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Subject Comments on 'Cleanup Goals Appropriate for DNAPL Source Zones'

Mr. Kenneth Lovelace,

The following comments concern the EPA document 'Cleanup Goals Appropriate for DNAPL Source Zones'. The comments are the mutual effort of Bruce Stuart and Rich Nussbaum, State of Missouri RCRA program.

Regarding the section on 'DNAPLs as a Source of Contamination': Why not include all NAPLs? Many of the concerns regarding technical practicability, characterization difficulties, balancing source depletion with cost savings in long term care, etc. are still pertinent to LNAPLs. The only notable difference between light and dense NAPLs is that the distribution of LNAPLs in the subsurface is somewhat constrained by the water table in the vertical sense. However residuals are still difficult to determine in two of the three dimensions for LNAPLs; and really not known, but rather bounded in the vertical dimension.

Also, in that same section, there exists a discussion of DNAPL entry into and mobility in an aquifer (Page 3, beginning with line 7). This discussion overstates the mobility of DNAPLs if one considers the circumstances following the initial release. This discsusion would be better served by noting that this mobility is strongly dependant upon a continuous head of NAPL. This head drives the NAPL entry into pores, providing the 'pore entry pressure' necessary to enter through small pores (and perhaps expel water through even smaller pores). When this head is diminished or removed by 'snap off' of the invading NAPL column or interruption of the release at the surface, mobility quickly diminishes. Significant mobility without a column of NAPL is limited to the most coarse of unconsolidated materials.

Regarding the 'EPA Cleanup Goals' section: Risk Based Corrective Action has become a significant factor in determining cleanup goals. The value of the aquifer as a water resource and the value of the property for redevelopment have strong weight and are balanced by the costs to achieve risk based cleanup goals and provide long term care appropriate to manage risk. Thus, source zone depletion is favored at sites with high property values where returning the property to unencumbered use is attractive. Few properties will seek cleanup exceeding risk based levels for industrial/commercial exposure scenarios unless the property and/or groundwater are very valuable.

Regarding the 'Cleanup Technologies' section, Page 4, beginning with line 39: The listing of reasons for the limited application of source depletion should include additional entries to reflect those listed in the following discussion on Page 5, line 34. A fifth item should include: Potential mobilization of DNAPL's and the associated hydraulic control issues that may arise in the application of emerging technologies (use of surfactants, steam, etc. to facilitate enhanced recovery).

Regarding discussion of MCLs as cleanup goals, Page 6, beginning on line 28 and elsewhere in the document: We have chosen MCLs as cleanup goals at some sites in lieu of site-specific risk-based goals simply because they may only be applicable goals for a limited amount of time. Toxicology may change prior to reaching a site-specific risk based goal. Setting the cleanup goals at initiation of the remedy can be a source of un-necessary conflict with the regulated party. Technical Impractibility usually must be preceded by an attempt at remedy and premised on the results of actual experience remediating. Determining the practical limit of remediation and associated cleanup standards requires extensive experience at a particular site. In these circumstances the MCL acts as a sort of 'place holder' for a future decision which will likely relax the MCL level to a risk-based level.

Regarding Item 5 on page 8: Petroleum reservoir engineering provides a lot of potential light on this issue and many of the issues here. Oil recovery is typically expressed as a percentage of the 'original oil-in-place' (OOIP). Estimating OOIP is usually based on geophysical logging and refined with analyses and testing of core samples. Enhanced oil recovery utilizes a higher level of core studies and cores maintained at reservoir conditions. This is a rather expensive proposition. Oil reservoirs are usually bounded by confining materials and the oil entered the 'trap' and filled throughout the trap in geologic time. The distribution of oil saturation is bounded by the trap dimensions and a bottom elevation. Variability in oil saturation is characterized closely by pore volume. NAPL has the added complexity of not having filled a bounded space; but having left residual along branching and fingering paths. It seems nearly impossible to obtain enough cores to characterize the distribution of NAPL saturation and quantify the 'original NAPL in place'.

Also, petroleum reservoirs rarely give up more than 65 percent of their OOIP. OOIP is a highly scrutinized number because it is used along with a likely recovery percentage (and decline curve analyses) to establish oil reserves for a producing property. The oil reserves are the producible portion of OOIP and are considered assets of the oil companies and enter into calculations of taxation and bond ratings. Good reasons for intensive scrutiny on OOIP! The maximum 65 % recovery of OOIP means that 35% or more of the oil remains as 'residual' even with enhanced recovery methods including carbon dioxide flooding, water flooding, miscible gas flooding, surfactants, etc. The oil industry terms this an 'irreducible oil saturation'. Oil recovery is motivated by profit, yet no one has managed to recover all of the oil from any reservoir. Although the distribution of pore sizes probably yields a higher average porosity and pore throat size for aquifer materials, there will be some residual NAPL which can not be mobilized. For fine-grained aquifer materials it is not possible to move any significant portion of residual or force treatments into the spaces it occupies because pore entry pressures can not be generated and managed safely. In comparison, pore size favors a higher recovery for NAPL in aquifers but higher reservoir pressures allow entry of smaller pores in petroleum production. Containment is the only current solution for this portion of the residual NAPL, the irreducible residual if you will. The numeric value of this irreducible residual may be less than 35% of the pore space, but will not approach zero (closely) in most aquifer materials. The only way I can imagine challenging this limit in a cost-effective manner is to create or identify a biota which is small enough to enter the pores which access the residual saturation and then survive to metabolize the high concentration wastes. Or, perhaps a nano-machine tiny enough to enter and destroy the wastes.

Decline curve analyses are also limited to the configuration of the oil production system, as discussed for NAPL recovery at the end of Item 5. Decline curve analyses may indeed similarly reflect limits in the design of the recovery system. Oil companies have identified ways to increase production and 'beat the decline curve'. One method is to make sure the proper vertical interval is open in each producing well (and in various kinds of floods make sure it is also open in injectors). Another is to add wells, either diminishing the spacing between wells and/or changing the patterning of injectors and producers. Another is to manage pressures by keeping producers pumped to as low a level as possible (minimizing pressure at the producer and encouraging flow to it) and managing pressure distribution at injectors by operating them just below pressures which would fracture the reservoir materials and change the point-source injection to a line source (in the two horizontal dimensions). The last method is to use fluids with properties managed to change wetting, change oil viscosity, expand the oil by entering into an oil solution, or increase the flooding fluids viscosity. So "poorly designed recovery systems" can be fixed by managing production and injection intervals, diminishing well spacing, managing patterning of producing wells, keeping pumping levels low in producers, etc. However, the flooding 'fixes' don't translate well to NAPL recovery because most NAPL situations involve water table (unconfined) aquifers and creating and controlling injection patterns and pressures is difficult if not impossible. Methods involving injecting treatment fluids have the same difficulty of needing to generate pressures adequate to overcome pore entry pressures in an unconfined aquifer. The potential shortcomings in the NAPL recovery system design are easily assessed for the pumping well configuration except having knowledge that the recovery system matches the extent of recoverable NAPL.

Item 6 asserts that site owners are the ones who believe that if containment is needed then source removal has little value. But what is described here is basically a RBCA remedy. It doesn't seem appropriate to limit attribution of this view to site owners, since EPA and the states have embraced RBCA.

Regarding Item 7, it seems appropriate to include changes in toxicology as a potential reason for revisiting operating remedies.

Thanks for the opportunity to comment,

Bruce Stuart