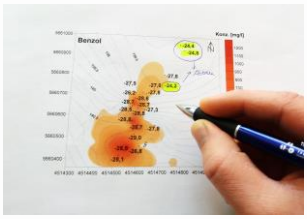
Compound-Specific Isotope Analysis (CSIA) for Degradation Evaluation

Due to the preferential transformation of lighter stable isotopes (e.g. ^{12}C, ^{1}H, ^{35}Cl), contaminant molecules bearing a heavy stable isotope (e.g. ^{13}C, ^{2}H, ^{37}Cl) will accumulate in a plume leading to increasing stable isotope ratios (delta-notation: $\delta^{13}C$, $\delta^{2}H$, $\delta^{37}Cl$). This effect is proportional to degradation, which is reflected in the isotope enrichment factor (ε). Thus, compound-specific stable isotope analysis (CSIA) will provide quantitative evidence of pollutant degradation, independently from concentrations. Multi-element CSIA is a valuable tool to elucidate degradation pathways.

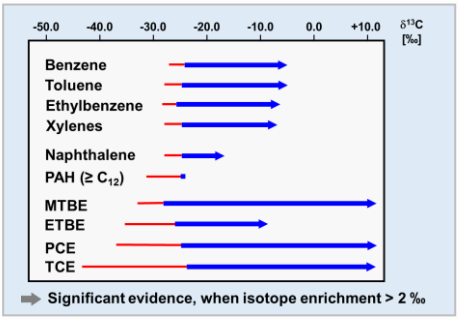
Sampling

Preparation

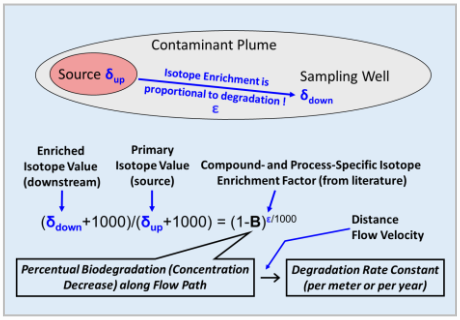
Analysis



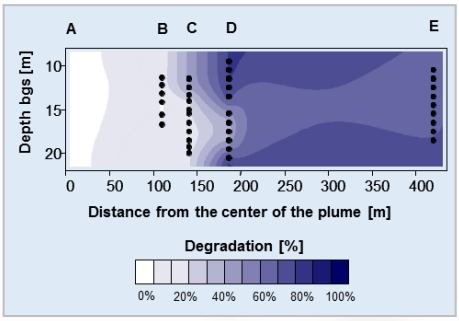
Expertise



Degradation of many contaminants leads to an increase of heavy isotopes (^{13}C, ^{2}H, ^{37}Cl) downstream of the source. Primary isotope ratios (red) are shifted towards more positive δ-values (blue).



Isotope enrichment is proportional to degradation as described by the isotope enrichment factor ε. Thus already two isotope values (from source and a downstream well) are feasible to quantify in situ biodegradation.



As a result of area-wide monitoring by CSIA the intensity of in situ degradation can be mapped along the plume. A sound site concept will enable the implementation of cost-efficient remediation.

Workflow

- In a joint concept, we select target contaminants and spots of the field site to be investigated.
- We provide sampling flasks and protocols for sampling.
- We analyse stable isotope ratios of target pollutants.
- We qualitatively and quantitatively evaluate the isotope data in order to use pollutant degradation in the context of a sound site concept and a cost-efficient remediation strategy.

Outcome

Proof and quantification of pollutant degradation
Validated site concept and remediation strategy

Costs

$^{13}C/^{12}C$, $^{2}H/^{1}H$: 250 - 320 € per sample
$^{37}Cl/^{35}Cl$: 320 - 450 € per sample
$^{15}N/^{14}N$: 320 – 450 € per sample

Further reading

Kuntze K, Eisenmann H, Richnow H-H, Fischer A (2019): Compound-specific stable isotope analysis (CSIA) for evaluating degradation of organic pollutants: An overview of field case studies. In: Boll M. (eds) Anaerobic Utilization of Hydrocarbons, Oils, and Lipids. Handbook of Hydrocarbon and Lipid Microbiology. Springer, Cham.

Thullner M, Centler F, Richnow H-H, Fischer A (2012): Quantification of organic pollutant degradation in contaminated aquifers using compound specific stable isotope analysis - Review of recent developments. Org. Geochm. 42: 1440-1460.

Fischer A, Manefield M, Bombach P (2016): Application of stable isotope tools for evaluating natural and stimulated biodegradation of organic pollutants in field studies. Curr. Opin. Biotechnol. 41: 99-107.

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