Is There a Conceptual Model in a 3-D Heterogeneous Multilayer Aquifer, and How Can It Be Approached?

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Background/Objectives. As the major objective of conceptual site models is to simplify the view of the contamination and analyze risk issues their use at complex heterogeneous sites may be questioned. In other words: is it possible to simplify, and to provide information on risk issues? Underlying the CSM building they are several assumptions that are not always clearly specified. The first assumption is mobility and continuity, meaning that there exist one or several pathways inside what is commonly called a plume. The second is mass balance: as plumes are often quite old the daily mass emitted at the source shall be recovered downgradient. Another key issue is concentration decrease along flowpath, that concerns tracers or, by extension calculated values like molar sums of chlorinated solvents. Moreover, there are impossible chemical paths, for instance cis-DCE cannot be transformed to TCE, while the reverse is true. Finally, underlying these points a conceptual model of the sedimentary deposits is present but not often enough described.

Approach/Activities. The study has been done at a site that will be taken as an example to illustrate a more general approach. The contamination lies under an active factory where drilling are possible only during three weeks each year. Due to indurated clays, geoprobe access was not possible. The sediments consist of intercalated clay and sands leading to one top aquifer located in quaternary sediments and another aquifer in similar tertiary layers. The first CSM considered several sources and did not provide clues for the presence of chlorinated solvents (CS) in tertiary aquifer. After the classical historical approach, several wells were drilled for geological investigation and source identification. Then we continuously used the data to test the major CSM options in a numerical 2-D and then 3-D model and these options were further tested during two drilling campaigns.

Results/Lessons Learned. The first stage was used to test head data consistency, revealing a common behavior of most of the wells, validating the flow continuity option. However, the head data of the tertiary aquifer could not be interpreted. Then, two assumptions were used jointly: concentration decrease of CS molar sum along flow path and impossible transformation of cis-DCE to TCE (or VC to TCE). This approach led to several possible flow paths within and between the aquifers. Next, using all available data the fluxes were calculated at some major lines downgradient the source. These fluxes then tend to favor some flow path and eliminate others. Combining with chemical analyses (major ions), this allowed to discover the presence of “holes” between the quaternary and secondary aquifers. Only this option could explain both the complex head pattern in the tertiary aquifer and the fluxes spatial distribution. The remaining question was the presence of one or several sources. One source led to very high sediment heterogeneity, while with several sources, the model was simpler, but harder to justify from the factory history. The head gradients in the quaternary aquifer varied a lot and were used to have a first idea of the heterogeneity in this aquifer. This has shown that the aquifer may contain areas of sandy clay leading to the plume spreading. Including all data in a 3D heterogeneous model allowed to reproduce the head and total CS concentration measurements. This model shows a very complex plume with different flow directions and some holes in the aquitards heading the contamination to lower layers (consistent with geological information from cored boreholes). However, the spatial distribution of the hydraulic conductivity could not have been obtained without the use of CS concentrations as a constrain and the flux approach. The approach is then generalized to other complex sites.