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Estimating maximum contaminant plume lengths by a new and easy-to-use process-based approach

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The protection of receptors and the estimation of the size of the contaminated area downstream of a pollutant source in an aquifer can be highly facilitated if a reliable site-specific estimate of the plume length is available. We present a process-based approach to determine the maximum contaminant plume length. The underlying new model overcomes two drawbacks: First, we account for a sharp front caused by the complete consumption of the pollutant ("electron donor") and some electron acceptor in an instantaneous reaction, thus replacing purely conservative or first-order degradation models which lead to theoretically infinite plumes and, in addition, depend on some debatable concentration threshold. Second, a vertical aquifer cross-section with finite thickness M is selected as model domain to better represent the supply of electron acceptor (e.g. oxygen) mostly entering the aquifer from the top. With regard to groundwater risk assessment at the field scale, it is important to note that our approach tends to over-estimate the actual plume length as, for instance, the contaminant degradation takes place only at the plume fringes and the source is assumed to extend over the entire aquifer thickness. The maximum plume length L can be calculated by a simple equation involving α_T = vertical transverse dispersivity, c_D^0 = source concentration (electron donor), c_A^0 = electron acceptor concentration at the aquifer top, and γ = stoichiometric ratio. The presentation will include practically relevant analyses such as the dependency of the maximum plume length on the grouped aquifer parameter α_T/M^2. In particular, an aquifer-dependent upper limit of L will be shown to exist if there is at least some minimal supply of electron acceptor.