Ohio Department of Health
Bureau of Local Environmental Health Services

May, 2000

Dye Testing Wells

Tracing dyes have been used extensively in ground water and surface water hydrology investigation and experiments since the early 1960s. Tracing dyes may also be useful for conducting investigations of problem drinking water wells. An improper grout seal between the casing and the outer wall of the borehole, called the annular space, can allow the rapid infiltration of surface water or shallow ground water into the aquifer. When rapid infiltration occurs, the natural attenuation of microorganisms does not take place. Wells may be dye tested when there is a question about the integrity of the annular space grout seal.

Wells may also be dye tested when there is a question about the proper installation of the pitless adapter. Because the excavation made to install the pitless adapter is usually back-filled loosely with natural soil, improper installation of the pitless adapter inside and outside gaskets, or a roughly constructed hole, may provide an avenue of entry for surface water.

Wells drilled with the cable-tool method of construction have the potential for three additional problems related to improper grout placement or the complete lack of grout in the annular space. During the construction process an enlarged borehole can be created by the wobble that occurs during the installation of each section of casing. This can form a micro annulus between the casing and the borehole that allows the downward movement of surface water. In addition, before the 2000 Ohio Private Water System Rules were made effective, driven wells were not required to have dry bentonite grout placed as the casing was being driven into the borehole. Therefore, when grouting is inadequate other construction deficiencies are compounded. Poorly sealed joints, due to inadequate welding, can provide an avenue for entry of surface or shallow groundwater. Finally, there is the potential for leakage at the end of the casing when the drive-shoe end of the casing is not seated tightly into the rock.

The basic concept behind using dyes as tracers is to simulate the pathways that contaminants might follow to the ground water. The problem with this concept is that different contaminants travel at different rates under varying soil and subsurface conditions. Also, dyes tend to travel slower than water because of adsorption onto soil particles. Positive or negative dye test results do not always provide conclusive evidence that a problem exist. Therefore, dye testing should be considered as only one of several tools that may be used in conducting a drinking water well investigation. A dye test should be considered prior to doing a down hole camera inspection.

Typically, a dye test is most beneficial when the tracing dye is detected in a water sample within hours or a few days of its application. This rapid detection of dye normally indicates a problem with the grout seal of the well or a poor pitless adapter connection. Proper grouting of the annular space should prevent the movement of dye into the borehole. If the dye begins seeping down the outside boundary of the grout, it should be binding with bentonite or natural clay particles that, in effect, slow the movement of the dye. However, caution must be taken in conducting a dye test when wells are constructed in sandy type soils because the dye may not be adsorbing readily to the soil or overburden particles and may appear in a well that has been properly constructed. Because sand has larger air spaces, the attenuation of some microorganisms can take place during dry periods due to desiccation. Conversely, surviving microorganism populations may be carried by water movement during wet periods to shallow aquifers without being adequately filtered out.

Wells constructed in karst or fractured bedrock formations can have direct pathways from the surface that can lead to water well contamination even when the well has been constructed in compliance with regulations. Another factor affecting the downward movement of dye is the moisture content in the soil. If soils are already saturated from recent rains the water and dye will move downward more slowly. In conditions where soils are not already saturated, the water and dye used in the test may initially move downward quickly and subsequently the dye may become bound in the soils with greater porosity and low conductivity such as clays and silts. Water and dye movement could again be initiated after a heavy rain event. Also, construction violations may be present on a well that has a negative dye test. For example, a well may be constructed with insufficient casing constructed through a heavy clay overburden. The clay would have a tendency to adsorb the dye. Dye has been observed in well water several weeks and even months after an investigation has been conducted. The lack of appearance of dye in wells constructed in any of these conditions does not mean that a contamination pathway may not exist.

When dyes appear in a well more than 72 hours after application then more information about the soil and subsurface conditions is needed. More precise calculations of potential contaminant transport can be made using well log information, soil survey information, infiltration rate calculations for unsaturated conditions, and applying *Darcy's Law* equations for saturated soil conditions. The point at which a dye test is going to be regarded as inconclusive may be based on this information. The appearance of dye in a well more than a week after its application is generally regarded as inconclusive.

The Dyes

There are several different dyes that may now be used based on their listing on ANSI/ National Sanitation Foundation (NSF) Standard 60: Drinking Water Treatment Chemicals - Health Effects. Any dye listed in NSF Standard 60 may be used in Ohio for private water systems investigations. These dyes have different properties based on the ability to bind with clay particles, how well they contrast with the natural background, and their abilities to fluoresce.

The following is a description of the dyes that may be used for private water well investigations:

Rhodamine WT (FWT Red)

Rhodamine WT is a red fluorescent tracing dye in the anionic xanthene group of dyes. Of the dyes available for groundwater investigations, it has the least affinity to bind with clay particles. Rhodamine WT comes in either a liquid or powdered form, and is visually detectable at about 4-5 ug/l. The dye fluoresces orange under a black light and may be observed microscopically with a fluorometer at levels as low as .01 ug/l. Rhodamine WT is generally more expensive than the other dyes listed on NSF Standard 60. It also has a higher relative toxicity than the other NSF Standard 60 listed dyes depending on the percent concentration used. Rhodamine WT may also combine with nitrates in the groundwater to form diethylnitrosamine (DENA). Therefore, caution should taken when Rhodamine WT is used where nitrate contamination is suspected. As with most dyes, Rhodamine WT can be visibly removed from water by oxidizing it with chlorine bleach. It should be noted, however, that the addition of chlorine to high concentrations of dye might cause the production of chlorophenols, which can impart undesirable taste to the water. Another similar dye, **Rhodamine B red florescent dye, should not be used** for water well investigations because of issues with it's higher toxicity.

Fluorescein (FLT Yellow / Green, uranin, pthalien)

Fluorescein is a green/ yellow florescent anionic xanthene dye. This is the dye that has been most commonly used for septic system investigations in Ohio. Fluorescein binds with clay particle more readily than Rhodamine WT, but has lower relative toxicity. It is also somewhat less expensive than Rhodamine. Microscopically it may be difficult to distinguish from other naturally florescent material, but will have more contrast than non-fluorescent blue dye.

Non-fluorescent Blue (FLT Blue)

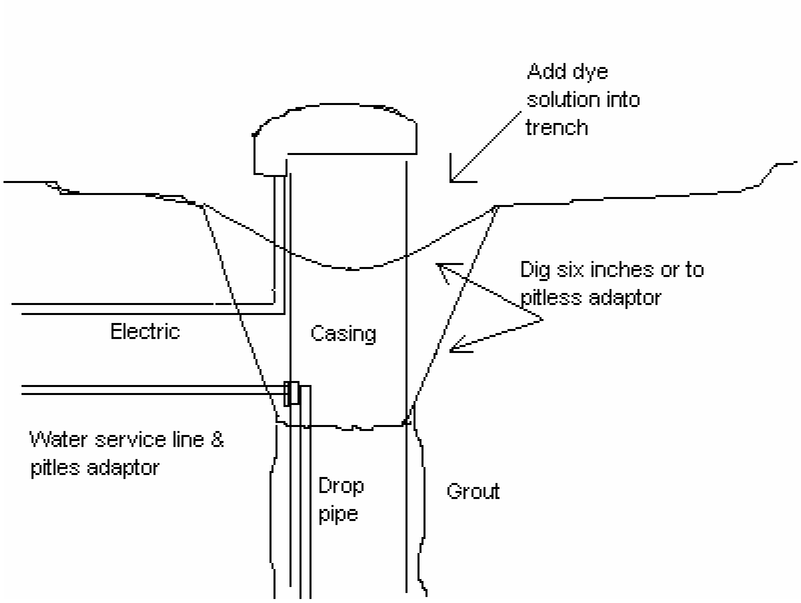
Blue dyes, while not algaecides, have been used to shade out the formation of algae in ponds. For water well investigation applications, this dye will have the highest affinity to bind with clay particles. FLT Blue does not fluoresce making it difficult to see when it is diluted. However, FLT Blue does have the lowest relative toxicity of the group. This dye will require higher concentrations to make it visible, and should realistically be used when the contamination pathways are obvious.

Conducting a Dye Test

A thorough review of the well log and completion forms should be done prior to attempting a dye test. This will help establish if proper grout materials and placement were used, casing and well screens were properly placed at the appropriate depths, and the pitless adapter was installed properly. The amount and density of grout material needed for the proper construction of a well should be calculated and then compared to the information provided on the well log.

Dig a shallow trench about six inches deep around the well casing, being careful to avoid damaging the electrical conduit (see diagram following page). This trench acts as the reservoir in which to place the dye solution. Do not probe the ground prior to placing the dye as this may allow the dye to penetrate the annular space faster. Saturate the trench with water prior to placing the dye in it. Mix about one quarter to one third bottle of concentrated dye in a five-gallon bucket of water then pour this into the trench on all sides. If the dye is a powder or lower concentration liquid flowable, then more dye may need to be added to increase the concentration to be placed. The overall dilution of the dye that takes place is completely dependent on the amount of water that the initial dye solution must pass through. An additional five gallons of water should be added to the trench in order to facilitate water movement similar to a heavy rain event.

Diagram of Well and Trench



Another option is to excavate down to the pitless adapter and place the dye at that point. Excavating below the pitless adapter and introducing the dye at this point is done because after the pitless adapter installation the grout material that may have been present initially around the casing has been replaced with native materials when the excavation is back-filled. Grout would therefore only be present at the point below the pitless adapter. This also affords the opportunity to inspect the pitless adapter for leakage.

Take a control water sample from the sink or other tap just before pouring the dye into the trench and then take another sample immediately after the dye solution has soaked into the ground. Any clean clear container may be used. Look for the appearance of dye. Using a white background against the clear bottle can make visual detection of the dye a little easier. Dyes may be detected with a fluorometer at levels below visual detection. Take the next sample after 15 minutes and then repeat this procedure every 30 minutes for a couple of hours. Have the homeowner continue to take samples and record the exact time and date the sample was taken. The homeowners should not be drinking the water from a contaminated well unless the water has been disinfected by boiling or other equivalent means. Homeowners should limit their uses to laundry and flushing toilets. Advise the homeowner to contact you the moment there is any detection of dye. These dyes could cause possible staining on clothes and skin. Make arrangements to visit the sight at least once every other day to observe the samples. If the dye has been detected, it can be visibly removed with liquid chlorine. To do this, mix approximately one gallon of chlorine bleach in a five-gallon bucket of water and place this in the well and annular space to visibly remove the dye.

Fluorometers and Microscopic Examination

For the most part, typical water well investigations using tracing dyes are going to be subjective and unscientific. There is a reliance on rapid and obvious visual detection. One of the advantages in using fluorescent dyes, however, is just that, they fluoresce. Fluorescence occurs when certain wavelengths of UV light excite molecules. Fluorometers are used to detect fluorescent materials. Because the dyes can become diluted to the point beyond visual detection, microscopic examination using a fluorometer may be considered. This involves the submission of even clear samples to a lab for examination. Currently there is no listing of laboratories that can do this, therefore check with your lab to see if they have the capability of conducting this kind of analysis.

Companies That Have Certified Tracing Dyes on ANSI/NSF Standard 60: Drinking Water Treatment Chemicals - Health Effects

*Dyes are listed in the category “Miscellaneous Treatment Applications”

Cole Parmer Instrument Company
625 E. Bunker Court
Vernon Hills, IL 60018
(847) 549-7600

Crompton & Knowles Corporation
Dyes & Chemicals Division
P. O. Box 341
Reading, PA 19603
(215) 582-8765

Kingscote Chemicals
1201 Taylor Street
Elyria, OH 44036
(619) 693-4062

**Norlab, Inc
P.O. Box 380
Amherst, Ohio 44001
1(800) 247-9422

** Some companies purchase their dyes from the manufacturers listed above. If the dyes have not been remanufactured or altered from the NSF tested product then these dye brands would be considered acceptable for use in Ohio.

References:

EPA/625/6-90/016, Handbook Groundwater, 1990

Groundwater and Wells, Fletcher Driscoll, Johnson Division, 1986

ASNI/NSF Standard 60

A Toxicological Evaluation of Rhodamine WT (CAS # 37299-86-8), Hazardous Substance and Waste Management Research, Inc., 1992

Wisconsin Department of Natural Resources, Correspondence, 6-97