



# Bioremediation of hydrocarbons-contaminated soils with cyclodextrins as additives

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# Soil remediation technologies combined with CD treatment

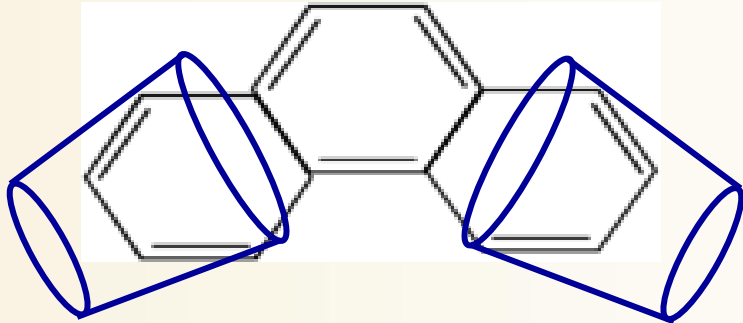
## Soil washing

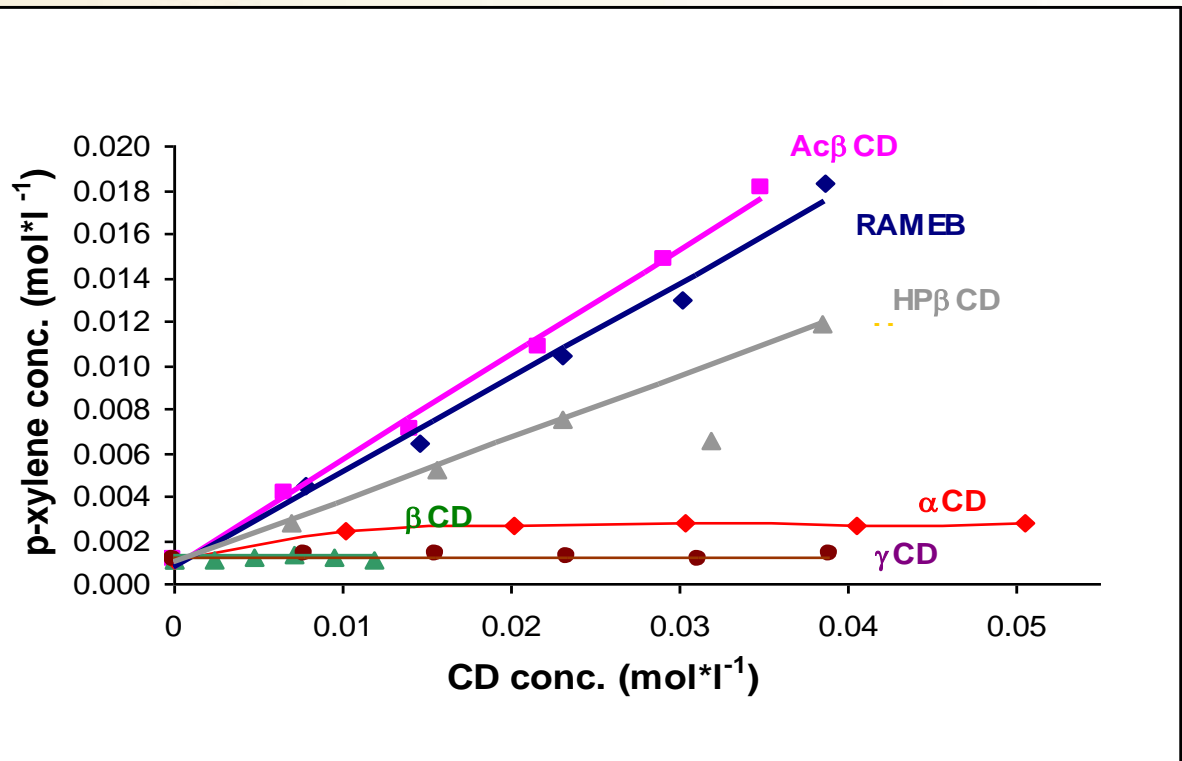
– treatment of the resulting waste water

(CDs may improve or decrease the effect of treatment)

## Bioremediation: Phytoremediation

Microbial degradation (Biodegradation)



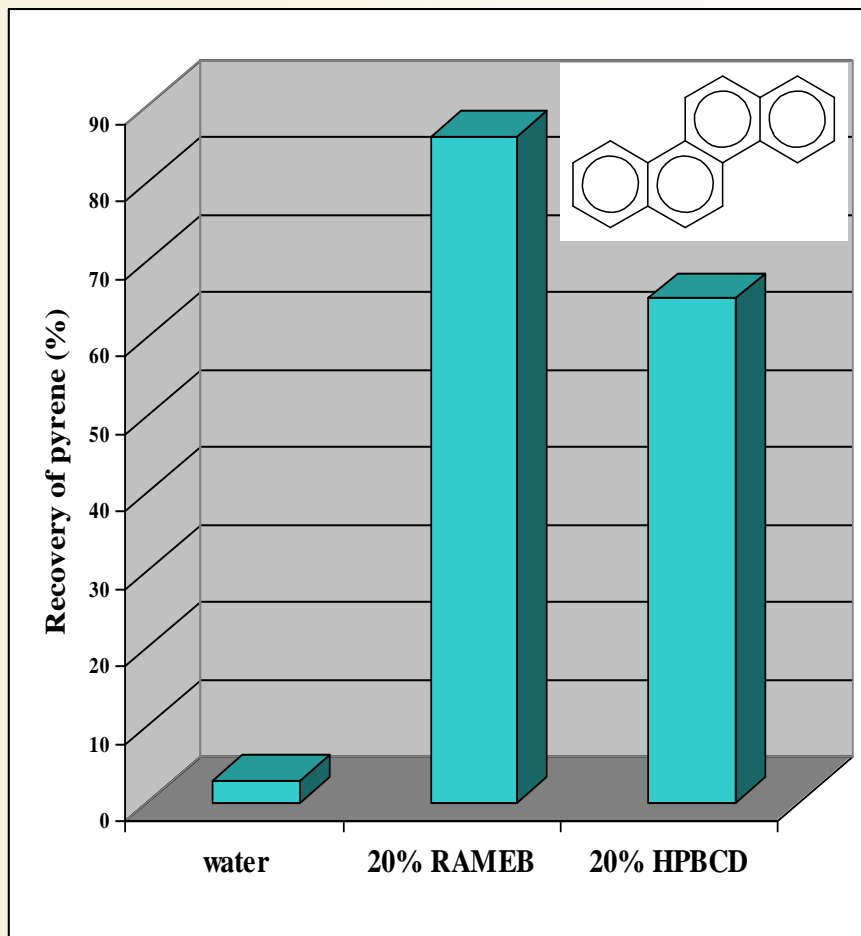


## Reduced partition into octanol (soil)

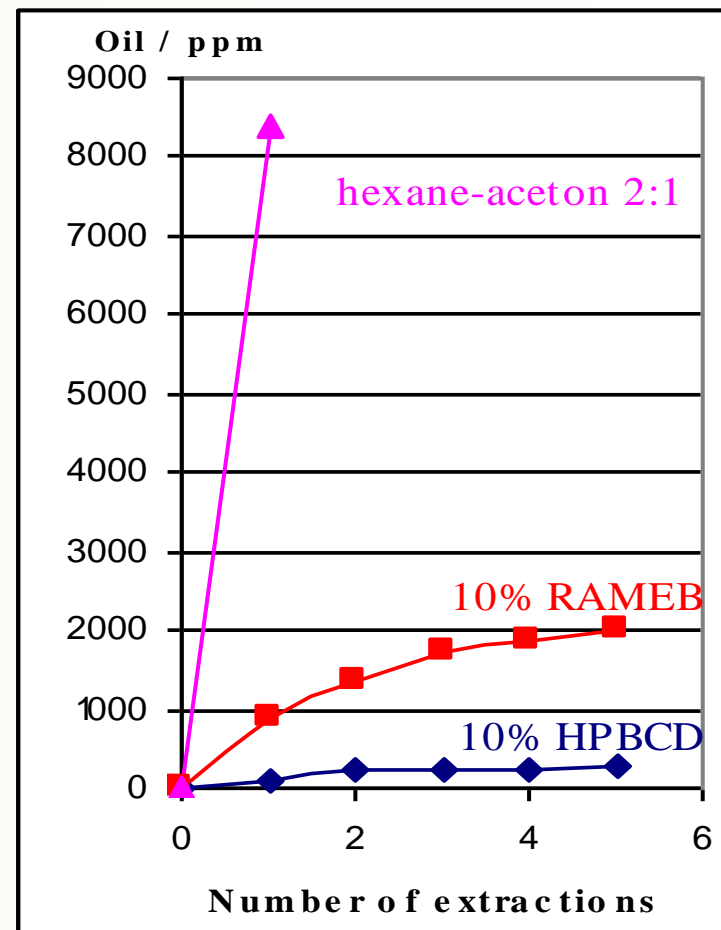
### Solubility of p-xylene in CD solutions

	LogK <sub>ow</sub>	LogK <sub>oCD</sub>	
	in water	in 10% solution of	
		HPBCD	RAMEB
p-chlororaniline	1.82	1.22	1,13
p-chlorophenol	2.39	1.61	1,45
toluene	2.92	2.20	2,12
1,2-dichlorobenzene	3.45	2.47	2,35
1-methyl-naphthalene	3.79	2.58	2,34
pentachlorophenol	4.16	3.00	2,84
phenanthrene	4.67	3.02	2,47

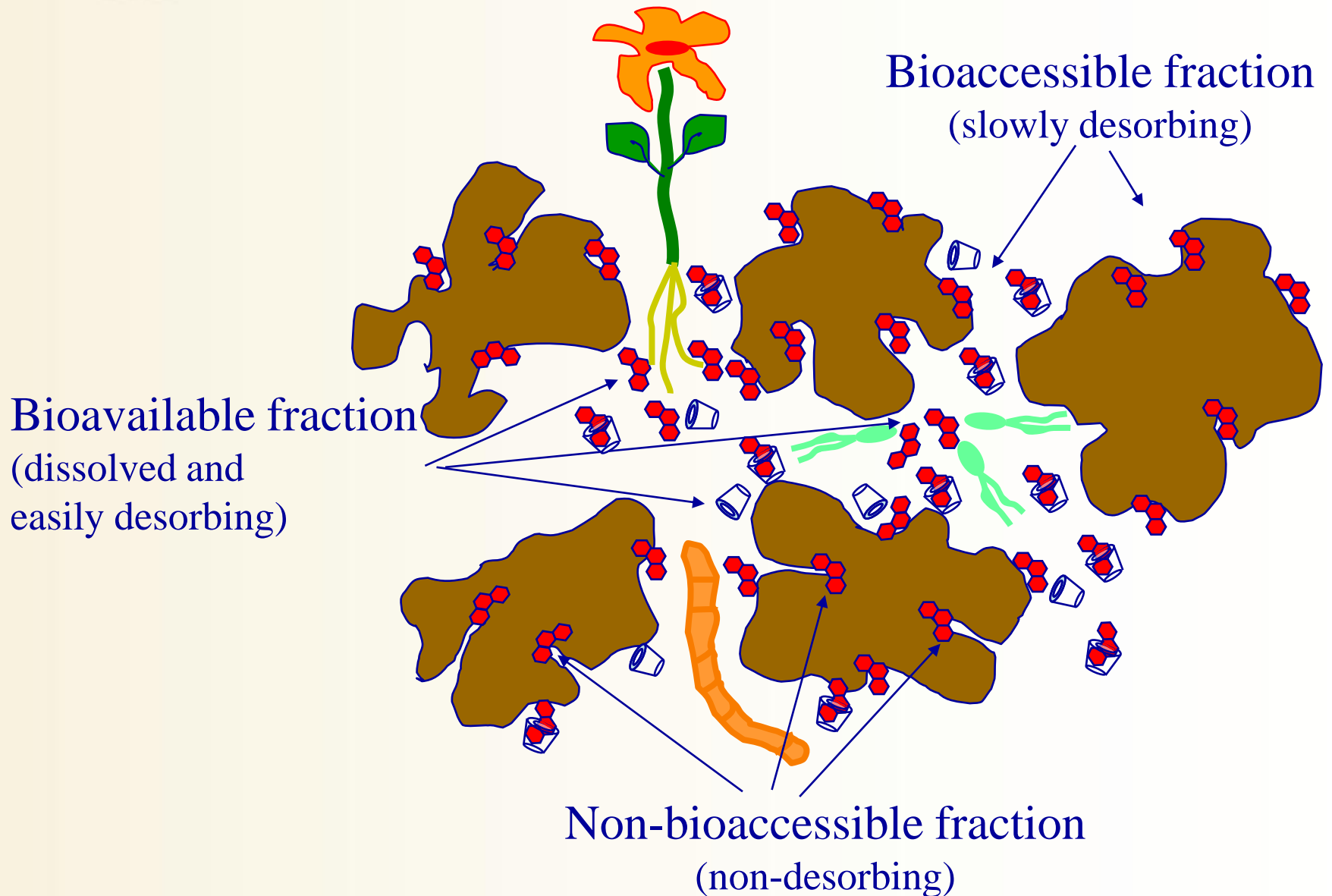
# Enhanced desorption of contaminants from soil



**Extraction of pyrene**

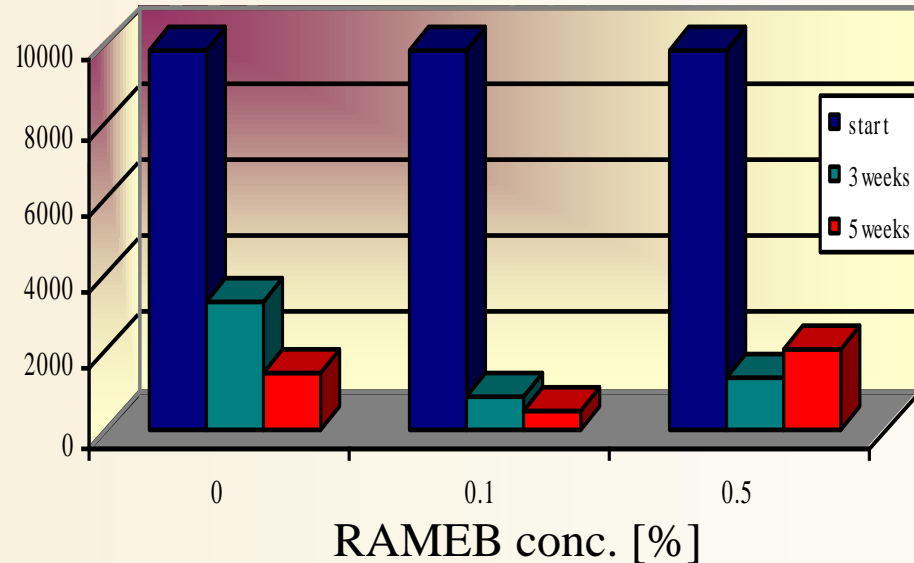


**Extraction of black oil by CD solution**

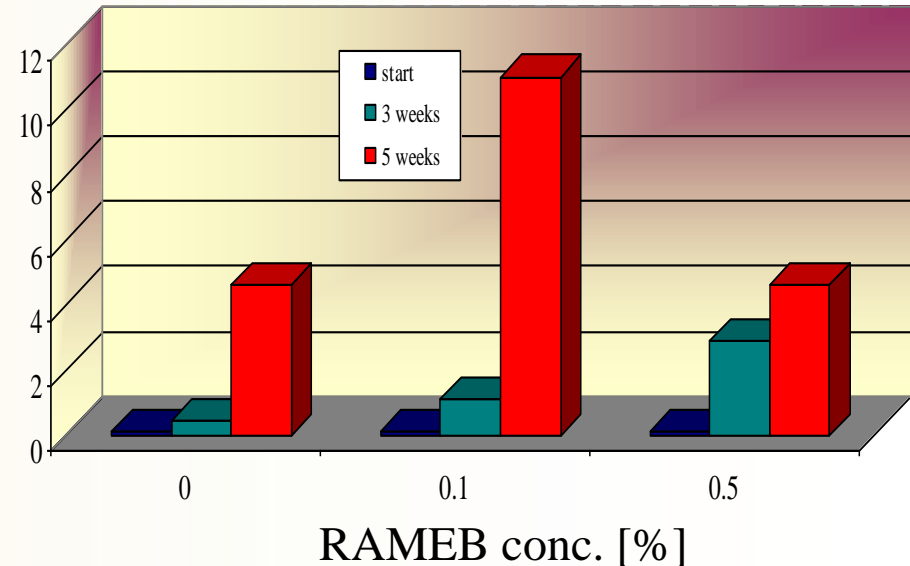




Oil [ppm]



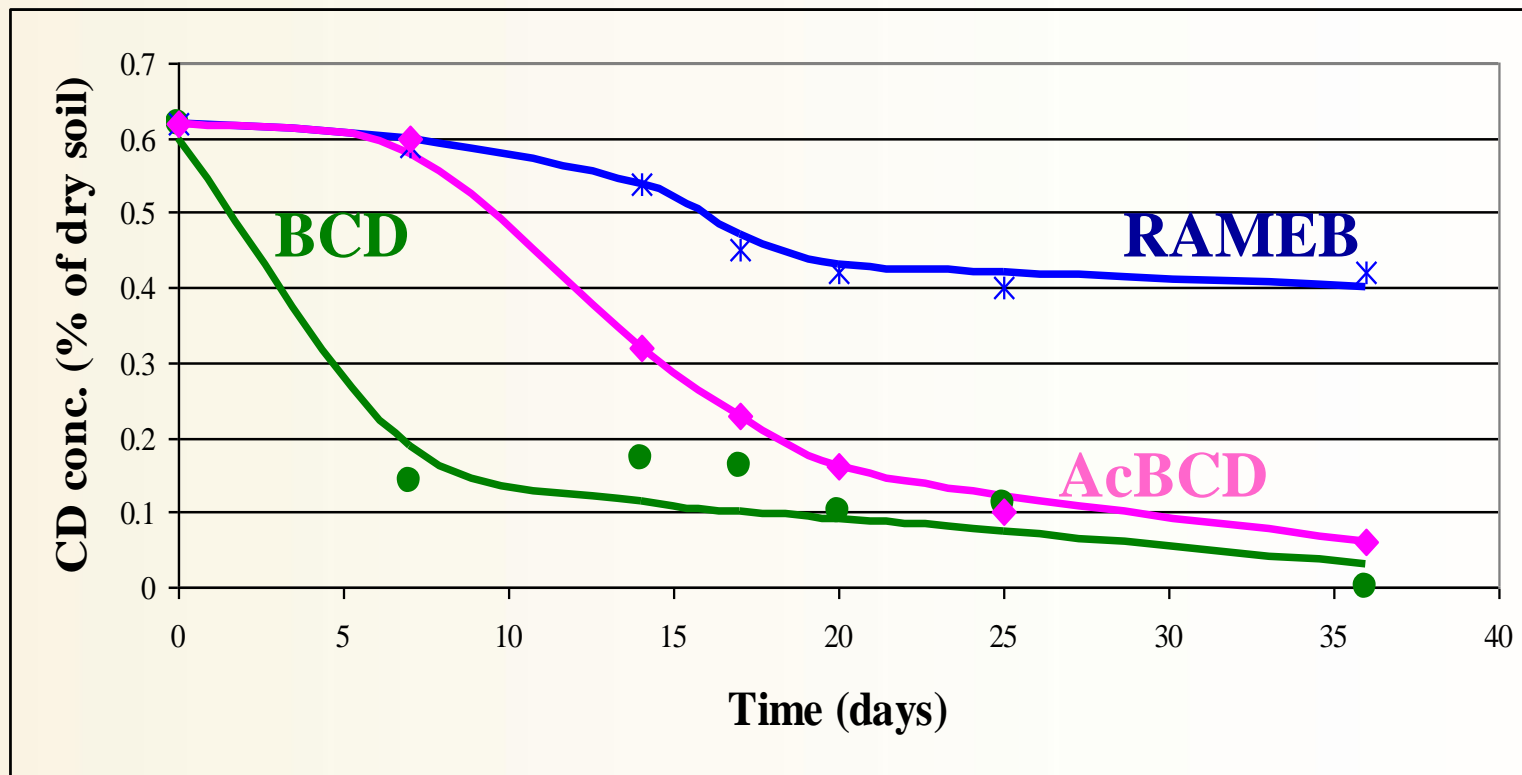
Oil degrading cell conc. ( $10^3$  cell/g)



Oil content and cell concentration in soil contaminated by 10000 ppm transformer oil after 3 and 5 weeks of treatment by laboratory bio-ventilation

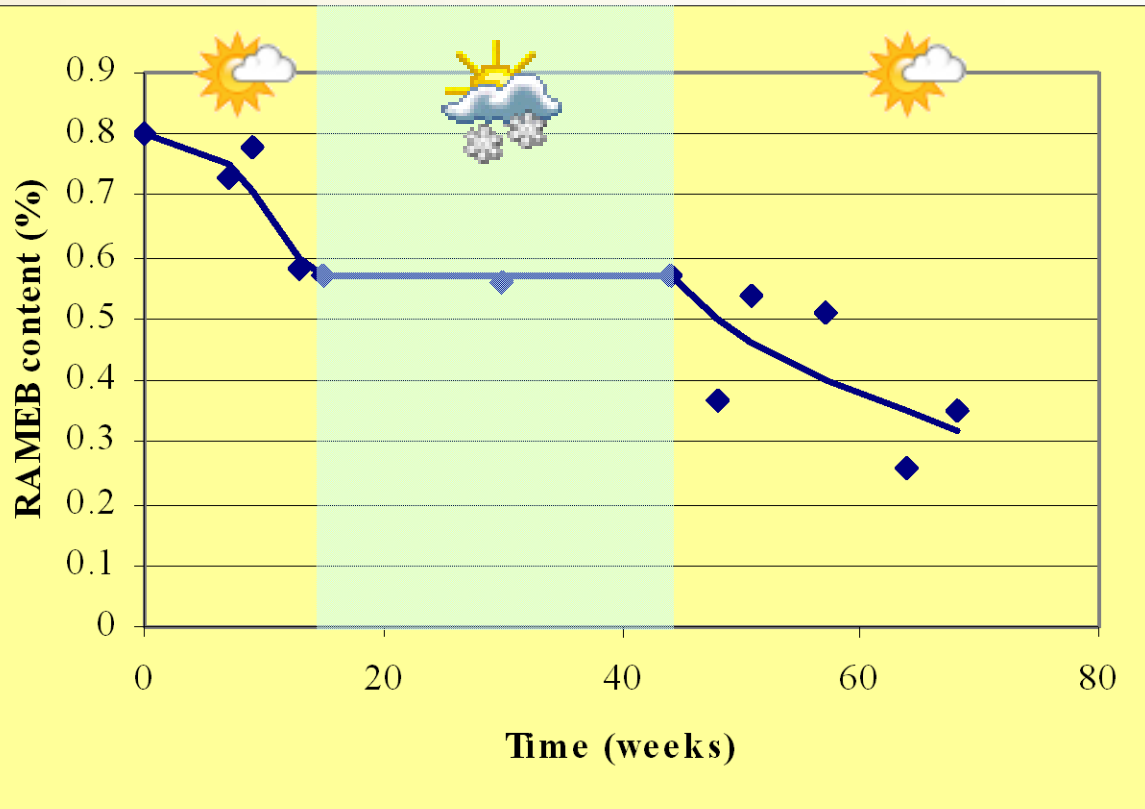


# Biodegradability of CDs in soil contaminated with 20000 ppm transformer oil (laboratory experiment)





# RAMEB concentration in the soil contaminated with engine oil during *ex situ* field experiment







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## Demonstration in field experiment



Former fuel station at an agricultural site  
Contaminants: diesel and engine oil

### Technology:

1. In situ ventilation
2. Ex situ physical treatment of groundwater
3. Periodical flushing with RAMEB/nutrients

C:N:P 100:10:1

### Technology monitoring:

Frequent analysis of soil gas and ground water  
Soil sampling at the beginning and end



# Results of field demonstration



Additives	CO <sub>2</sub> content in soil gas			Oil concentration in ground water			Concentration of heterotrophic cells in ground water		
	Before addition mg m <sup>-3</sup>	After addition mg m <sup>-3</sup>	Change (%)	Before addition mg dm <sup>-3</sup>	After addition mg dm <sup>-3</sup>	Change (after/before)	Before addition CFU 10 <sup>2</sup> dm <sup>-3</sup>	After addition CFU 10 <sup>2</sup> dm <sup>-3</sup>	Change (after/before)
3% RAMEB	780	1000	28	0.7	131	187	15	1800	120
1.5% RAMEB+ nutrients	600	970	62	0.15	2.48	16.5	77	2780	36
nutrients	590	620	5	0.1	1.37	13.7	21	62	3

# Results of soil analysis

Extractable hydrocarbons (mg/kg)	
Before treatment	10.000 - 29.000
After treatment	<1000 - 3000





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## Material balance in field experiment

Contaminant in ground water:

Total removed in 64 weeks: 7 kg

**Removed after RAMEB addition in 7 weeks: 4.9 kg**

Contaminant in soil:

Total initially: 720 kg

Remained: 312 kg

Total removed: 408 kg

$$408 - 7 = 401 \text{ kg}$$

**Removed by biodegradation**



## Advantages

- Not harmful for the soil
- Not harmful for the soil biota
- Non-toxic
- Biodegradable
- Low adsorption on the soil
- Mobilization of contaminants
- Enhanced biodegradation
- Time saving: 1-2 year

## Disadvantages

- High price





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