Storage and Release of Contaminants in Low Flow Zones

University Consortium For Field-Focused Groundwater Contamination Research
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Overview

Through the consortium's research it has been shown that dissolved and sorbed phase contaminants in low flow zones can act as persistent sources of groundwater contamination. This occurs both in source zones and plumes. Examples of low flow intervals included silt beds bounded by sand and sand layers bounded by gravel.

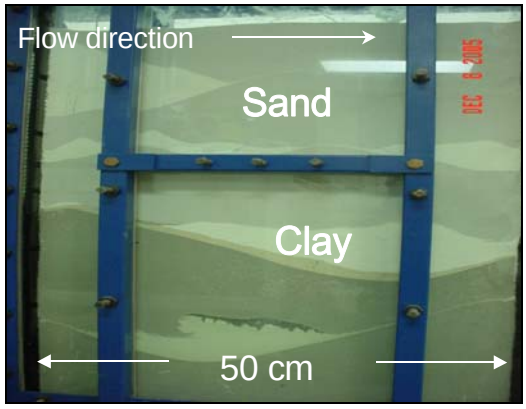
Primary processes governing storage and release of contaminants in low flow zones include sorption, diffusion, and slow advection. The challenges of stored contaminants are that they can sustain groundwater plumes and adversely affect the timing and magnitude of downgradient water quality improvements associated with remedial actions.

In many instances, recognizing and managing contaminants stored in low flow zones is critical to making sound decisions for inadvertent releases of chlorinated solvents and other persistent groundwater contaminants. The following provides a brief summary of governing processes, implications, ongoing research, and sources of additional information.

Processes

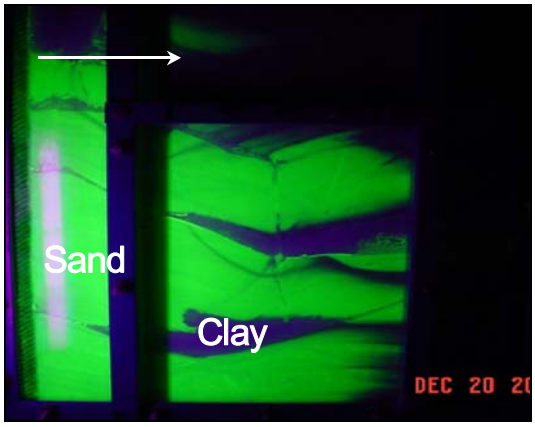
Abrupt contacts between transmissive zones (e.g. sand) and comparatively stagnant zones (e.g. clay) are ubiquitous in geologic media. Interbedded layers of geologic media are illustrated in the rock sample and the sand tank shown in the next two images.

Interbedded sandstone and shale



Setup of sand tank experiment

Initially, DNAPL or dissolved phase contamination preferentially moves into the pathway with the greatest transmissivity. This is illustrated in the sand tank below where fluorescein dye in water is being pumped through a tank containing interbedded layers of sand and clay. At early time, little if any contamination is present in the low conductivity layers (clay).



Fluorescein dye flushing through transmissive zones in a sand tank

With extended time, dissolved phase contaminants are driven into low flow zones by diffusion and/or slow advection. Contaminants in low flow zones are stored in both dissolved and sorbed phases. Ultimately, through natural processes and/or remediation, contaminants in the transmissive zones are depleted. This reduces aqueous concentrations in transmissive zones and drives releases of contaminants from low flow zones via back

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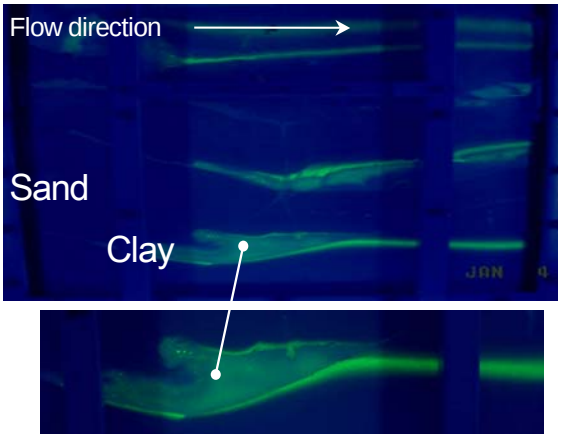
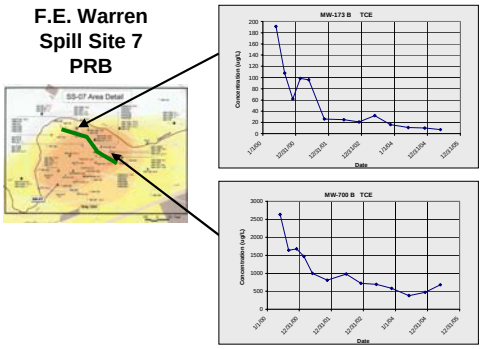
diffusion and slow advection. The release process is illustrated by the trails of water with fluorescein dye emanating from the clay layers in the image below.



Release of contaminants after removal of fluorescein in the flushing solution

Field data from F. E. Warren AFB, WY (shown in the next image) provides further insights. An iron PRB was installed in 2000 along the green line. This action reduced TCE concentrations at the barrier by multiple orders of magnitude to values less than 5 *u*g/L. After five years, TCE concentrations forty and sixty feet down gradient of the barrier dropped by only one order of magnitude. Sustained concentrations of TCE downgradient of the barrier are attributed to desorption and back diffusion from low flow zones.



Field data from F.E. Warren AFB courtesy of F.E, Warren and AFCEE

The degree to which stored contaminants can sustain plumes is dependent on site conditions. General conditions that favor sustained release of stored contaminants include:

- A large degree of geologic heterogeneity,
- Geologic settings with transmissive zones that are a small fraction of the total volume of the aquifer,
- Contaminants that have large aqueous solubility,
- Contaminants that are stable in their physical setting (e.g. chlorinated solvents in oxic environments),
- Systems with relatively slow groundwater flow rates,
- Sediments with high fractions of organic carbon,
- Sites where large amounts of contaminant were released, and
- Older sites where there has been a large amount of time for contaminants to move into low flow intervals.

Implications

Primary implications include:

- Release of stored contaminants can sustain contaminant discharge from source zones. This explains persistent releases of contaminant from plume heads where little, if any, DNAPL can be found.

- Given near perfect depletion and/or containment of sources, downgradient plumes can persist for extended periods. As such, removal and/or containment of sources may not provide substantial reductions in site care requirements for decades.

- A large fraction of the total stored contaminant mass can occur outside of the “Source Zones”.

- Source zone treatments that solely address transmissive zones may miss substantial contaminant mass in low flow zones and be subject to rebound.

- An emerging question is: when is it technically practical to treat contaminants stored in low flow zones, in source zones, and in plumes?

Path Forward

Our understanding of the science of the problem is largely mature. The challenge is to bring the ideas noted herein to mainstream thinking and to bear in the process of selecting remedies for sites. Building on this, consortium researchers and sponsors are prompting recognition of the themes presented herein through publications, presentations at conferences, and interactions with regulatory groups.

A critical research topic that has emerged from our initiatives is resolving the technical feasibility of treating contaminants stored in low flow zones. This will be a session topic at the consortium's May 2007 Annual Meeting in Toronto.

More Information

Comprehensive information on the topic of contaminant storage and release in low flow zones can be found in presentations from the Fall 2005 Focus Meeting. These are posted on the consortium's web page. In addition, Chapman and Parker, (2005), Water Resource Research, Vol. 41, No. 12, provide rigorous development of the ideas presented herein. Further unpublished information is available through the authors of this note.