Locating DNAPLs with Flexible Liners

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Abstract: The characteristics of flexible liners have been used to locate DNAPLs with two very different methods. The first flexible liner method uses a color reactive covering on an inflated liner to map the distribution of pure NAPL product in the subsurface. The color reactive material is emplaced via several different procedures to allow contact with the wall of a punched or bored hole. The covering is removed by inversion to avoid contact of the reactive material with any other part of the hole. The result is read at the surface as a stain pattern showing the distribution of the pure product in the formation. The second flexible liner method is a multi-level water sampling technique, which uses the sealing properties of a dilated liner to isolate water sampling intervals one from another. The easy installation by eversion, the high spatial resolution of many ports, the simple and quick sampling procedure, the large volume of fluid sampled, and the easy removal of the liner by inversion are characteristics that distinguish the flexible liner multi-level sampling system. Installations have been done for a very wide range of conditions. The easiest are installations in high conductivity formations with relatively shallow water tables. The challenges of deep water tables and tight formations have been met by special designs and procedures. Several hundred systems of both kinds have been successfully installed in 16 States plus Canada and Denmark.

The NAPL FLUTe system (FLUTe, pronounced like the musical instrument, has become the convenient term for Flexible Liner Underground Technologies) was developed by the combination of three important techniques. The first part is the reactive covering. Initially, a Sudan IV impregnated hydrophobic material was developed in concert with Westinghouse Savannah River Co. This material turned a brilliant red in contact with any oils and solvents. However, Sudan IV is too toxic to be used as we wished to use it to locate DNAPL. More recently, the Sudan IV has been replaced with a non-toxic striped dye pattern on the same hydrophobic material. The dye does not change color in contact with oils and solvents, but rather it is mobilized by the NAPL (e.g., TCE, Lindane, gasoline, coal oil, etc…). The contact of the covering with NAPLs immediately causes the pure product to be wicked into the hydrophobic material, carrying the dye with it. The leached dye causes a stain on the undyed, white, side of the hydrophobic material. The first photo shows the stains produced by several contaminant droplets, which were touched with the striped covering under water. The gasoline stain in the

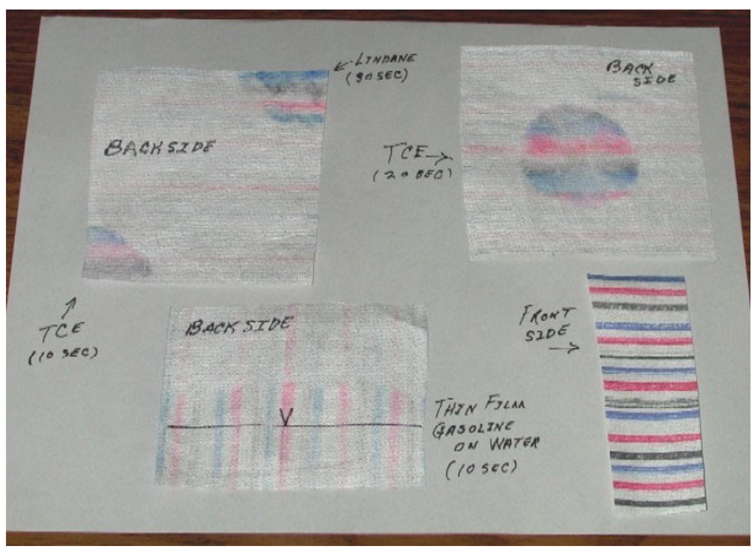

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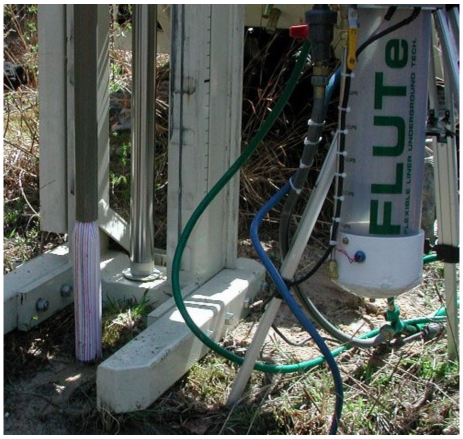
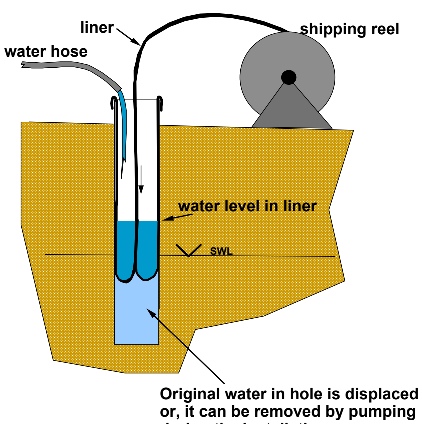
photo is less vivid than the other stains, but it was produced by a few drops of gasoline floating <u>on the surface</u> of a cup of water. The gasoline wicks quickly above and below the water surface shown. The contact times are shown in the hand lettering. They range from 10 to 30 seconds. The samples labeled “Backside” show the side of the covering opposite from the dye-striped side, labeled as “Front Side”. The leaching of the dye from the striped front side to the white backside makes the search for stains very easy.



The second necessity of the NAPL FLUTe system was the ability to emplace the covering in the earth without contacting the hole wall but once with the entire covering. That was effected by installing the covering/liner system in a driven casing (e.g., a cone penetrometer or Geoprobe rod). The rod is withdrawn, exposing the covering to the hole wall. The striped covering is on the outside of an impermeable pressurized liner which expands in the hole as it is uncovered by the rod. One can see the dilating striped cover in the photo at the bottom of the dark rod as the rod is drawn out of the ground. In the same manner, the liner and covering dilate to fill the hole as the rods are pulled. The patented technique employed prevents the liner from dilating in the rod. Were the liner to dilate in the rod, the friction would tear the liner and covering apart.

Once the liner and covering are in place in the hole, the covering is forced against the hole wall by the interior water pressure. After a prescribed time, usually about an hour, the liner is inverted from the hole (the third important feature of the method), carrying the covering with it. It is “peeled” out of the hole without touching any other part of the hole wall. The carrier liner is then pulled off the covering, now inside out, and the inside of the covering now exposed is “read” for the telltale stains. The third photo shows the smaller spots of stains formed by beads of DNAPL at a site in Md. The massive staining seen in the 4th photo at about 20 ft and 30 ft in a 45 ft hole are the result of two thick layers of solvent intersected by the push rod at the same site as photo 3. The brown color is that of the solvent. The dye stains are on the fringes of the brown stains. This technique allows a positive location of the elusive DNAPL.



The Water FLUTe system uses an everting liner to transport a sampling and isolation system into the hole as shown in the drawing at the left. The liner is attached to the well casing and everted into the hole by “Just adding water”. The fifth photo (next page) shows the installation, from a large reel, of a 330 ft. system with 15 sampling intervals in a 6-inch diam. hole for the Univ. of Waterloo at Cambridge, Ontario. The entire installation took about 8 hours to first remove a blank liner (a liner with no attachments which seals and supports the hole) from the hole and then to install the instrumented liner. It takes about an hour to sample all 15 ports, which produce about 15 gallons of water per stroke of the pumping system. These multi level sampling systems are being used at many sites to monitor the transport of a wide range of DNAPL contaminants. Installation depths of over 800 ft. have been done recently at Pantex (near Amarillo, TX) with a water table at 475 ft.

In summary, these two flexible liner methods are examples of a much wider range of flexible liner designs that have been installed for mapping and monitoring ground water contamination sources. The most common use of flexible liners is the "blank liner" used to seal boreholes immediately after they have been bored to prevent contamination spread via the open hole. This is especially useful for DNAPL situations. These blank liner installations are also done by "just adding water." New formation characterization methods, which are under development, use the installation velocity of the blank liner as a means of determining the vertical distribution of conductivity in the hole wall.

The evolution of these flexible liner techniques has been possible through the development of sufficiently rugged liner designs and the procedures that make the use practical. However, these designs are still evolving. That is especially true of the liners installed to great depths in relatively tight fractured rock formations. Other publications are available on the details of how these installations are performed. FLUTe holds 13 patents on the use of flexible liners with several more pending. The methods described herein are covered by those patents.