

Remediation of soil and groundwater
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Problem set # 6: soil treatment and washing

Problem 1: Windrow

The owner of a property contaminated with petroleum must remediate the site completely in one year. Approximately 40,000 m³ of soil with a mean total petroleum hydrocarbon contamination (TPH) of 10,000 mg/kg (maximum of 98,000 mg/kg) must be remediated to a mean of 100 mg/kg (maximum 500 mg/kg). The owner is considering windrow composting. Laboratory tests show a first order degradation rate of 0.07 d⁻¹. Can the goal be achieved? (Use hexane as a proxy for TPH)

Hexane: $K_D=39$ L/kg and $K'_H=6 \cdot 10^{-6}$ [-]

Soil: porosity $\varepsilon=0.3$ [-]. Volumetric water content $\theta=0.1$ [-]

Wet bulk density $\rho_{wb}=1500$ kg.m⁻³

Problem 2: Biopile or slurry

Acidic petroleum sludge-impacted soils from an oil refinery in Poland requires treatment. The soil was contaminated with PAHs and BTEX compounds. A volume of 3,300 m³ of wet soil with a concentration of 30,000 mg TPH/kg dry soil (hexane-equivalent) was targeted for treatment. The soil wet density is 1,440 kg/m³. The volumetric soil moisture content is 0.2. Density of water is 998 kg.m⁻³.

1. What volume of air-saturated water would be needed to degrade 1 gram of hexane? Considering the soil to treat, how much oxygen-saturated water is needed stoichiometrically to degrade 90% of the contaminant? Is slurry phase treatment a feasible option?

2. In the end, the soil was treated with an active biopile system. There were 5 operation campaigns:

OC1: Mobilization and air injection startup (2 months);

OC2: Air injection (2.5 months).

OC3: Air injection + fertilizer (2 months);

OC4: Air injection + fertilizer + leachate recirculation (3 months);

OC5: Air injection + fertilizer + leachate recirculation + surfactant (Triton N-101) (3 months).

Given the data below, what is the removal rate per operating condition and the average removal rate over the entire operation in day⁻¹? What is the total percent TPH removed over the entire operation? Which of the 5 operational phases has the best operating condition for optimal TPH removal? Can you speculate on why that might be?

OC	Concentration of TPH, mg/kg	
	Initial concentration	Final concentration
1	30,000	22,100
2	22,100	15,300
3	15,300	15,000
4	15,000	13,500
5	13,500	5,200

This is not a problem suitable for an exam. I would give you the degradation rate if such a problem were in an exam.

Problem 3: Slurry

A contaminated soil is to be remediated in a batch slurry reactor. The soil contaminant concentration, measured as COD, is 800 mg/kg dry soil and the allowable concentration is 40 mg/kg.

Based on laboratory studies, $K_D = 0.2 \text{ m}^3/\text{kg}$ and biodegradation can be described as a first-order function of the dissolved COD concentration. A value of the first order rate coefficient of 0.05 per day has been determined. Adequate mixing can be achieved at a solids concentration of 10 kg dry soil/ m^3 slurry.

Determine the time required to remediate the soil knowing that the solid density is $2,600 \text{ kg}/\text{m}^3$.