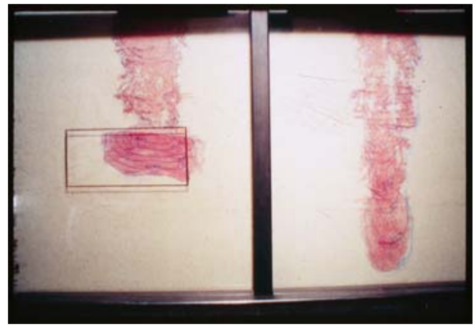

Figure 1a: NAPL propagation Figure 1b: NAPL entrapment

*( We can label the figures identifying the sand types etc.)*

**ENTRAPMENT OF NAPLs IN THE VADOSE ZONE:**

**Objective**:

To demonstrate the effect of heterogeneity on the flow and transport of a NAPL in the vadose zone.

**Experiment**:

The tank is divided into two symmetrical halves. The right half was packed with a single sand to create a homogeneous packing configuration. The left half of the tank was packed with the same sand as on the right, except a simple heterogeneity was created by embedding a lens of sand that is finer that the first sand. The basic properties of the two test sands are given in Table 1.

After packing the tank, the soil was fully saturated by raising the water table to the top of the soil surface. The water table was dropped and the water was allowed to drain to create unsaturated conditions on both sections of the tank. The residual water content in each of the soils defines the initial conditions.

Equal volumes of a dyed test NAPL was spilled during the same time period on both sides of the tank. The pictures show the propagation of the NAPL front and the final entrapment.

| Sand type | K (m/s) | $d_{50}$ (MM) | Uniformity coefficient. | Entry pressure $P_d$ (m) | Pore index $\lambda$ | Residual saturation $S_r$ |
|---|---|---|---|---|---|---|
| #30-coarse | 0.00145 | 0.49 | 1.50 | 0.055 | 2.1 | 0.20 |
| #70-fine | 0.00024 | 0.19 | 1.86 | 0.250 | 1.9 | 0.30 |

**Table 1**: Soil properties

**Process Description:**

A comparison of the two NAPL distributions clearly shows the impact of the fine sand lens on the propagation of NAPL front and the final entrapment. The fine sand lens immobilized the NAPL through entrapment. When the NAPL enters the formation, the two-phase air-water system becomes a three-phase system consisting of air-water-NAPL. The water is the wetting fluid and the air and NAPL are both non-wetting. When the

NAPL enters a pore containing water and air, it will try to displace the non-wetting air phase. At the same elevation above the water table, before the spill, the finer sand retained more water compared to the coarse sand. The higher water saturation in the finer sand implies low air saturation ($S_{air}$=1-$S_w$, in the two-phase system where $S_{air}$=air saturation and $S_w$= water saturation). The low air saturation also implies smaller available pore space for the NAPL to enter. With adequate driving head (as determined by the NAPL spill volume and head) the NAPL will enter the small pore spaces by displacing the air. As the pore size is very small, the capillary pressures in the NAPL phases become very high, thus entrapping the NAPL in the finer lens.

**Practical Implications:**

Finer sands preferentially retains the NAPL in the vadose zone. In remediating the vadose zone it is necessary to focus on the finer sand formations as most of the NAPLs will be retained in fine sands.