Attenuation of xenobiotic organic leachate compounds from a landfill to surface water: Transition in clay till settings

Numerous landfill sites worldwide have been recognized as a threat to clean water resources. Many environmental legal acts have been issued and improved to tackle this problem. The main concern is caused by slow degradation of the disposed waste and the high complexity of field conditions (landfill history, geology and hydrogeology), which together result in a virtually unique setting at each landfill site. Nevertheless, many general principles derived from research sites and case studies in homogeneous geological settings can be applied or adjusted to fit specific, complex landfill cases. Transition zones between different environmental conditions or between groundwater and surface water are regarded as places of high potential for contaminant attenuation. Special attention is given to the groundwater-surface water transition (hyporheic) zone, with a perspective that it can harbour particular microbial communities that can degrade even recalcitrant landfill-originating xenobiotic compounds. The overall scope of the study was to deepen knowledge about the degradation of xenobiotic organic compounds in landfill leachate contaminated groundwater and in the transition from groundwater to surface water and to improve concepts, tools and methods for the degradation assessment. High complexity in the field is challenging, since it influences the spreading of contamination and attenuation processes such as sorption and degradation. Clay till, a glacial deposit of low permeable clay with interbedded sand lenses, is a common soil type in Scandinavia and parts of North America. Therefore, a study site, the Risby Landfill west of Copenhagen, was chosen, since it encloses all key features for the research – an old landfill without leachate collection and liner, clay till-dominated geology and a local stream in the vicinity of the landfill. The degradation was assessed for three xenobiotic groups detected in the Risby Landfill leachate: phenoxy acid pesticides, chlorinated solvents and monoaromatic petroleum derivatives. The degradation assessment was based on a conceptual site model, using established lines of evidence of natural attenuation. The conceptual model was formulated for hydrogeology and water chemistry, providing water flow balance and mass discharges of selected contaminants. The model was improved by analyzing in situ indicators of biodegradation, some of which were applied for the first time to landfill leachate contaminated groundwater in a clay till. Natural attenuation of phenoxy acids was estimated to be significant in an area with very high concentrations of leachate indicators beneath the landfill (hotspot), along the groundwater flow towards the stream and in the hyporheic zone, using isotope, enantiomer and metabolite analyses. Phenoxy acids reached the Risby Stream, exerting local and small chemical impact. Nevertheless, the impact was seasonally very high in the periods of low stream flow. Chlorinated solvents and petroleum derivatives were detected only in the hotspot, and tracking of their fate along the groundwater flow direction was therefore not possible. Literature data on their isotope fractionation and degradation rates were used for the degradation assessment instead. Reductive dechlorination of chlorinated ethenes in the hotspot was shown, and back-release of the mother compound was indicated. Degradation of petroleum derivatives was also indicated in the hotspot. These findings on anaerobic degradation in the hotspot supported the indications of phenoxy acid degradation by reductive dechlorination. A microbial study was conducted only for the aerobic part of the contaminant pathway. Degradation of phenoxy acids was studied in the aerobic streambed sediment, confirming high degradation potential in the hyporheic zone indicated earlier by indirect methods. The field settings’ complexity influenced the choice of methods. Compoundspecific isotope analysis was applied for all groups of xenobiotic landfill leachate compounds, and its performance was evaluated with respect to its complementary usage with enantiomer and metabolite analyses. Isotope-based analysis without supportive microbial study sufficed for the qualitative assessment of degradation or for discrimination between different hotspots. Fractionation rates from literature or high fractionation along the groundwater flow would further improve the degradation assessment of the xenobiotic compounds to the quantification level. Degradation of xenobiotic organic compounds in landfill contaminated groundwater was shown using multiple methods and multiple compound approaches. Concepts, tools and methods used for the degradation assessment were applied in a clay till setting with groundwater discharge into a local stream.

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