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Hydrology and Earth System Sciences Discussions

Interactive comment on "A parameter identifiability study of two chalk tracer tests" *by* S. A. Mathias et al.

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General comment:

Mathias present a challenging research topic concerning the selection of appropriate transport models and the identifiability of associated parameters, in a just as much challenging hydrogeological environment, namely chalk. The methodology they use is clearly and concisely described. The topic is relevant for publication; however, I feel that there are several conceptual points to be discussed further and questions to be answered. The main important are listed here below, in order to start and feed the debate.

Specific comments:

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1. Model complexity and parameter identifiability

In their way of presenting their research, the authors seem to consider that the "best model" is the one that allows fitting as accurately as possible field results (here: tracer experiments) using the most simple model, i.e. the one that deals with the lowest number of fitting parameters. I disagree with this point of view. When modelling, the objective is to translate, as faithfully as possible, the complexity of physical systems in order to further use the model for running scenario and for managing efficiently such systems. Modelling a given "event" with great accuracy does not mean to have a good model. If the essential processes are not captured in that "event", it is likely that the model will rapidly fail when conditions change. To my opinion, it is more important to point out that the tracer experiment is not able to provide all the information to use a more detailed or complex model, rather than to show that a simpler model is apparently more accurate in the sense that it provides better "indicators" (RMSE, mass recovery or whatever) than others. In other words, the PFDM model (just an example) could still be the "best model" if it better corresponds to the actual functioning of the chalk system, even if some of its parameters are poorly identifiable.

2. Well bore mixing and capturing

At page "2443", the authors just reject well bore mixing on the pretext that this would introduce further parameters in the calibration procedure. This further seems to indicate that they give priority to low-dimensionality models (few parameters) rather than to physically consistent models (i.e. models that are able to deal with all possibly acting processes). In this case, this is particularly strange when one thinks that well bore mixing and capturing are likely to alter breakthrough curves just like dual porosity effects (peak concentration attenuation and tailing), see Brouyère et al. (2005) in Ground Water. I do not mean that well bore mixing has played a role here, but at least, the authors need to provide the information on the experimental device (well radius, screen length etc) for the reader to make his/her opinion on it and they could check, using analytical or numerical solutions dealing with this effect, if they were likely to play a role. If it was

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the case, all the rest of the analysis would be meaningless.

3. Analytical solutions and the true complexity of chalk

When one thinks about the complexity of chalk formations (fracturation, dual porosity, heterogeneity etc), one can have some doubts about the real applicability of analytical solutions, considering parallel fractures connecting injection and pumping wells ideally etc. Furthermore, most of these models rely on the strong assumption that mass transfer processes occurring between mobile and immobile water are related to molecular diffusion. Recently, there have been several works showing that a contrasted heterogeneity of hydraulic conductivity is likely to produce non-equilibrium solute transport with same "visible" consequences such as concentration attenuation and tailing. To my opinion, a "generalized" dual-porosity model, considering an immobile phase and a first order transfer process between the mobile and immobile fractions without trying to "give a detailed" name to the physical processes behind, is very often largely sufficient to model many tracer test results. Of course, in this case there is always a remaining doubt about the possibility to extrapolate the results, but this is a more general problem.

4. Dealing with tracer mass recovery

In "page 2446", the authors mention a typical problem when calibrating breakthrough curves : the difficulty of calibrating accurately the recovery factor (Mout/Min), in fact, the difficulty to explain mass losses during the tracer transport in the aquifer. I have two comments on this topic: - I do not agree too much with using tricks to constrain calculated and observed mass recovery in models. Doing so is still making strong and often inaccurate assumptions. If the recovered factor is $<$ 100%, the model should be able to explain it as much as possible. I wonder if the analysis and conclusions of the paper would remain the same if the different models were forced to use the true injected mass of tracer. Talking about mass recovery, the authors should indicate the observed recovery factors in Table 1. - Why not basing the fitting procedure on the evolution of mass recovery (Mout(t)/Minj) rather than on the evolution of concentration at the recovery well (Cout(t)), so on the integral of the concentration evolution? Indeed, we are here more concerned by retardation processes (dual porosity effets) and using the evolution of mass recovery would force to better model the tail of the breakthrough curve, where all the information on the retardation processes resides. I have shown in a ageing paper (Brouyère et al 2001, ModelCARE) that the concentration level and the "slope" of the tail is a function of the volume of immobile water in the system. As an example, in the present manuscript, based on a visual analysis of Fig1, my feeling is that the SFmodel does not fit well because the calculated tail decreases more rapidly than the experimental oneĚ

5. mechanical dispersion and diffusion in the matrix

To my opinion, there is nothing surprising in noticing that there is an indetermination between mechanical dispersion and matrix diffusion. Both mechanisms lead to global dispersion of the tracer in the chalk massif and it is probably not so evident to distinguish between both contributions on the tracer transport.

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