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Can Bayesian Belief Networks help tackle conceptual model uncertainties in contaminated site risk assessment?

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A key component in risk assessment of contaminated sites is the formulation of a conceptual site model. The conceptual model is a simplified representation of reality and forms the basis for the mathematical modelling of contaminant fate and transport at the site. A conceptual model should therefore identify the most important site-specific features and processes that may affect the contaminant transport behaviour at the site. The development of a conceptual model will always be associated with uncertainties due to lack of data and understanding of the site conditions, and often many different conceptual models may describe the same contaminated site equally well. In many cases, conceptual model uncertainty has been shown to be one of the dominant sources for uncertainty and is therefore essential to account for when quantifying uncertainties in risk assessments. We present here a Bayesian Belief Network (BBN) approach for evaluating the uncertainty in risk assessment of groundwater contamination from contaminated sites. The approach accounts for conceptual model uncertainty by considering multiple conceptual models, each of which represents an alternative interpretation of the site settings. For each conceptual model the downward vertical contaminant transport to groundwater is simulated using Monte Carlo simulation to additionally account for uncertain input parameters. A BBN is developed and used to assess the beliefs in the conceptual models. BBNs are graphical probabilistic models that are effective for integrating quantitative and qualitative information, and thus can strengthen decisions when empirical data are lacking. The developed BBN combines data from desk studies and initial site investigations with expert opinion to assess which of the conceptual models are more likely to reflect the actual site conditions. The method is demonstrated on a Danish field site contaminated with chlorinated ethenes. Four different conceptual models based on two interpretations of the source zone (presence or absence of free-phase NAPL) and two interpretations of the geology (fractured or unfractured clay till) were set up for this site. The contaminant concentrations reaching groundwater are simulated for all four models, and the results are combined according to the beliefs in each of the models, as determined by the BBN and available evidence. We discuss how our method can help inform future investigations at a contaminated site.

Key words Bayesian Belief Network; groundwater contamination; risk assessment; uncertainty; conceptual models