NATURAL ATTENUATION OF BENZENE AS EVIDENCED BY ISOTOPE ANALYSIS

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1 Site Description and Investigation

The site investigated is a fuel depot in the harbor of Amsterdam. The sandy top layer is heavily contaminated with BTEX. At a depth of 3-6 m bgs, a clay layer separates the top zone from a middle-deep sandy layer, the zone of interest for this study. In 1995, two isolated spots in this layer were found to be contaminated, mainly with benzene (up to 6.000 µg/L). The underlying peat layer and first aquifer were found to be slightly contaminated. The hydrological situation is complex due to strong stratification and influence of salty water. Simplified, a vertically infiltrating freshwater layer is resting on top of a saltwater tongue infiltrating horizontally from the harbor. In 1999, a site investigation was performed to assess the potential of natural attenuation for the middle-deep sandy layer. The investigation involved analysis of BTEX, redox species, and chloride. Additionally, compound-specific stable carbon isotope analysis was perfumed to provide evidence for anaerobic biodegradation of benzene. This is based on recent research showing a preferential degradation of the ^{12}C-isotope with anaerobic degradation of aromatic compounds, leaving the residual pollutant with a higher ^{13}C-content. Finally, tritium (^{3}H) analysis was applied to elude the groundwater flow.

2 Results

The contaminant concentrations in the top layer in 1999 were similar to those in 1995. In the middle-deep layer, the 1999 data show a clear reduction of the all BTEX concentrations over the last four years. The groundwater in the middle-deep layer was found to be anoxic, with sulphate reduction being the main redox process. Chloride analysis showed the saltwater/freshwater interface to occur generally at ±8-9 m bgs. At the two originally contaminated spots,

however, this interface was found at a depth of 13-14 m bgs. It was concluded that the two contaminations in the middle-deep layer were caused by increased vertical groundwater transport, presumably due to the presence of anthropogenic drains in the clay layer. Based on the above results, it was inferred that biodegradation is preventing the migration of toluene, ethylbenzene and xylenes from the top layer to the middle-deep layer. Moreover, it was considered likely that anaerobic benzene degradation is limiting further migration of benzene. This was unexpected, as anaerobic degradation of benzene is a controversial issue. Additional support for benzene degradation was obtained using compound-specific $^{12}C/^{13}C$-analysis. Benzene in the plume was found to contain significantly more ^{13}C ($\delta^{13}C$ = -24,0 ‰ PDB) than benzene in the most likely source zone ($\delta^{13}C$ = -28,0‰ PDB). Although the number of analyses was limited, the carbon isotope shift from source to plume was considered an additional indication for anaerobic benzene degradation.

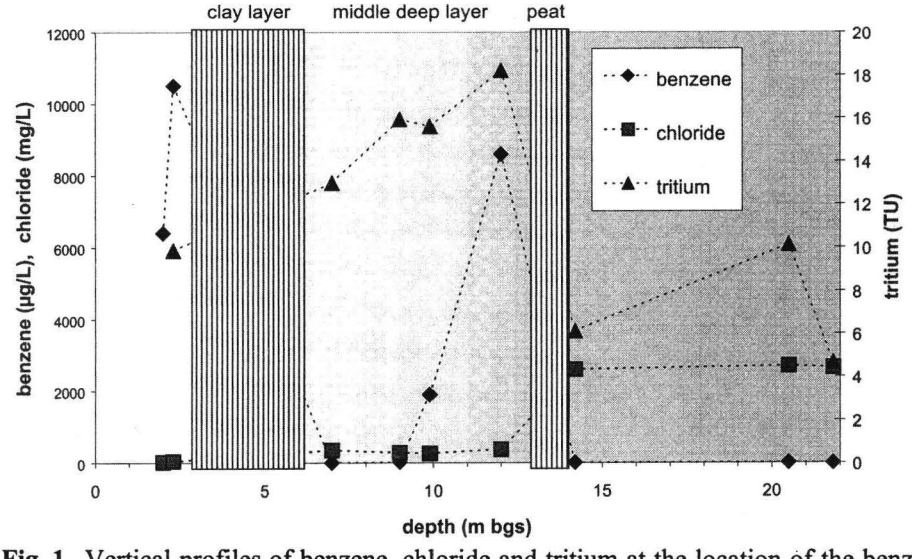

Fig. 1. Vertical profiles of benzene, chloride and tritium at the location of the benzene contamination in the middle-deep layer

The vertical groundwater infiltration was studied using ^{3}H analysis to date the infiltrating water (Fig.1). The results show a steady vertical infiltration in the middle-deep zone, implying the benzene pollution at the bottom of the layer to be the front of an old plume, now being disconnected from the source in the top zone. Moreover, it was found that the peat layer at 13-14 m-bgs is functioning as a hydrological barrier, limiting the influence of the increased vertical infiltration.

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