

- **Viscosity – Milli Pascal seconds (mPa-s) of**

- ✓ Trichloroethene 0.55
- ✓ Gasoline 0.7
- ✓ Water 20 °C 1
- ✓ Mercury 1.5
- ✓ Diesel 4
- ✓ Asphalt 10^5
- ✓ Glass 10^{18}

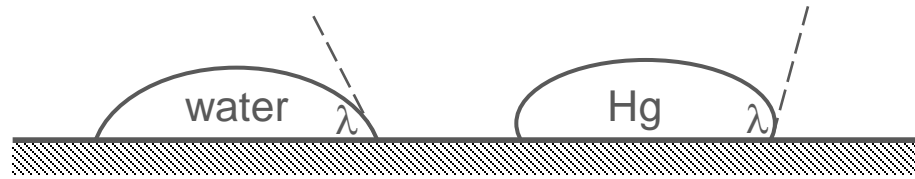


Viscosity PCB ranges from oil to a thin, light-colored liquids to yellow or black waxy solids

The more chlorine atoms in the molecules, the more viscous the PCB is

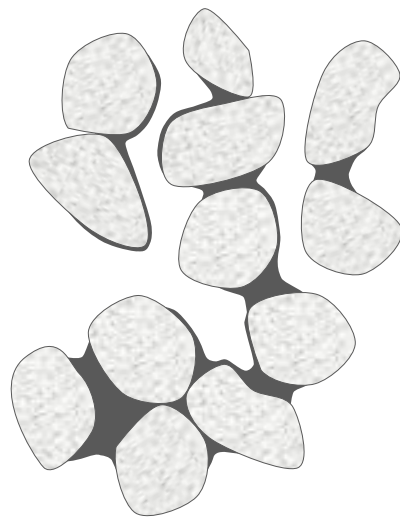
Contaminant behavior in soil and groundwater

Surface Tension and Residual Saturations

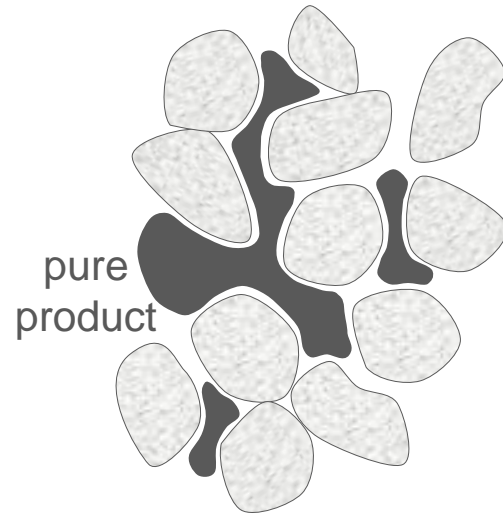


wetting

non-wetting



wetting



non-wetting

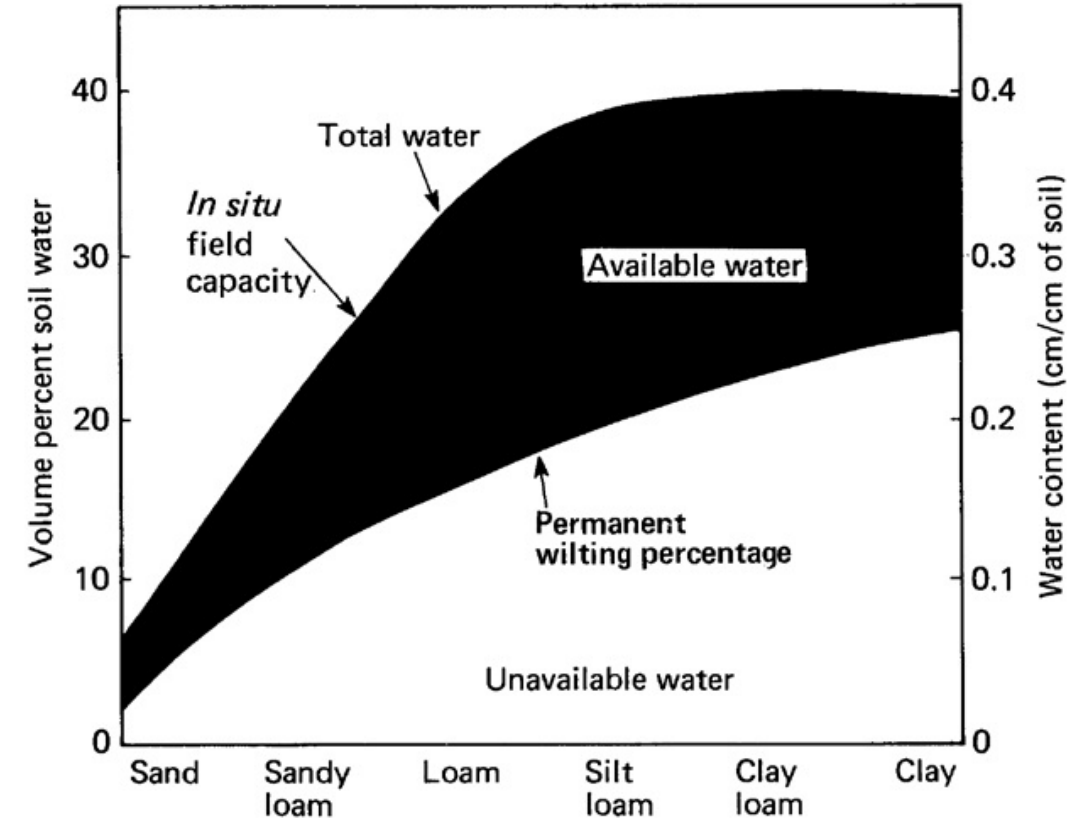


Contaminant behavior in soil and groundwater

Residual Saturation

Liquids are retained in soil pores

- Residual Saturation = $\frac{\text{Volume retained liquid}}{\text{Total pore volume}}$ l/m³



- Soil with high permeability: Residual Saturation = 3 - 5 l/m³
- Soil with low permeability: Residual Saturation = 20 - 40 l/m³

Contaminant behavior in soil and groundwater

Biodegradation

- Bacteria benefit from biochemical reactions (transfer of electrons)
- Essentials:
 - ✓ Bacteria
 - ✓ Reducer is an electron-donor, substrate
 - ✓ Oxidizer is an electron-acceptor



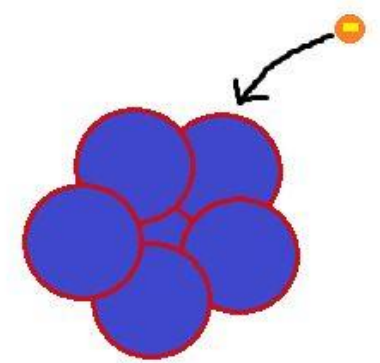
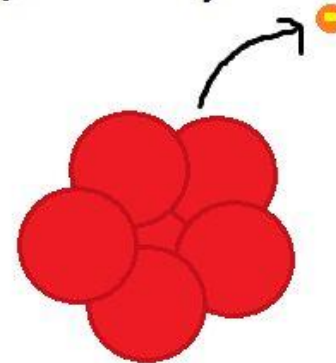
Contaminant behavior in soil and groundwater

Biodegradation

- **Oxidative degradation**
 - ✓ Contaminant is electron donor
 - ✓ Oxygen is electron acceptor
- **Reductive Degradation**
 - ✓ (Natural) organic matter is electron donor
 - ✓ Contaminant is electron acceptor



Layers of Learning



Oxidation & Reduction

Contaminant behavior in soil and groundwater

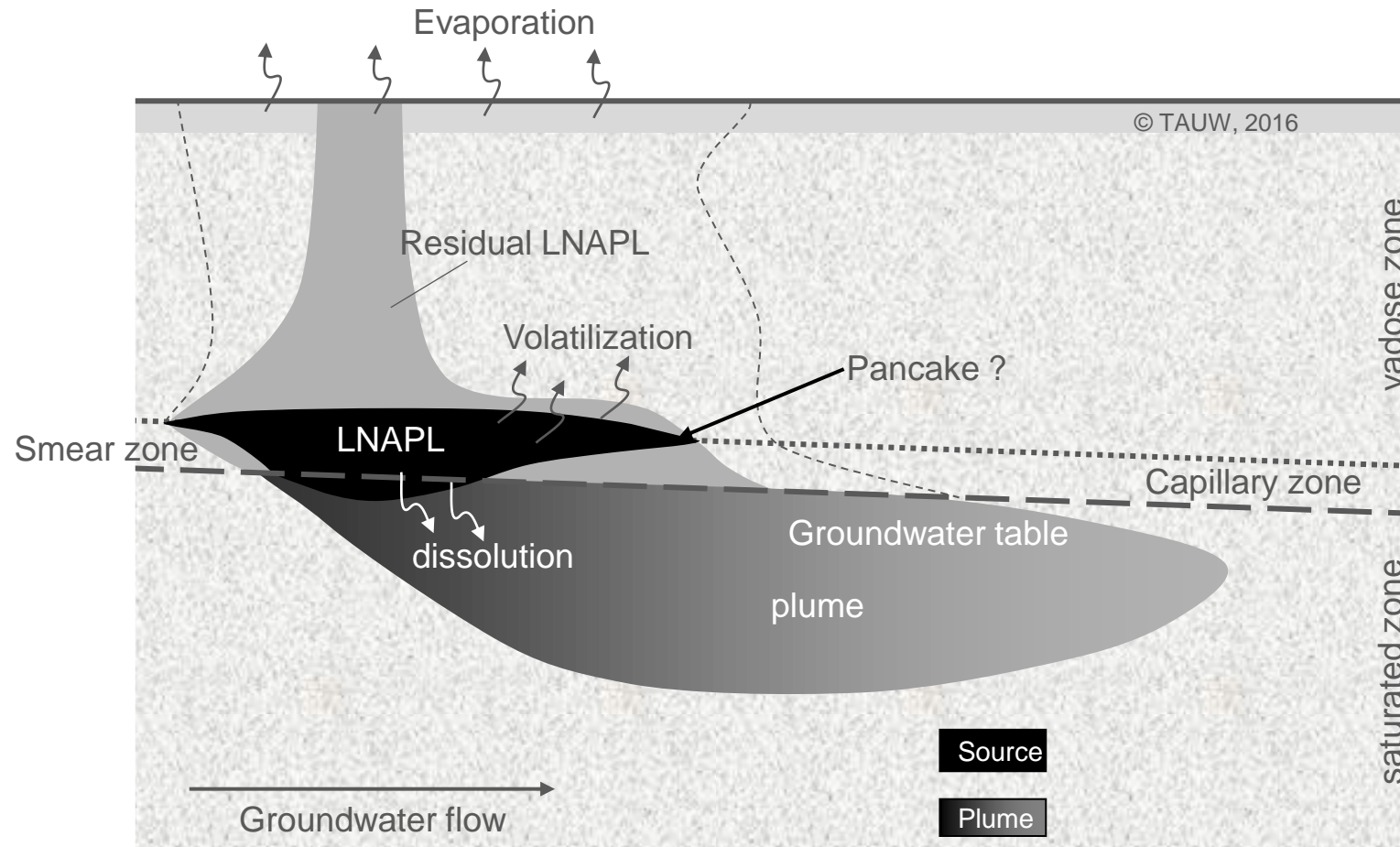
Biodegradation

- Practically all organic matter can be biodegraded
- How can we accelerate biodegradation processes
 - ✓ Balancing electron donor and acceptor
 - ✓ Increase temperature
 - ✓ Addition of nutrients (N and P)
 - ✓ Addition of bacteria (bio-augmentation)
 - ✓ Keep moist



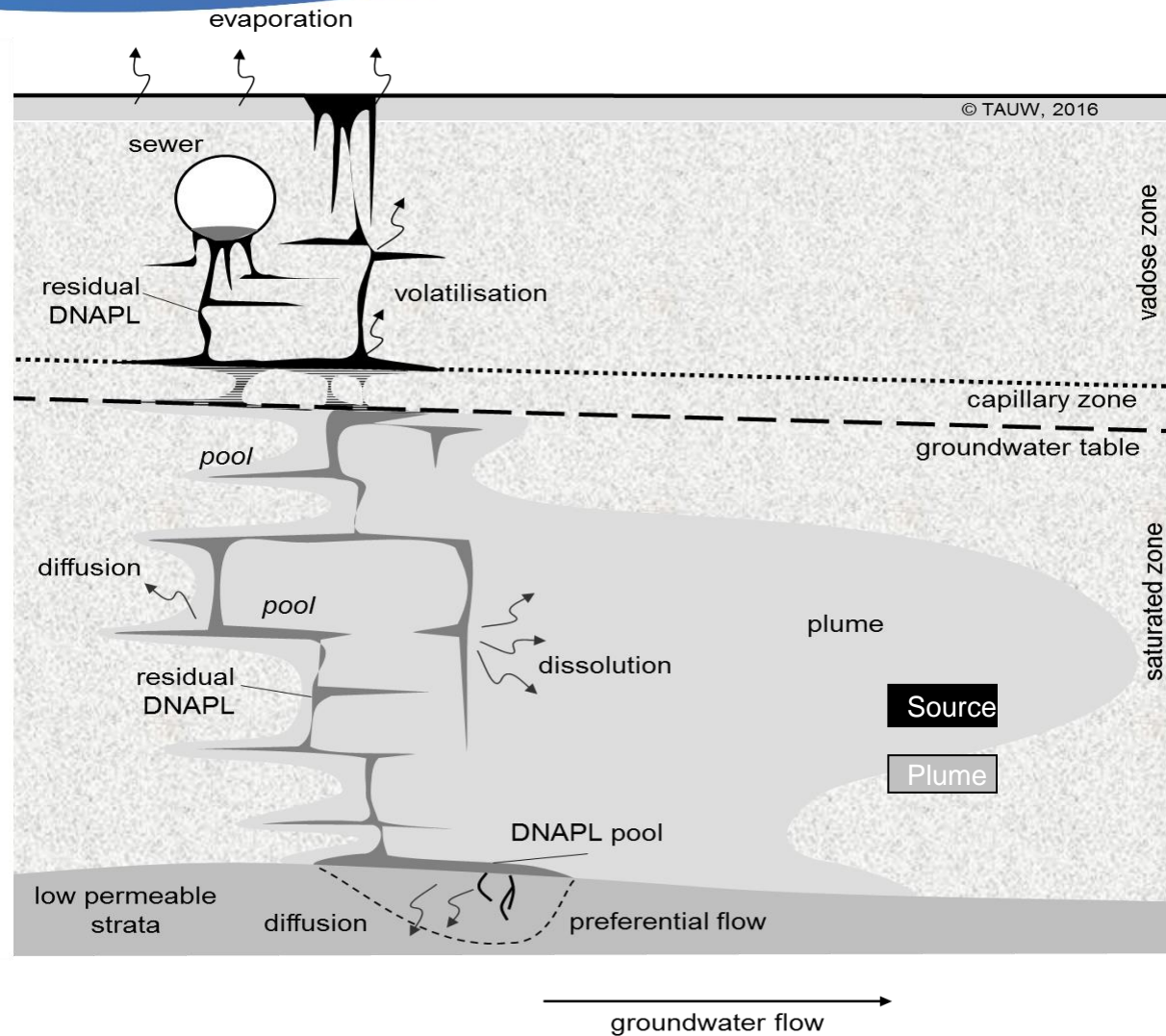
Petroleum hydrocarbons

Conceptual model of migration



Volatile chlorinated solvents

Conceptual model of Migration



Questions?

Contact



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