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The Use of Monitoring Equipment to Detect Contamination in Ground and Soil Waters of the Saturated and Unsaturated Zones

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Abstract

Water is found within two different settings within the subsurface commonly referred to as the saturated zone and the unsaturated zone. Chemical analyses of ground-water and soil-moisture samples from these zones help to determine local and regional water quality. In addition, the chemistry of water can indicate how water has infiltrated from the ground surface down through the soil/rock profile and into the ground-water aquifer. Water sampling requires access into the subsurface without alteration of the water quality. The Kansas Geological Survey (KGS) has commonly used observation wells to monitor the saturated zone and lysimeters to monitor the unsaturated zone. Recent KGS studies have been focused on determination of the general water chemistry and hydraulic characteristics of aquifers, detection of selected contaminants (nitrate and atrazine), the observation of water-level fluctuations, and assessment of saltwater in various aquifers throughout the state.

Saturated-zone Monitoring

The most common method for monitoring ground-water characteristics in the saturated zone involves the installation of individual monitoring wells or well nests. A nest of wells can consist of several wells in a single borehole. The number of wells in a nest depends upon the thickness and stratification of an aquifer as well as the subsurface behavior of the contaminant within the aquifer. Within each nest, the wells vary in depth and contain small screened sections to sample discrete intervals of the aquifer (fig. 1).

The shallowest well is typically screened across the water-table interval. This interval is selected to evaluate the effects of a fluctuating water table on the presence and movement of a contaminant. Fluctuating water tables result from a variety of factors including variations in the amount of recharge entering an aquifer relative to natural discharge or pumping, and recovery following long-term pumping.

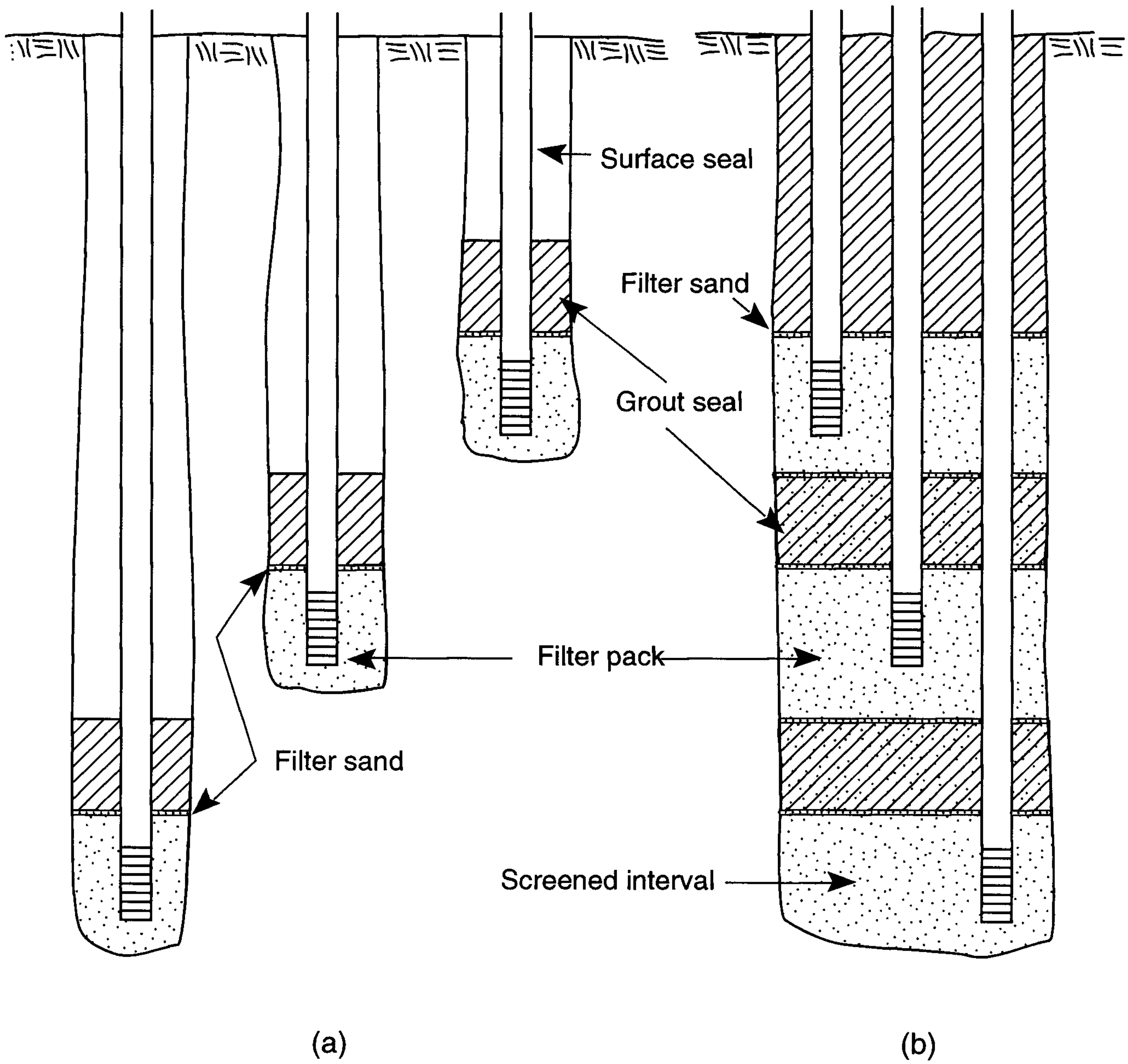

Figure 1. Diagrammatic representation of the construction details of individual monitoring wells (a) and monitoring-well nest (b). Each borehole is backfilled with gravel or filter pack around the well inlet and succeeding borehole materials. The sampling intervals are similar for either installation (Aller et al., 1989).

The occurrence of a contaminant near the water table can be caused by porosity differences between the water table and the capillary fringe located just above it. In the capillary fringe (fig. 2), the pore spaces in the soil/rock profile are filled with a mixture of air and water. The vacant pores fill with water when the water table rises and drain as the water-table level drops. A contaminant, as well as water, that moves downward through soil/rock profile can become trapped in these pore spaces by the air/water mixtures. The contaminant may be moved with the next fluctuation of the water table or remain trapped in the fringe.

Some contaminants, such as nitrate, become stratified in the shallow ground-water aquifers. The exact cause of this stratification is unknown, but studies have shown that nitrate concentration is frequently higher in the shallowest portion of the aquifer and decreases with depth. Thus, when designing a monitoring site to detect nitrate, screening at least one well at or just below the average water-table level is necessary. The deeper monitoring wells of the nests are necessary to determine vertical gradients at the site, occurrence and extent of mixing, and level of contamination. Multi-level well nests also may indicate the occurrence of chemical changes which could affect the migration of a contaminant.

KGS Monitoring Wells *

Construction - Monitoring wells can be constructed of a variety of materials. Although well depth plays a role, the type of contaminant under investigation often dictates the materials used in monitoring-well construction. Some contaminants adhere to materials made from polyvinyl chloride (PVC); therefore, stainless steel or Teflon construction materials need to be used. The Kansas Geological Survey (KGS) typically investigates inorganic constituents including nitrate and atrazine, which are not known to adhere to PVC. For this reason, PVC is most commonly used. Other benefits of PVC include low cost and ease of installation.

**(This is for information only. All KGS well installations follow the Kansas Department of Health and Environment rules and regulations. All individuals responsible for installations of wells and other ground -water-monitoring devices should do so in accordance with KDHE Rules and Regulations Article 30 of KSA. Contact KDHE, Topeka, Kansas, for guideline regarding such matters).*

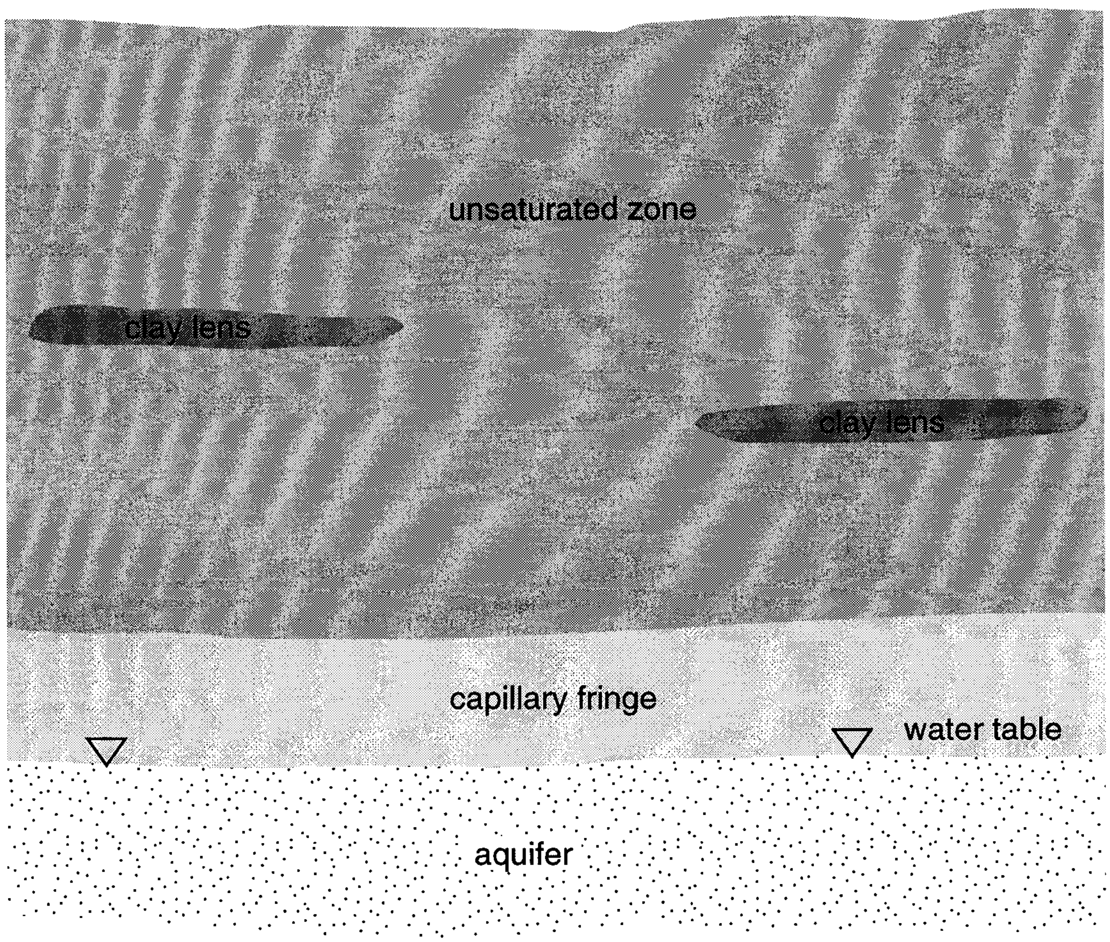

Figure 2. Representation of the relationship among the unsaturated zone, capillary fringe, and the saturated zone (aquifer). Shallow wells of a monitoring-well nest are screened across the water-table and within the capillary fringe.

KGS monitoring wells are usually constructed of 2-to 5-inch diameter schedule 40 (or schedule 80) PVC with an appropriate screen length. The screen, also constructed of PVC, has milled openings or slots which allow water to flow freely into the well casing while preventing very fine sediments from entering. The size of the well casing is determined by sampling and testing protocols (i.e. water level, contaminant, slug or pump tests, etc.) required for the site investigation.

The PVC wells are constructed of either bell-or screw-joint pipe. The type of casing joint used is determined by the contaminant under investigation. The bell joint pipe must be glued together with PVC solvents and glues. These solvents and glues may contain traces of synthetic organic compounds that would give false readings of site contamination. Therefore, in pesticide-contaminant investigations, screw-joint pipe is often used. In nitrate studies, glued bell-joint PVC is considered sufficient and does not interfere with chemical analysis.

Drilling and Installation- During the drilling phase of the well installation, sediment samples (drill cuttings) are collected, described, and typically logged at 5-foot intervals. These return samples may be collected less frequently if no lithological change is noticed.

After stabilizing the drill hole, the string of PVC screen and casing is lowered into the open borehole. An appropriately sized gravel pack is poured or tremied (introduced through a small pipe) evenly into the hole around and approximately 5 ft. above the screen (see fig. 1). On top of the gravel pack, a fine sand is tremied in to support a bentonite or neat cement-seal material which follows. These seals are essential to prevent the migration of surface water down the well bore and into the screened interval. After the sealing material has cured, the well is developed until clear (less turbid) water is removed from the well. This process is repeated for each well in the nest at the particular site.

Sampling - During the last stages of the development, a water sample is collected from each well to determine the general chemistry. The specific conductance and temperature of the well water must be monitored and both must stabilize before sampling. This stabilization indicates that the water is representative of the aquifer and is not residual water from the drilling phase. The wells are usually sampled using submersible or hand-operated pumps or a bailer.

If a submersible pump is used, the well is pumped until the specific conductance and temperature have again stabilized over a period of 10 to 15 minutes to assure that aquifer water and not stagnant water in the bore of the well is being sampled. At the KGS, at least 10 well-casing volumes of water are removed prior to collecting a water sample. The well casing volume is determined by measuring the static water level in the well and calculating the volume of the water column. Pumping begins at static water level and the pump is lowered until a stable pumping level can be established. If a bailer or hand pump is used, at least three well volumes of water are removed before a sample is collected.

Sampled water is filtered in the field (depending on the type of analyses to be made) to remove any fine sediment and then placed directly into bottles. Tests such as pH, specific conductance (an estimate of total dissolved solids of the water), and temperature are recorded at the site. This information assists the laboratory personnel in proper preparation of samples for analysis. The sample bottles may contain preservatives depending upon the transit time to the lab for an analysis of the sample. Plastic or glass bottles are used depending on the constituents to be determined. Plastic is satisfactory for samples to be analyzed for nitrate and major constituents. Samples for most analyses should remain refrigerated after collection to prevent degradation changes in constituent concentrations.

Unsaturated-zone Monitoring

In the unsaturated zone, water does not occupy all the pores at any one particular time. Water within this zone is tightly held within the pore spaces and therefore not readily available for sampling purposes. Hence, well installation is not a practical means for water sampling. The unsaturated zone requires a special mechanism to extract and recover the pore fluids. One such device or type of equipment used by the KGS is the soil-water sampler or lysimeter (fig 3).

Lysimeter-type Soil/Water Samplers

Construction - Lysimeter samplers extract moisture from the surrounding fine grained soils by an applied vacuum. Samplers are of two general types: one with a single access tube and another with two tubes. In general, they consist of a PVC tube with a porous porcelain cup on one end and a stopper with one or two holes for tubing on the other. The very small pore size of the porcelain cup permits soil-water to pass into the cup without drawing in the surrounding material. The stopped end with tubes is used to create a vacuum and/or collect a water sample. The single-tube sampler is generally used for depths of 6 feet or less. At greater depths, using a two-tube arrangement is easier. One tube goes to the bottom of the sampler and is used for retrieval of the water

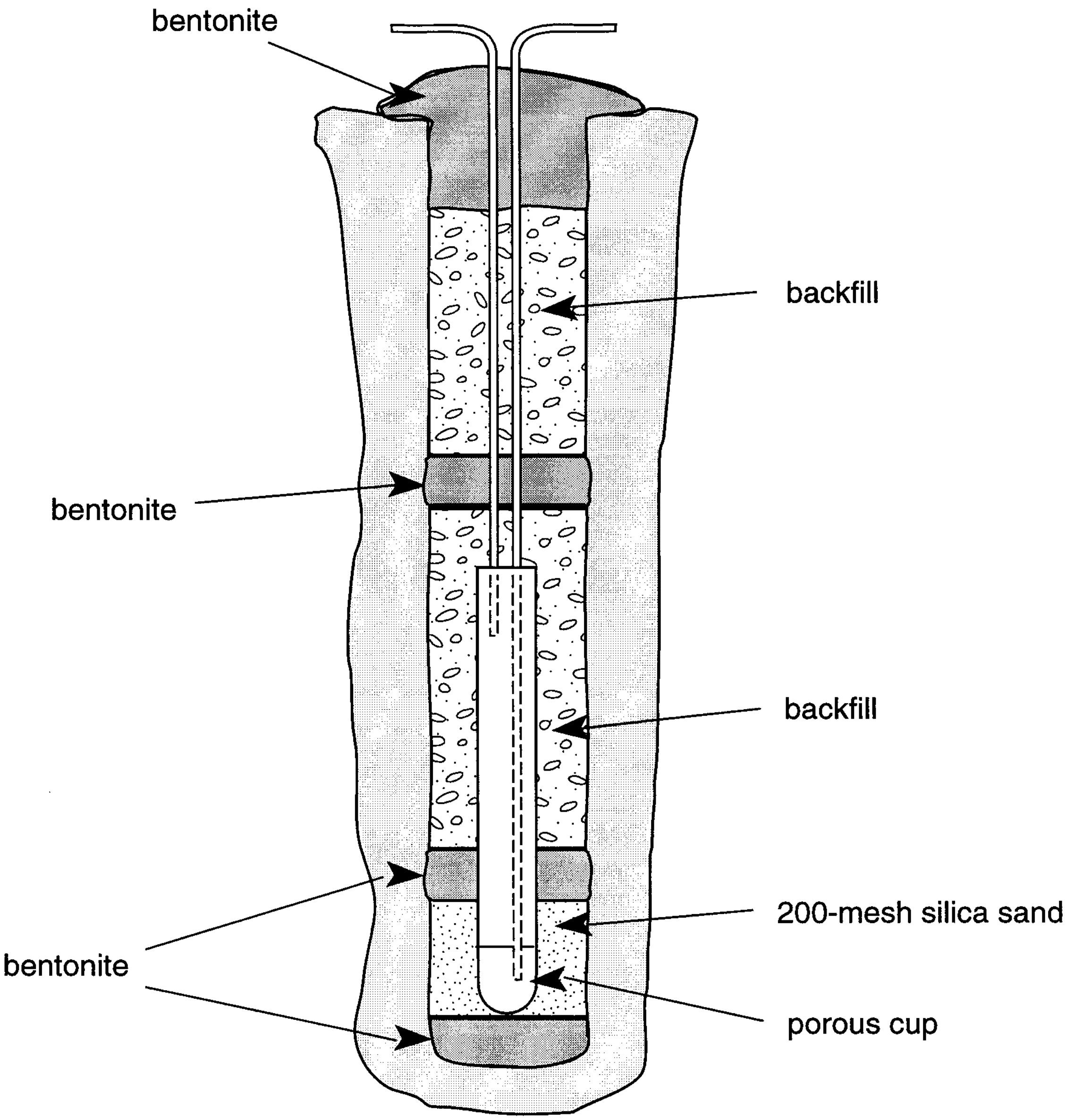

Figure 3. Soil-water samplers or lysimeters extract water from sediments by applying a vacuum to a porous porcelain cup. Illustration demonstrates the alternating sequence of backfill and bentonite materials. The silica sand (flour) occupies the annular space between the cup and native sediments (Soilmoisture Equipment Corp., 1980).

sample. The shorter tube is used either to set a vacuum on the sampler or for the use of air or an inert gas to push the sample out of the sampling tube via pressure buildup (fig. 3).

Drilling - Installation of lysimeter samplers is similar to well installations; however, augering is the preferred method. Soil characterization should be done during the drilling and the final lysimeter position determined by gross lithology of the soil. Soil cores, collected during lysimeter installation, can be used to determine the concentration of nitrate directly from the soil.

An augered hole approximately 3 to 4 inches in diameter is drilled to the appropriate depth. A small Giddings soil probe can be used at depths less than 30 feet depending on the soil stratigraphy. Deeper applications usually require a large drill rig equipped with hollow-stem augers and a wireline-spoon sampling system or similar device. The type of sediment in which the lysimeter is placed is of utmost importance. For example, in a porous sandy soil, pore fluids are very mobile and pass through the soil profile rapidly as indicated by consistently low nitrate levels. Experience indicates that after augering 30 feet within unconsolidated material the drill cuttings do not accurately represent the substrate. Without spoon sampling, the soil type remains an uncertainty.

After sediment cores are sampled, logged, and described, installation of the lysimeter begins with a layer of bentonite on the bottom of the hole to prevent leakage from below the sampler cup. Next, a layer of silica flour (very fine-grained material) is used as a "filter media" for the porous cup (fig. 3). The sampler is usually attached to PVC pipe with a coupling to facilitate retrieval if necessary. The tubing from the sampler is threaded through the PVC pipe to the surface. The sampler is then lowered into the hole and more silica flour is added. The top of the silica flour must be measured to assure coverage of the porous cup. A bentonite plug is placed above the silica flour to prevent downward migration along the borehole. The remainder of the hole is backfilled with alternating plugs of bentonite and soil with a final bentonite plug placed at the surface.

Sampling -A simple-vacuum pump (hand operated) is used to apply a vacuum on the lysimeter (fig. 4). This applied vacuum on the sampler draws water through the native sediments toward the cup. To collect a water sample in a single-tube arrangement, simply remove the stopper and insert a pumping tube. With a two-tube sampler, the tubing of the pump is reversed. Pressurized air is applied to force the captured water up the sample tube to the surface and into the sample bottle. For some other contaminants, the effects from any potential interaction of air with the sample

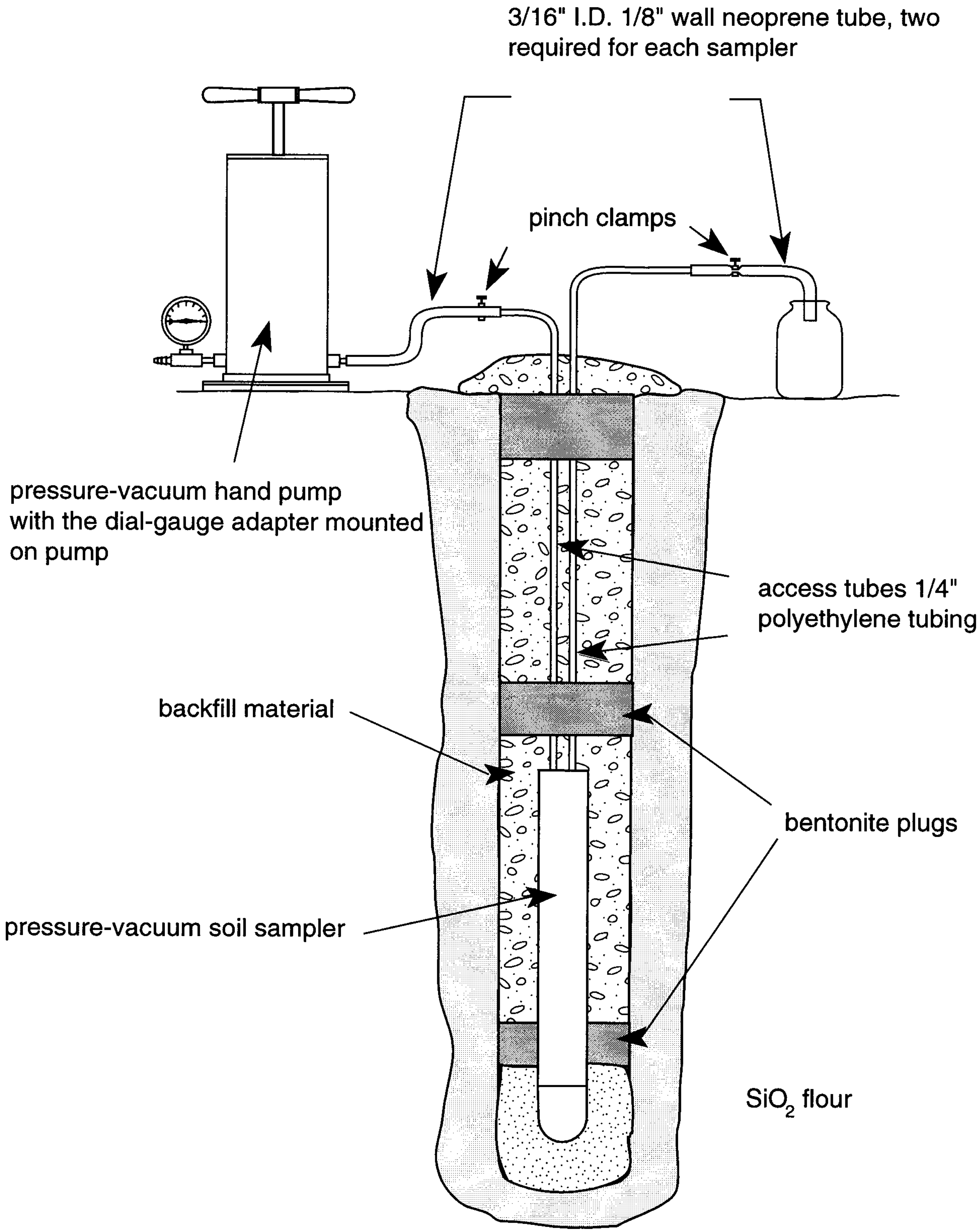

Figure 4. Equipment required for collecting water samples within the unsaturated zone. The dual-tube arrangement of the lysimeter allows for easy vacuum application and sample retrieval (Soilmoisture Equipment Corp., 1980).

should be considered. In the case of sampling for nitrate, this type of pump is favored and more than adequate for collecting samples. Exposure to air does not cause degradation in the nitrate concentration.

The sampler is placed under vacuum and is checked weekly until water is found in the sampler. At this point, a water-sampling schedule is established and continued until the study is completed.

Problems Encountered With Lysimeters

Monitoring wells and lysimeter samplers are effective tools for collecting samples in either the saturated or unsaturated zone, respectively. Each instrumentation has its own restrictions regarding installation and use. Both types require good installation practices as well as routine maintenance. Users of lysimeters should be aware of the drawbacks associated with lysimeter samplers. First, they are difficult to install to great depths because they are fragile. Second, the silica flour and seal materials have a tendency to bridge. Bridging is a blockage within the borehole caused by administering material too rapidly; it is the most common cause of lysimeter failure. Third, the sampler requires weekly maintenance until the first water sample can be drawn and before a sampling schedule can be established. In addition, a vacuum must be placed on the sampler a minimum of a week before collection. It may only take a short period of time for the sampler to fill if the soil is very moist or for the vacuum to dissipate if the soil is very dry. If the samplers are left for more than a week, the chemistry of the water in the cup may change or bacteria may degrade the sample and affect constituent concentrations. A major concern with using lysimeter samplers in a very dry area of sandy soil is that the vacuum on the sampler may continue to dissipate before sufficient sample can be collected. Although there are shortcomings to using the lysimeters, the KGS has had reasonable success in installing lysimeters in areas with complex stratigraphy.

Application to Agricultural-waste Lagoons

In the case of the swine-waste lagoons, installing the samplers at an angle under the lagoons might be possible. However, to angle drill would most likely be expensive. Installing the samplers prior to installation of the lagoons is not feasible because of potential damage to the samplers during the lagoon-construction process. Installing a nest of samplers and wells at various points around the lagoon would probably result in the most efficient method of monitoring. However, the time required to sample each group of samplers should be considered in determining the depth interval and number of samplers installed. As an example, one KGS site had 14 samplers installed, and it took at least 2-1/2 to 3 hours to collect the samples and to apply a vacuum on all 14 of the samplers during each sampling period.

In Morton County, the soil type appears to be very sandy with minimal clay. Whether if this area is too dry to effectively use soil-water samplers is unknown. Discussion with the agricultural extension farms in the area, including ones located in southeastern Colorado, would be prudent.

References

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