

Characterisation of a BTEX contaminated aquifer by using compound-specific stable carbon and hydrogen isotope analysis

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Problem outline

- Many industrial areas in Flanders are contaminated by VOCs: BTEX, chlorinated solvents
- Multiple source & mixing of contaminant plumes
- To define remedial action important to identify:
 - the source & contribution
 - *in situ* biodegradation

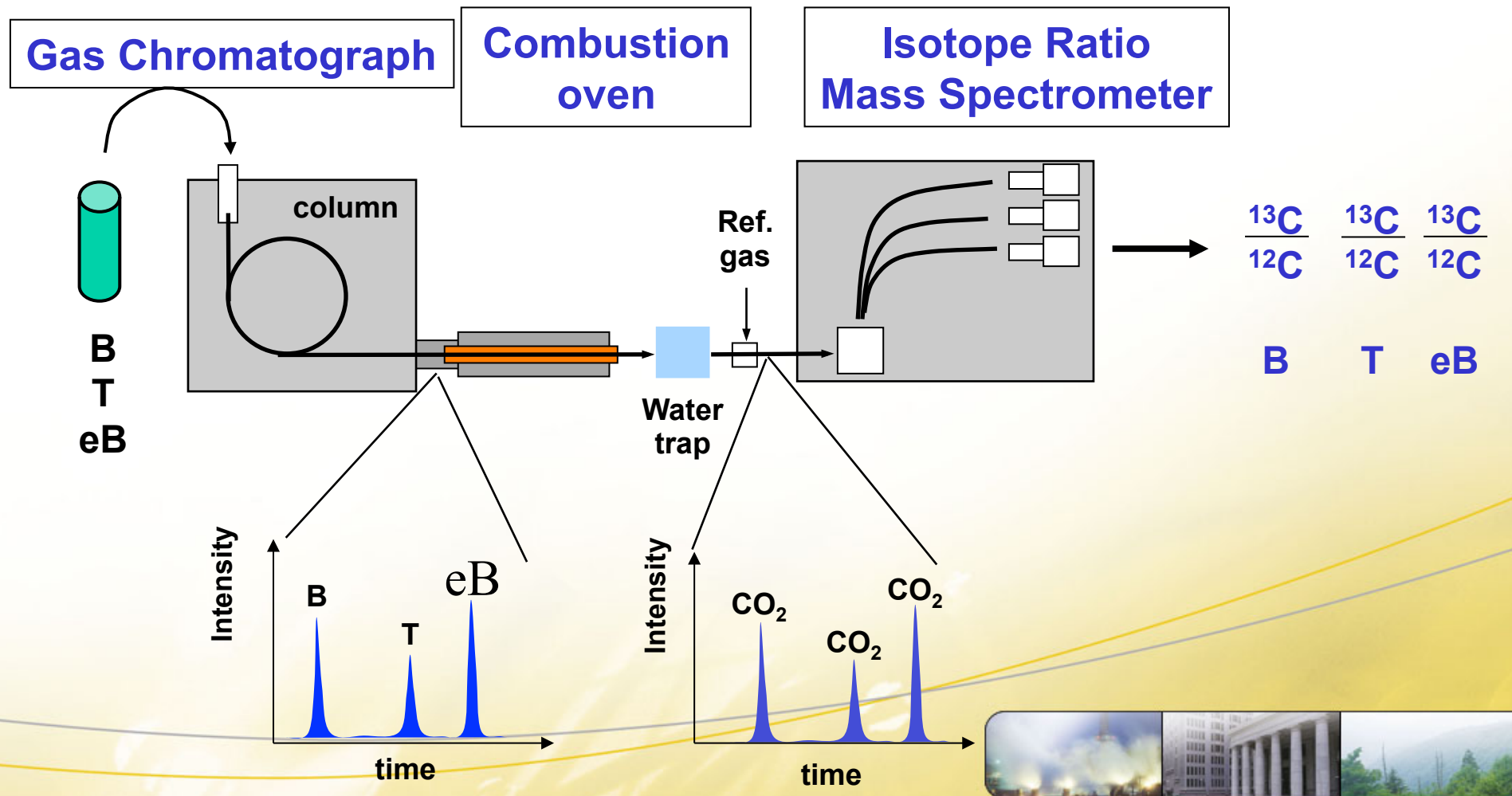


Goal

- Compound-specific stable isotope analysis (CSIA) is used to evaluate:
 - the contribution of multiple sources to groundwater contamination
 - the presence of biodegradation processes



Compound-specific isotope analysis



Delta notation

- Because of small variations in isotopic abundance, the δ -notation is used with units of parts per mil (‰)

$$\delta^{13}\text{C} = \left(\frac{^{13}\text{C}/^{12}\text{C}_{\text{sample}}}{^{13}\text{C}/^{12}\text{C}_{\text{reference}}} - 1 \right) * 1000 (\text{‰ VPDB})$$

VPDB: Vienna Pee Dee Belemnite



Source characterisation

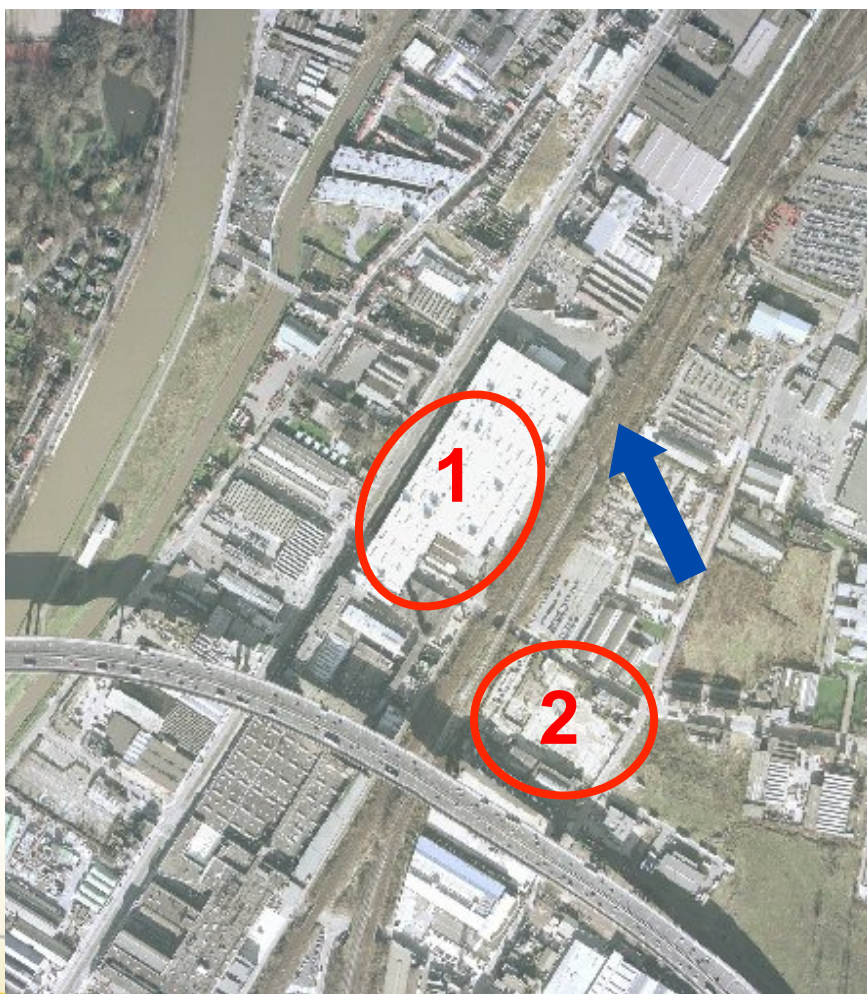


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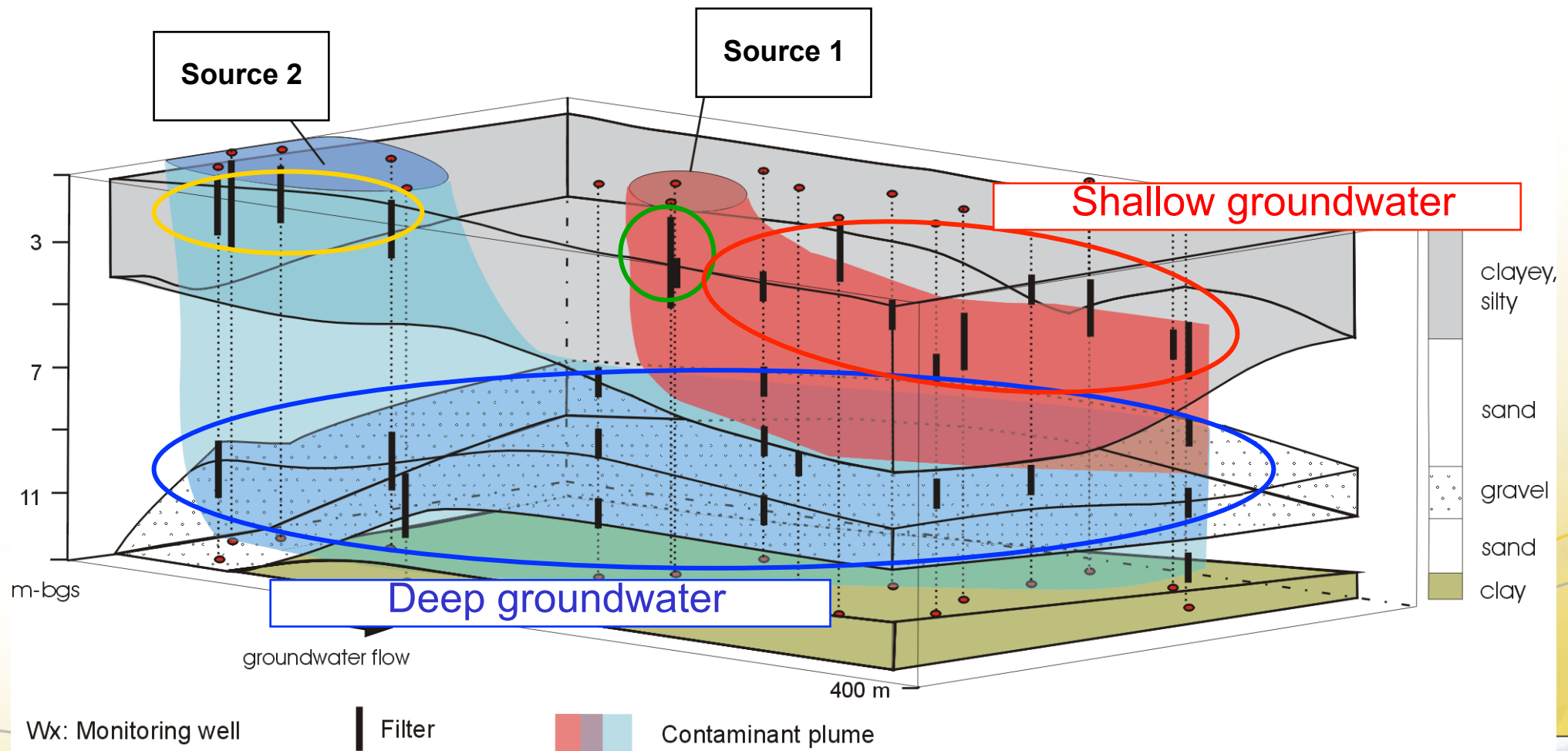
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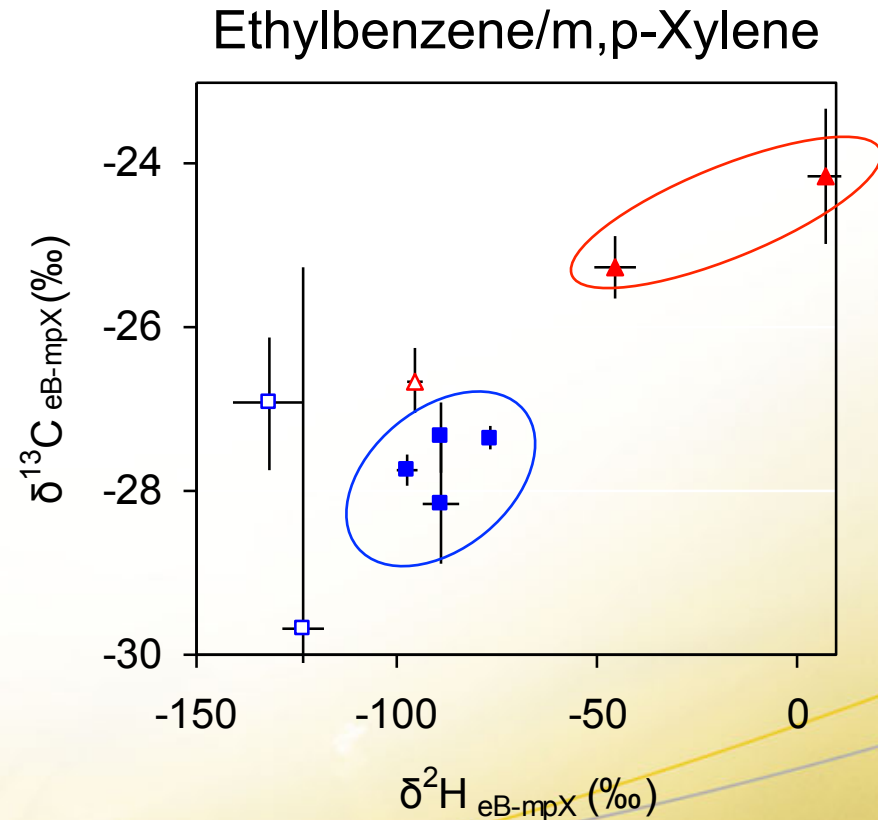
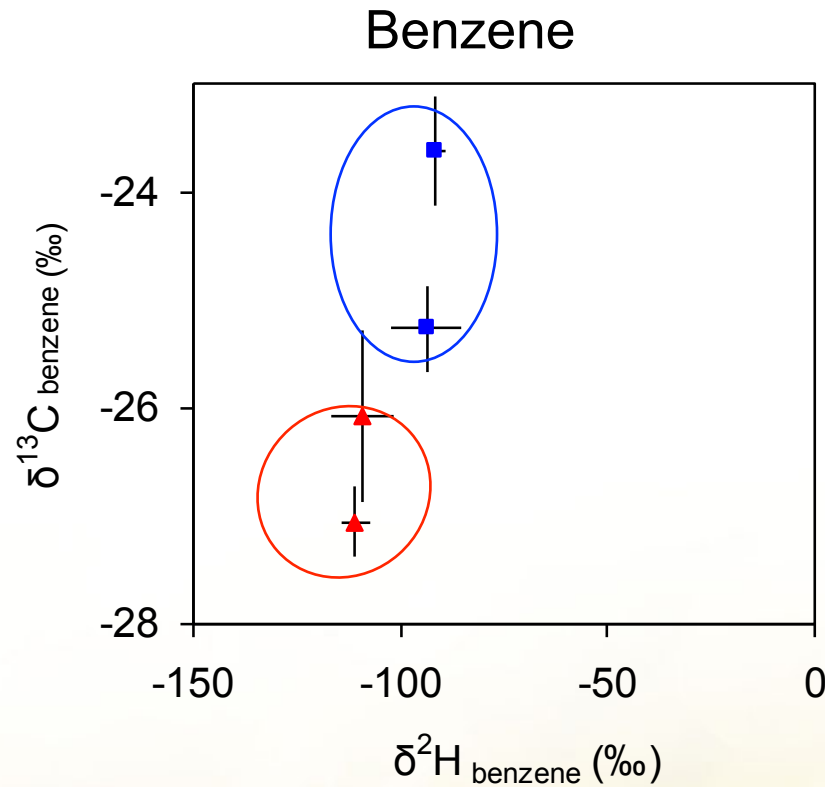
Case study: BTEX contamination



Case study: BTEX contamination



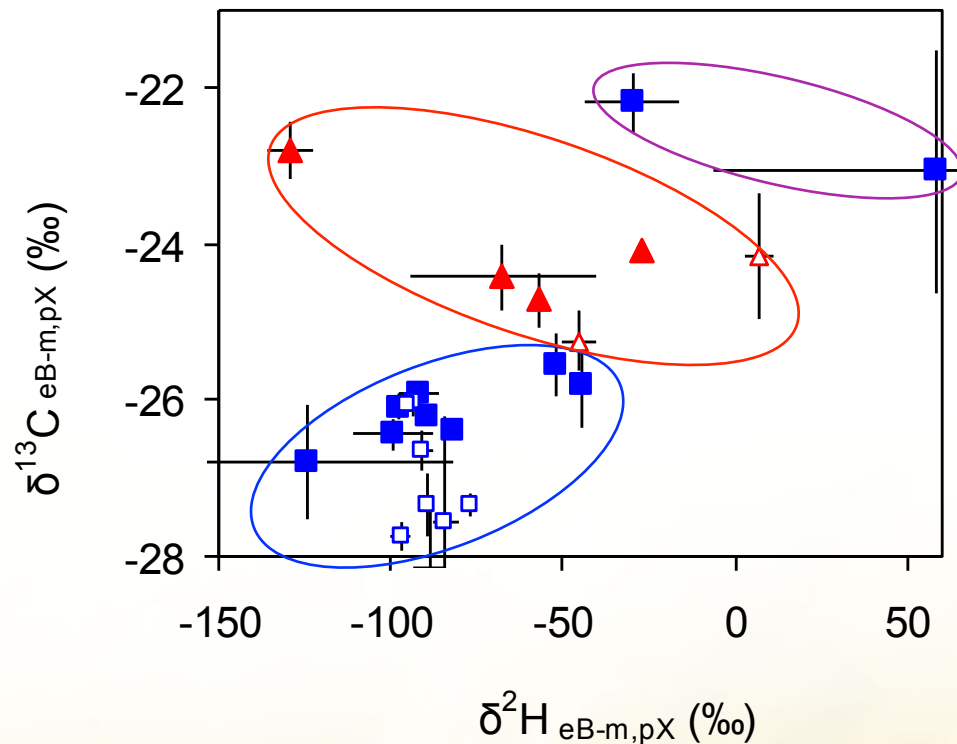
Characterisation: sources



■ Groundwater source 2
□ NAPL source 2

▲ Groundwater source 1
△ NAPL source 1

Characterisation: contaminant plumes



→ Distinction between plumes less clear

▲ Shallow groundwater ■ deep groundwater
□ Source 2 ▲ Source 1



Identify in-situ biodegradation

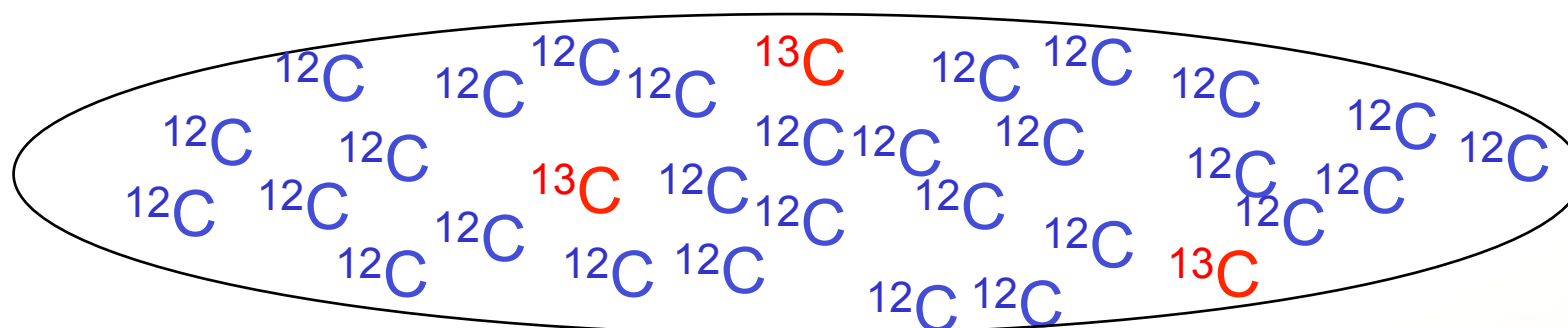


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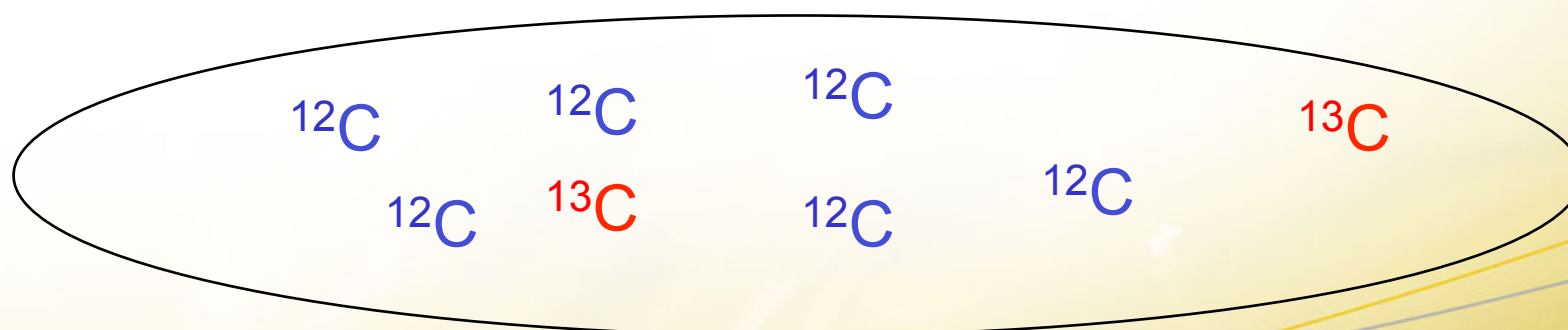
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Background: kinetic isotope effect

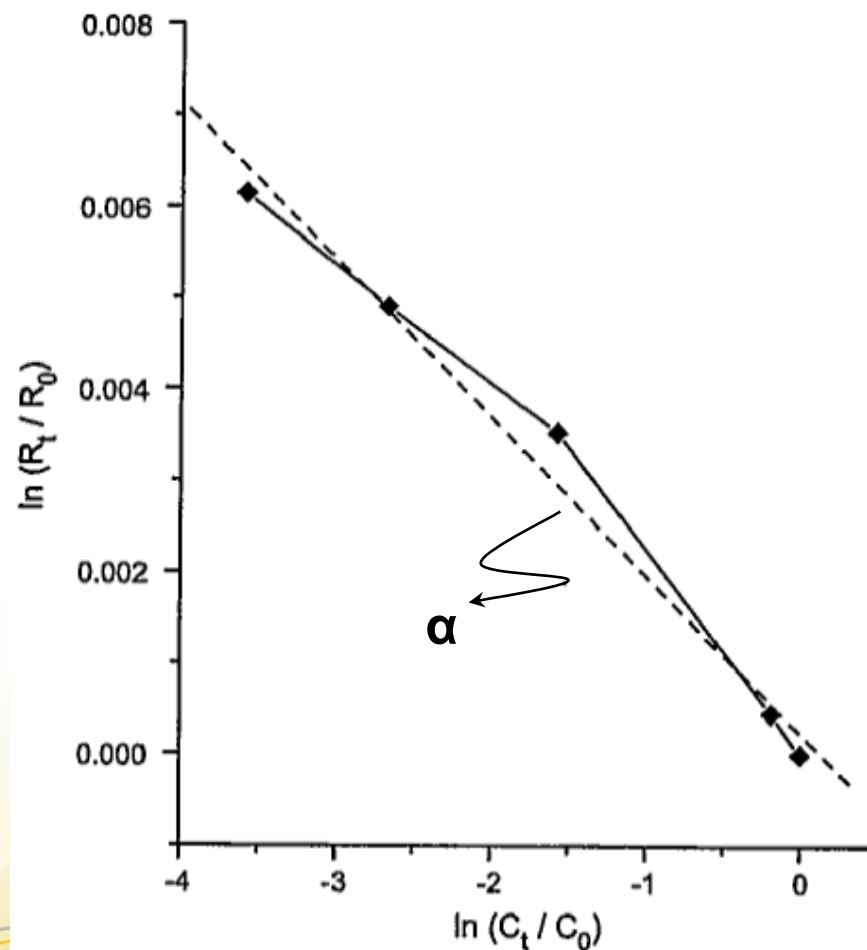
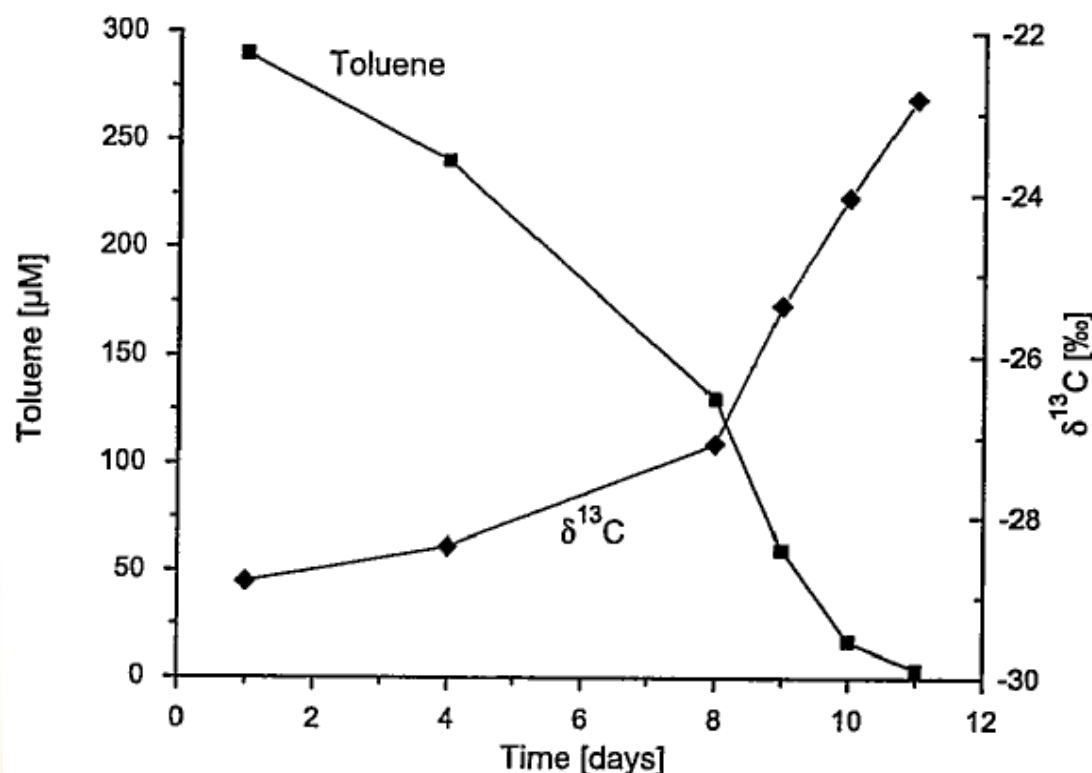


biodegradation ↓ $k_{^{12}\text{C}} > k_{^{13}\text{C}}$



→ residual pollutant fraction enriched with ^{13}C

Biodegradation – Rayleigh plot



Taken from Meckenstock et al. (2002)

Case study: BTEX contamination

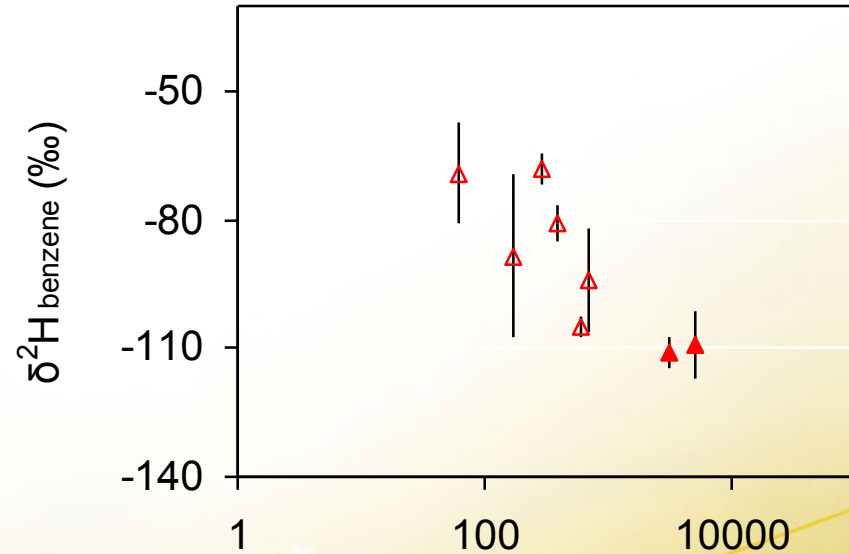
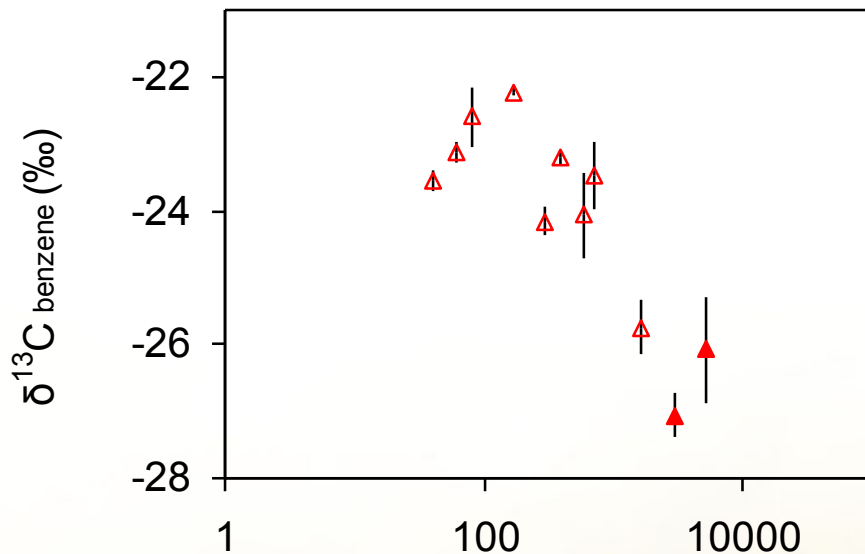
- Traditional monitoring
 - pollutant and degradation products
 - e⁻-acceptors: NO₃⁻, SO₄²⁻, Fe, Mn

		Fenolindex	Fe(II)	Mn	SO ₄ ²⁻	CH ₄	O ₂	BTEX som
		(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)	(µg/L)
Ondiep grondwater	V21	<10	1730	374	24	1073	0,13	<5
	31	<10	31700	3330	190	1277	6,14	<5
	136	199	14400	1760	<1	17524	1,3	6710
	116C	<10	26100	5510	<1	11918	3,85	27
	118	20,2	30000	1750	<1	15998	2,67	737
	V6	30	45700	913	1,8	19107	2,5	423
	V7	<10	15000	4280	3,6	14371	0,45	30
	V36	22,9	26100	2020	6,2	12218	0,33	568



Identification of biodegradation

- Stable isotopes: Benzene

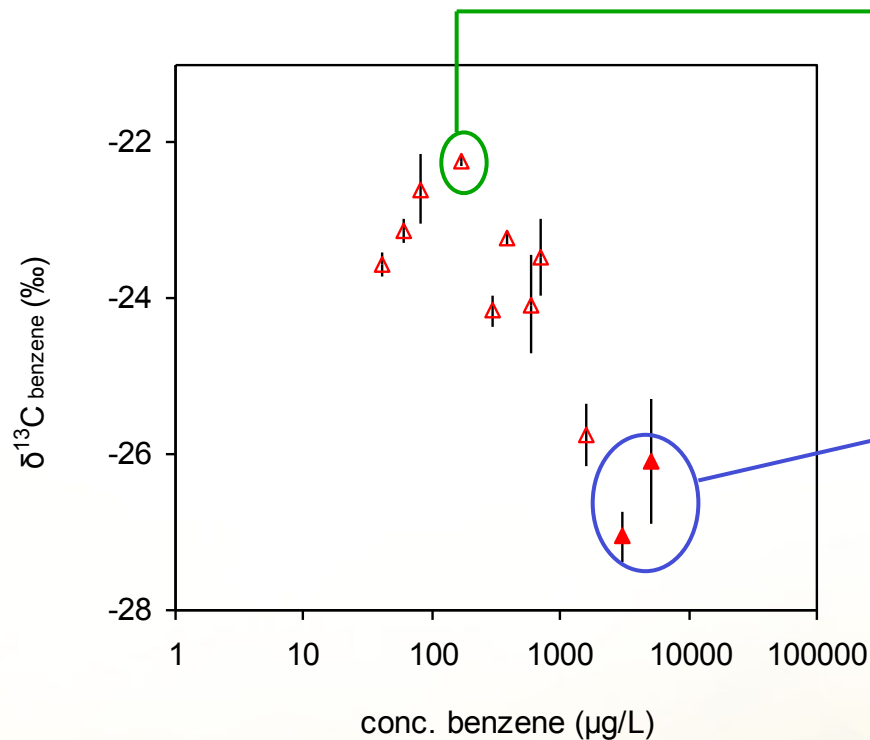


conc. benzene (µg/L)

conc. benzene (µg/L)

△ Shallow groundwater ▲ groundwater Source 1

Quantification biodegradation



△ Shallow groundwater △ groundwater Source 1

$$B (\%) = 100 (1 - R_t/R_0)(\alpha - 1)$$

Literature
-1,9 tot -3,6‰



$B_C = 58 \text{ to } 94\%$

$B_H = 17 \text{ to } 38\%$



Conclusion



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Source characterisation

- Distinction of different sources possible
 - Distinction of contaminant plumes more difficult
- ➔ changes of the isotopic composition



In-situ microbial degradation

- Advantages of CSIA
 - Prove for degradation of a specific compound
 - Little or no influence by other in-situ processes, such as sorption, dispersion,...
 - Easier quantification possible

