Remediation of soil and groundwater
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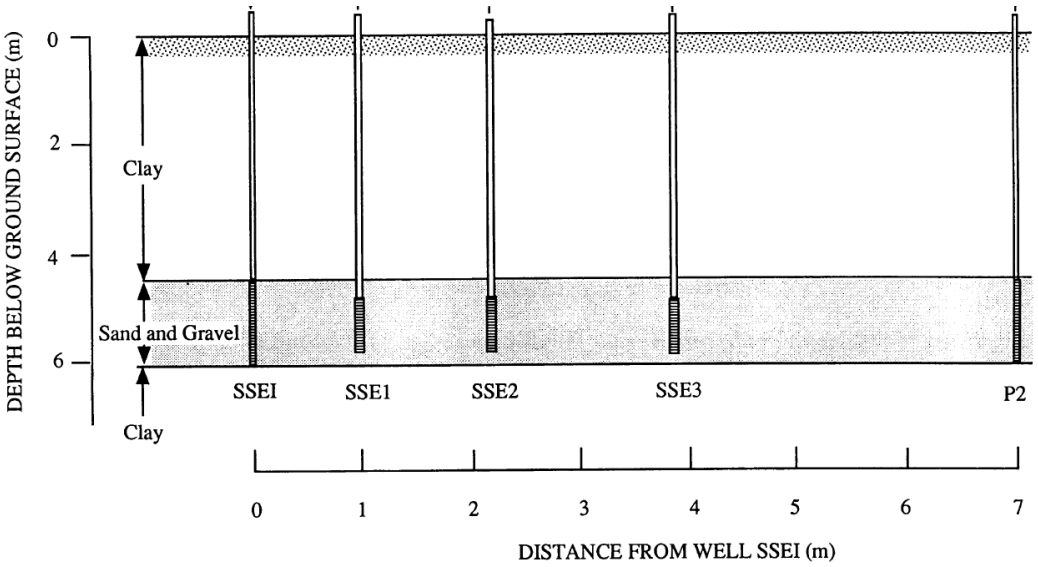
Problem set #3 solution: physicochemical monitoring

Problem 1:
An *in situ* pilot study of the aerobic cometabolic biodegradation of TCE with phenol was carried out in California. Oxygen and phenol were injected in the injection well and water was extracted in the extraction well. Monitoring wells were installed to observe the processes underway.
The wells consisted of standard 5-cm polyvinyl chloride pipe installed by using a hollow stem auger. These wells contained 1.5-m slotted screens, installed 4.5 to 6.0 m below the ground surface. Based on laboratory experiments, the initial rate of degradation of TCE in the presence of phenol and oxygen is 0.05 µg/L-hr. The aquifer contained approximately 40 µg/L TCE.
The goal of this experiment is to evaluate the effectiveness of this strategy for the bioremediation of TCE. Please propose a monitoring program for this experiment. Where do you propose to sample, how often, what do you propose to measure? Please consider a combined physicochemical and microbiological monitoring option.



Solution:
The pilot study seeks to stimulate microorganisms that cometabolically degrade TCE with phenol utilizing O_2 as an electron acceptor. Thus, it would be important to monitor DO, phenol and TCE as well as the potential degradation products of TCE, DCE, vinyl chlorine and ethene. The injection well is SSEI, thus, SSE1, SSE2 and SSE3 should be monitored. P2 is likely used for extraction and recirculation of the groundwater. In terms of the frequency of the measurement, we do not have information about the pumping rate (from P2 into SSEI), however, based on the degradation rate, it is likely that little will happen before a few days given the rate of degradation of 0.05 µg/L-hr determined in the lab and the 40 µg/L TCE in the aquifer. Hence, sampling should happen at an approximate frequency of every 2-4 days and adjusted as data come in.

As for microbiological monitoring, we are looking for the activity of the phenol monooxygenase. There are two options: (a) samples are collected over time in the same wells as those probed for chemical data and analyzed for the content of the phenol monooxygenase gene by qPCR. An increase in PMO content relative to 16S rRNA content would suggest growth of organisms harboring this gene. (b) A more direct approach is the extraction of mRNA from the groundwater and the measurement of the concentration of this gene by qRT-PCR. Finally, since we are considering aqueous samples, it is also possible to extract protein from the samples and quantify the presence of PMO.

Problem 2:
A contaminated aquifer is being characterized to help determine whether remediation is required. In order to probe the need for remediation, an environmental engineer would like to obtain cores down to 30m from the site to determine the extent of the contamination of the solid phase with arsenic (As). The top part of the aquifer is clay and starting at a depth of about 15m, the aquifer material is unconsolidated sandy sediment. What do you recommend the engineer do? What type of drilling?

Solution:
Obtaining cores from a clay aquifer is relatively straightforward. It requires cable percussion drilling that retrieves a complete core from this type of highly cohesive material. However, this will not work for the unconsolidated sand layer. There, either one can freeze the san in place and pull it out as a block (a bit tricky) or one can collect the cuttings from an auger and collect the cuttings for characterization as they come up.