Natural Attenuation at petroleum hydrocarbon contaminated sites

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Keywords: Groundwater; natural attenuation; petroleum hydrocarbons; biodegradation; direct-push technology

Natural Attenuation (NA) has emerged as an important additional or alternative remediation option, especially at petroleum hydrocarbon contaminated sites. Natural Attenuation processes comprise destructive (e.g. biodegradation) and non-destructive processes like dispersion, sorption or volatilisation. While sorption and volatilisation lead to a possibly only temporary reduction in mass in the respective compartment groundwater, dispersion and diffusion are only concentration but not mass reducing processes in groundwater (Peter et al., 2011).

Two major challenges arise when implementing Natural Attenuation at a site: (1) proving the efficacy of NA processes currently taking place and (2) predicting the efficacy of NA processes in future (Peter et al., 2010). While the first task requires comprehensive site investigations, the second demand detailed process-based simulations of flow and reactive transport processes based on site specific data.

The present study gives an overview of the comprehensive site investigations and modelling undertaken to prove and predict NA at a kerosene contaminated former military air-field in north-east Germany, approximately 60 km southeast of Berlin. At the former tank farm, the subsurface is massively contaminated with kerosene as LNAPL (light non-aqueous phase liquid) over an area of approx. 120’000 m².

Comprehensive site investigations to prove NA were performed, using rapid and adaptively implemented direct-push soundings in combination with different sampling and measurement techniques for different targets (Miles et al., 2007; Peter et al., 2010). Groundwater sampling showed a rapid decrease of contaminant and electron acceptor concentrations as well as increasing reaction products with increasing travel distance from the source. Further quantitative indications for NA processes taking place were obtained by compound specific $^{12}C/^{13}C$-isotope analyses as well as by mass flow rate measurements, that both confirmed that mass reducing processes like biodegradation prevail. As a site specific characteristic, it was shown, that groundwater recharge has a strong influence on the development of the contaminant plume, as groundwater recharge provides or limits the supply of electron acceptors like oxygen and sulfate.

The high-resolution direct-push data was used to build a three-dimensional geological structure model that served as input for a three-dimensional flow model (Miles et al., 2007). Based on the findings of the flow model, a multi-component reactive transport model was set up to simulate transport of four major contaminants, a bulk contaminant as well as of four electron acceptors (Miles et al., 2008). In total, 20 degradation reactions with inhibition according to the thermodynamically favored order of electron acceptor consumption were considered, as well as two reactions to account for reoxidation of Fe(II) and precipitation of FeS. Model predictions of plume development confirmed the steady state conditions of the actual plume, however they

also showed that after depletion of Fe(III) as immobile electron acceptor methanogenesis will become the dominant degradation path for the dissolved contaminants, leading particularly for benzene to renewed small growth of the contaminant plume after being in steady state for decades.

The application of detailed and efficient direct-push measurements in combination with accurate multi-species reactive transport modelling allowed for a sound proof of actual occurring NA processes on the one hand and the prediction of NA processes and plume development on the other hand. On the basis of this study a monitored natural attenuation concept was implemented at this site.

References

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