Examples of discussions related to diagnostic quiz questions

**Unit: RISK ASSESSMENT**

• Do you agree with the statement “in general, we worry less about naturally-occurring substances in soil and groundwater”?

Yes 🞏 No 🗹

***Comments*** *There is a popular belief, e.g. for dietary and environmental issues, that everything “natural”, i.e. made by nature, is good. Some students associate contaminants in the subsurface with releases of wastes and, hence, have conceptual difficulties relating the presence of some toxic substances such as arsenic and chromium to the chemical composition of rock formations.*

**Unit: SUBSURFACE FLOW**

• The average linear velocity or seepage velocity ... (check all correct answers)

🗹 is the Darcy velocity divided by porosity

🗹 is discharge divided by the portion of the cross section that is available for flow

🗹 gives good estimates when used in calculations of travel time of contaminants in laboratory experiments

🗷?? is a good approximation of the actual groundwater velocity within the soil pores

***Comments*** *Multiple questions can provide an opportunity to summarize all main points or provide alternative ways of thinking about the same concept. Since students know that there may be more than one correct answers, they have a motive to read each one carefully. An extra challenge is added if the instructor includes questions that can be argued whether are correct or not – for which the instructor gives her opinion but not an authoritative answer. For this question, the first statement corresponds to how we calculate average linear velocity. The second statement the rationale of dividing by porosity. The third statement gives the empirical evidence that average linear velocity is useful. The fourth statement is a matter of epistemic belief. This instructor believes that since we cannot know the actual velocity at the microscale, it is better not to consider the average linear velocity a good approximation of an unknowable quantity.*

• The Laplace equation (∇2h=0) is valid when we have... (check all correct answers, one or more)

🗹 constant fluid density

🗹 homogeneous and isotropic soil

🗹 no pumping, no injection

🗹 something else

***Comments*** *Like the previous question, here the students have a motive to read each one carefully and also think whether an important condition for the validity of the equation is missing (something else: steady-state conditions!).*

**Unit: SOIL-CONTAMINANT INTERACTION**

• Do you agree with the statement “all contaminants sorb to soil”?

Yes 🗹 No 🞏

***Comments*** *Students have difficulty answering yes to this question. It is a similar difficulty accepting that no substance is “insoluble in water”, as they see sometimes in material property sheets. This difficulty gives a good opportunity to stress that something considered “(practically) insoluble in water” in other applications, e.g. when mixing of liquids is of interest, may be of concern for environmental geotechnics at a parts-per-billion concentration. Discussion of this simple question has the potential to reinforce the idea that all substances partition to all phases, to bigger or smaller extent. All substances volatilize in air (some very little), all substances dissolve in water (some very little), all substances sorb to soil (a few very little: useful as tracers!).*

• The solubility of trichloroethene (TCE) is equal to 1100 mg/l. Chemical analysis of a groundwater sample from a well gives a concentration >1100 mg/l. What do you conclude from this result?

🗷 The analysis is wrong (it gave an impossible value)

🗹 TCE is present as a nonaqueous phase liquid at the well

🗷 Pumping caused sorbed contaminant to enter the well

***Comments*** *This is a question that requires a “high difficulty” alert.* *In addition, before inviting the students to answer this question, the instructor needs to explain how is TCE extracted from a liquid sample obtained from a well.* *The initial version of this question included only the first two statements and meant to stress the possibility that when we sample water, on rare occasions, we may draw NAPL mass with the pumped water. If the presence of NAPL is not noticed and we assign the total contaminant mass to the aqueous volume, we end up with a concentration higher then solubility. The third statement was offered by a student during class discussion and it is an example of incomplete knowledge concerning solid-liquid partitioning. The discussion of the question revealed that the student envisioned the sorbed contaminant as a stored quantity of contaminant mass that could be moved as a result of hydraulic phenomena instead of physicochemical phenomena.*

**Unit: TRANSPORT OF SOLUTES (DISSOLVED CONTAMINANTS) IN SATURATED SOIL: ΜATHEMATICAL DESCRIPTION**

• An aqueous solution of two contaminants has been released in the subsurface and reached the water table. You use the same transport equation to study their spreading in groundwater. From the parameters listed below, mark which ones you expect to be the same and which different in the equation used to describe the spreading of each contaminant:

- Duration of contaminant release Same 🗹 Different 🞏

- Contaminant concentration at the source Same 🞏 Different 🗹

- Advection velocity Same 🗹 Different 🞏

- Retardation factor Same 🞏 Different 🗹

- Coefficient of diffusion Same 🗹 Different 🗹

- Coefficient of mechanical dispersion Same 🗹 Different 🞏

- Half life Same 🞏 Different 🗹

***Comments*** *This question belongs in the family of questions that ask “this parameter… is a function of? is related to? is a property of? depends on?” Herein the parameters belong in three categories: (a) boundary conditions at the source (duration of contaminant release, contaminant concentration at the source), (b) characteristics of the flow domain-medium (advection velocity, coefficient of mechanical dispersion) and (c) joint characteristics of the contaminant and the medium (retardation factor, coefficient of diffusion, half life). It is interesting that when dispersion is discussed, students are told that dispersion is advection in micro-scale. However, when faced with all the parameters of contaminant transport together, some say that each contaminant will have a different coefficient of dispersion. For coefficient of diffusion, both answers can be considered to be correct: whereas different coefficients of diffusion are measured experimentally (different 🗹), the differences are typically small and often a common value, equal to 10-9 m2/s, is used for all contaminants (same 🗹).*