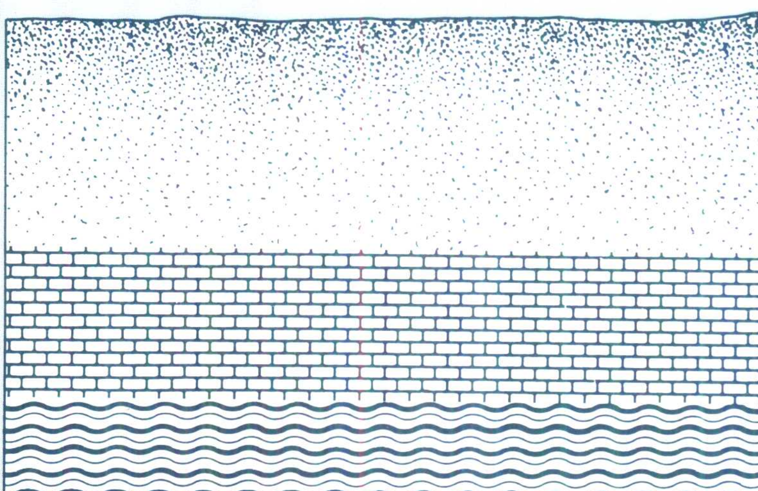
GROUND WATER AND VADOSE ZONE MONITORING



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David M. Nielsen and A. Ivan Johnson, editors

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Foreword

This publication, *Ground Water and Vadose Zone Monitoring*, contains papers presented at the symposium on Standards Development for Ground Water and Vadose Zone Monitoring Investigations, which was held on 27–29 Jan. 1988 in Albuquerque, New Mexico. The symposium was sponsored by ASTM Subcommittee D18.21 on Ground Water Monitoring, a subcommittee of ASTM Committee D-18 on Soil and Rock, and was developed in cooperation with the U.S. Environmental Protection Agency's Environmental Monitoring Systems Laboratory and the U.S. Geological Survey's Office of Water Data Coordination. David M. Nielsen, of Blasland, Bouck & Lee, presided as chairman of the symposium and also served as editor of this publication. In addition, A. Ivan Johnson, of A. Ivan Johnson, Inc., also served as editor of this publication.

Contents

Overview

The decade of the 1980s has been a period of explosive growth for the field of ground-water and vadose-zone monitoring and a time of both great achievement and confusion for those involved in conducting investigations of ground-water contamination. Passage of the Resource Conservation and Recovery Act (RCRA) by Congress in 1976 and subsequent promulgation of the first of the regulations authorized under RCRA by the U.S. Environmental Protection Agency (EPA) in May 1980 provided the primary impetus for the growth of the field. RCRA, which is EPA's main tool for managing hazardous waste from generation through disposal, includes provisions for establishing ground-water or vadose-zone monitoring systems, or both, at all of this country's hazardous waste treatment, storage, and disposal facilities, which number in the hundreds of thousands. Recent provisions of RCRA specify similar monitoring systems for each of the country's solid-waste facilities (i.e., sanitary landfills), which number in the thousands. Still other provisions of recent Amendments to RCRA (the Hazardous and Solid Waste Amendments of 1986) call for the installation of ground-water or vadose-zone monitoring systems, or both, at underground storage tank locations, which number in the millions across the country.

Passage of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), better known as Superfund, by Congress in December 1980 addressed the national threat caused by so-called "uncontrolled" hazardous waste sites, which probably number in the tens of thousands. Cleanup of these sites requires the installation of monitoring devices to investigate the extent of environmental contamination and to monitor the progress of the cleanup. Ground-water and vadose-zone monitoring is also done under other environmental regulatory programs, and for a variety of nonregulatory purposes, creating a tremendous demand for knowledge in this relatively young field.

Like most fields that experience such tremendous surges in growth, the ground-water and vadose-zone monitoring field, if it can truly be called that, saw prolonged periods of disorder and disorganization. In the early 1980s, those persons involved in the newly created field of ground-water monitoring were cautioned that they had to learn from the mistakes that scientists conducting surface-water monitoring programs had made in the 1970s. But the cautions went largely unheeded. Many ground-water quality monitoring investigations were conducted strictly to meet the letter of the law, and many data of poor quality were produced. No real procedural guidelines or standards were developed for those conducting ground-water monitoring investigations to follow. At the same time, the technology for monitoring ground water and the vadose zone was evolving at such a rapid rate that it was difficult for practitioners to keep up. Clearly there was a need to step back and take a long, hard look at the direction in which the field was headed.

Many questions had to be answered. How could we address the millions of sites that now fell under government regulation? Were enough trained and experienced specialists available to do the work and to evaluate the work that would be done? Could we do the work that we were being asked to do with existing methods and technologies?

It was soon realized that if practitioners of ground-water monitoring were to establish credibility for the investigations they were conducting, the state of the art or science had to be improved through the development of useful, practical guidelines and standards. But the idea of developing standards for a mostly inexact science (hydrogeology), in which one commonly has to deal with unexpected conditions (the subsurface) in an exceedingly inhomogeneous environment, was by no means without controversy or without its detractors. Yet, a number of technical fields in which there were similarly difficult and seemingly insurmountable obstacles to standards development have now adopted the "standards approach." The chemical industry or profession, the energy industry, the medical profession, the computer industry, the biotechnology industry, the petroleum industry, and other industries have succeeded in improving the state of their art or science through the development and use of voluntary consensus standards. Could ground-water monitoring follow suit?

The answer to this question was initially explored by ASTM through the conduct of a symposium on Field Methods for Ground-Water Contamination Studies and Their Standardization, sponsored by ASTM Committee D-18 on Soil and Rock and ASTM Committee D-19 on Water, in Cocoa Beach, Florida, in February 1986. The papers from that symposium have been published as *Ground-Water Contamination: Field Methods, ASTM STP 963.* Following this symposium, ASTM Subcommittee D18.21 on Ground-Water Monitoring, a subcommittee of ASTM Committee D-18, was formed to begin the task of identifying where standards were needed and how they could be developed. Subcommittee D18.21 is charged with the responsibility of developing standards for methods and materials used in the conduct of ground-water and vadose-zone investigations. Sections within the subcommittee have been formed to address a variety of narrower subject areas, including (1) surface and borehole geophysics; (2) vadose-zone monitoring; (3) well-drilling and soil sampling; (4) determination of hydrogeologic parameters; (5) well design and construction; (6) well maintenance, rehabilitation, and abandonment; (7) ground-water sample collection and handling; (8) design and analysis of hydrogeologic data systems; (9) special problems of monitoring in karst terrains, and (10) ground-water modeling. With this organization in place it was then possible to start a concentrated effort to use the ASTM consensus process to develop standards needed to ensure the collection of high-quality data that are comparable, compatible, and usable, no matter where or by whom collected. In January 1989 the name of Subcommittee D18.21 was changed to Ground Water and Vadose Zone Investigations to indicate more properly its broad subsurface coverage and interest in all types of ground-water investigations, not just monitoring. Although hundreds of existing ASTM standards related to ground-water quantity and quality investigations already are available, and many others are in the draft stage of development by ASTM Committees D-18 on Soil and Rock, D-19 on Water, and D-34 on Waste Disposal,[1] there are many other standards that are needed.

But what are these "standards" that need such serious development for use in ground-water investigations? If one turns to the definition used by ASTM, a standard is defined as a "rule for an orderly approach to a specific activity, formulated and applied for the benefit and with the cooperation of all concerned," which is essentially what Subcommittee D18.21 is trying to develop as speedily as possible for each of the many operations that can be involved in ground-water investigations. However, the effort to develop standards is by no means meant to discourage new ideas or stifle innovation. Rather, it is an attempt to bring order to a science that is currently struggling to keep pace with sister disciplines.

The editors believe that there are two key points, illustrated by the ASTM definition, that make the standards-developing process work for other professions or industries and

[1] See the *Annual Book of ASTM Standards,* most recent edition, Vol. 04.08.

will make it work for ground-water science. The first is that an orderly approach be developed. Few people would argue against this being a desirable goal for any endeavor. The second is that the approach be developed and applied for the benefit and with the cooperation of all concerned. In order to make the standards development process work, the community of professionals in ground-water science must be enlisted—there are now many hard-working volunteers working many hours and days to develop those standards needed for ground-water investigations, but additional expert help is needed. In addition to having more specialists volunteer to work on the ground-water sections and task groups, potential future standards can be found among scientific methods papers presented by authors at symposia and, thus, the incentive for organizing symposia is provided.

To provide a bank of information on new methods that may lead to the development of needed new standards, Subcommittee D18.21 sponsored another symposium in Albuquerque, New Mexico, in January 1988, on Standards Development for Ground-Water and Vadose-Zone Monitoring Investigations. The papers contained in this Special Technical Publication were presented at that symposium and represent a collection of some of the information being used to develop standards for the rapidly growing and evolving field of ground-water and vadose-zone monitoring. The intent of the symposium was to foster interdisciplinary communication and to make available state-of-the-art technology to those scientists and engineers engaged in ground-water and vadose-zone monitoring. A side benefit, but an important one, is that some of the papers may be useful in developing acceptable standards.

The two-and-a-half-day symposium was sponsored by ASTM in cooperation with the U.S. Environmental Protection Agency's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada, and the U.S. Geological Survey's Office of Water Data Coordination, in Reston, Virginia. Featured at the meeting were 40 invited presentations by some of the most noted authorities on the subjects discussed at the meeting. After three peer reviews and review by the editors, 22 papers were accepted for publication. The topics covered in this publication include: (1) vadose-zone monitoring; (2) drilling, design, development, and rehabilitation of monitoring wells; (3) aquifer hydraulic properties and water-level data collection; and (4) monitoring well purging and ground-water sampling.

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Vadose Zone Monitoring

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Methods for Sampling Fluids in the Vadose Zone

REFERENCE: Wilson, L. G., **"Methods for Sampling Fluids in the Vadose Zone,"** *Ground Water and Vadose Zone Monitoring, ASTM STP 1053,* D. M. Nielsen and A. I. Johnson, Eds., American Society for Testing and Materials, Philadelphia, 1990, pp.7–24.

ABSTRACT: This paper reviews available methods for sampling water-borne pollutants in the vadose zone. The "standard" method for sampling pore fluids in the vadose zone is core sampling of vadose zone solids, followed by extraction of pore fluids. The preferred method for solids sampling is the hollow-stem auger with core samplers. Core sampling does not lend itself to sampling the same location time and again. Membrane filter samplers and porous suction samplers are an alternative approach for sampling fluids in both saturated and unsaturated regions of the vadose zone. There are three basic porous suction sampler designs: (1) vacuum-operated suction samplers, (2) pressure-vacuum lysimeters, and (3) high-pressure-vacuum samplers.

Suction samplers are constructed mainly of ceramic and polytetrafluoroethylene (PTFE). The effective range of ceramic cups is 0 to 60 cbar of suction. The operating range of PTFE cups installed with silica flour is 0 to 7 cbar of suction. This paper reviews a method for extending the sampling range of suction samplers using an injection-recovery procedure. Factors affecting the operation of porous suction samplers include the physical properties of the vadose zone, hydraulic conditions, cup-wastewater interactions, and climatic conditions. Innovative procedures include the water extractor and the filter-tip system sampler. The free-drainage samplers include pans, blocks, and wick-type samplers. Techniques for sampling from perched ground-water zones include profile samplers, sampling from cascading wells, and sampling from dedicated wells.

KEY WORDS: ground water, vadose zone monitoring, soil core sampling, porous suction samplers, free-drainage samplers, perched ground-water sampling

Until recently, the major emphasis in monitoring programs at waste management sites was on ground-water sampling. This emphasis ignores the value of vadose zone monitoring techniques for the early detection of pollutant movement from a waste management unit. In regions with deep water tables, such as in the southwestern United States, the potential consequence of ignoring vadose zone monitoring is that the vadose zone and the ground-water system may become polluted before tangible evidence of leakage is evident in ground-water samples. Today, federal regulations for hazardous waste land treatment units (Subtitle C of the Resource Conservation and Recovery Act, Section 264.278 of 40 CFR, Part 264) mandate vadose zone monitoring. Some states (for example, California) also require vadose zone monitoring at waste management facilities.

Essentially vadose zone monitoring is a component of a comprehensive monitoring system at a given waste management facility. Such a system includes surface liquid and solids sampling, vadose zone monitoring, and ground-water monitoring. Similarly, there is a

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suite of methods available for vadose zone monitoring systems. Everett, Wilson, and McMillion [*1*] reviewed the available methods for premonitoring and active vadose zone monitoring, including both sampling and nonsampling methods. Both sets of methods are required since nonsampling techniques establish movement of liquids in the vadose zone (such as during a leak from an impoundment) and sampling techniques obtain liquid samples for laboratory analysis. For example, evidence of water content changes by neutron logging in access wells triggers the need to sample from pore-liquid samplers. Morrison [*2*], Everett, Wilson, and Hoylman [*3*], Rhoades and Oster [*4*], and Gardner [*5*] discuss available nonsampling (indirect) techniques for vadose zone monitoring in detail.

The primary purpose of this paper is to review techniques for extracting liquids from the vadose zone. Sampling techniques are divided into three groups: solids sampling followed by extraction of pore liquids, unsaturated pore-liquid sampling, and saturated pore-liquid sampling.

Solids Sampling for Pore Liquid Extraction

Solids sampling, followed by laboratory extraction of pore liquids, is the standard method for characterizing pollutant distribution in the vadose zone. Solids sampling also provides useful geological information, such as the lithological characteristics of the vadose zone layers, and the water content distribution. Comprehensive references on solids sampling include a book by Hvorslev [*6*], the text by Driscoll [*7*], an Environmental Protection Agency guidance document for ground-water monitoring at RCRA sites [*8*], and reviews by Riggs [*9*], Everett and Wilson [*10*], and Hackett [*11*]. There are two broad categories of solids sampling methods: hand-operated samplers and power-operated sampling rigs.

Hand-Operated Samplers

Hand-operated samplers are basic sampling units developed by agriculturalists for determining soil texture, soil water content, soil fertility, and soil salinity. Common units include tube-type samplers and auger samplers.

The Veihmeyer or King tube is a commonly used tube sampler for obtaining a long continuous sample near the land surface (see Fig. 1). This sampler consists of a hardened cutting point and head, threaded into a body tube. The upper end of the body is connected to a head containing two opposing, protruding lugs. A drop hammer is provided. The operation of the sampler is illustrated in Fig. 1. Gentle tapping on the head removes the sample. These samplers are commercially available in lengths from 1.22 m (4 ft) to 1.83 m (6 ft) [*12*]. The inside diameter of commercially available samplers is 1.9 cm (¾ in.).

Other commercial tube-type samplers are available for obtaining larger, 8.9-cm (3½-in.)-diameter, continuous soil cores [*12*]. Brass retaining cylinders, slipped into the sampler barrel, provide undisturbed samples for extraction of pore liquids. Samples are extracted from inside the drive barrel by means of a pusher rod.

Chong, Khan, and Green [*13*] described a soil core sampler for obtaining shallow samples using a hand-operated two-ton jack. Sharma and De Datta [*14*] reported a core sampler for obtaining undisturbed samples from the upper 10.2 cm (4 in.) of puddled soils.

Another common hand augering tool is the bucket auger. The basic components of bucket augers are shown on Fig. 2. Types of bucket augers include the common posthole auger, ditch augers, and regular or general purpose barrel augers [*10*]. Variations of the general purpose auger include sand and mud augers. These samplers are best suited for sampling shallow soil depths. However, using a tripod and pulley allows sampling to depths up to 24.4 m (80 ft) in some types of materials.

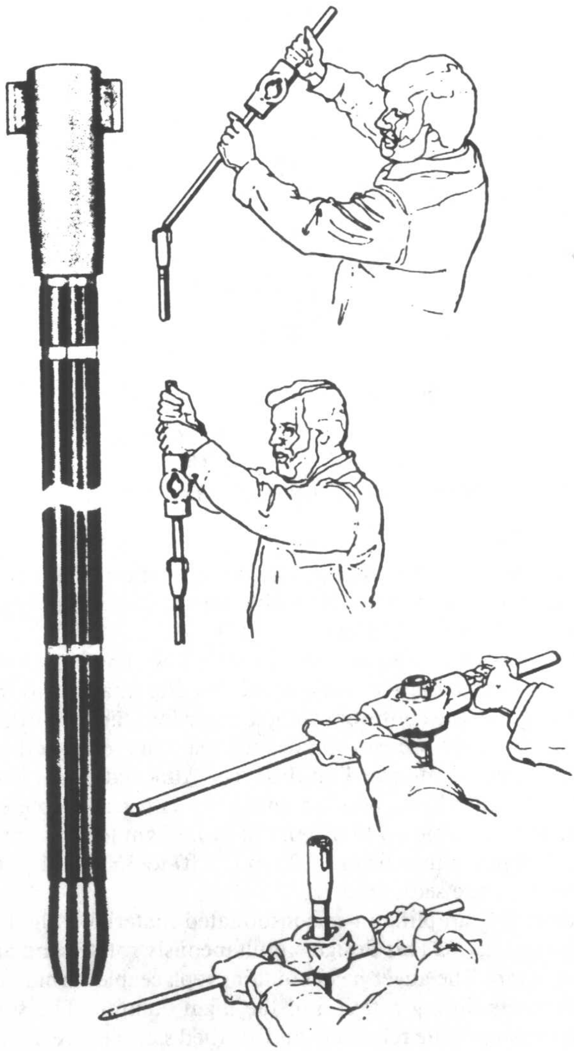

FIG. 1—*Tube-type sampler, showing the operational procedure* [12].

Power-Operated Sampling Rigs

Power-operated samplers are identical to the units used to sample below water tables. However, commonly used drill rigs, such as cable tool and rotary units, are not recommended because they generally require drilling fluid. Air drilling is undesirable when attempting to obtain pore liquids at field moisture content. Two suitable power-driven techniques are bucket augers and flight-type auger drill rigs.

Bucket augers are large-diameter, that is, 1.83-m (6-ft)-diameter cylindrical buckets with auger-type cutting blades on the bottom [7]. In practice, the bucket is rotated with depth in the vadose zone until the bucket is full. Sampling consists of extracting small-diameter core samples from the interior of the bucket after the full bucket is lowered to the ground.

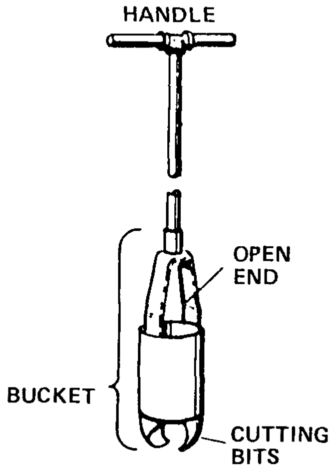

FIG. 2—*Bucket-type hand auger* [12].

This approach minimizes problems with cross-contamination of samples. Bucket augers are best suited for sampling from relatively stable formations. Common sampling depths are between 15.25 m (50 ft) and 45.75 m (150 ft) [*7*].

Solid and hollow-stem augers are also used for sampling. The most basic, power-driven flight auger is driven by a small air-cooled engine. Handles attached to the head assembly allow two operators to guide the continuous-flight auger into the soil. Additional flights are added as required. Samples are brought to the surface by the screw action of the auger.

Larger solid-stem augers are mounted on drill rigs. Attached to the lowermost, or leading, flight of augers is a cutter head, about 5 cm (2 in.) larger in diameter than the flights [*7*]. Auger diameters are available up to 61 cm (24 in.). Flight lengths are generally 1.52 m (5 ft). Typical drilling depths range from 15.25 m (50 ft) to 36.6 m (120 ft), depending on the texture of the vadose zone sediments [*7*].

The favored method for sampling in unconsolidated material is the hollow-stem, continuous-flight auger (see Fig. 3). This design simultaneously rotates and axially advances a hollow-stem auger column. The auger head contains replaceable carbide teeth that pulverize the formation deposits during rotation of the flight column. The solid flight column serves as a temporary casing while relatively undisturbed samples are obtained from within the hollow stem [*7*]. Recently, Hackett [*11*] published an excellent state-of-the-art review of this technique.

According to the U.S. Environmental Protection Agency (EPA) [*8*], wells with diameters up to 10.2 cm (4 in.) have been constructed with hollow-stem augers. In addition, attempts are under way to construct augers with inside diameters of about 25.4 cm (10 in.). The cutting diameter is somewhat greater than the flighting diameter because of the protruding carbide teeth. Individual flights are generally 1.52 m (5 ft) in length, although auger flights up to 3.05 m (10 ft) in length are available. The total completion depth is about 45.75 m (150 ft). Water is not added to the hole during augering to avoid diluting and contaminating pore fluids.

Tubular samplers provide "undisturbed" vadose zone sediments from inside a hollow-stem auger (see Fig. 3). Three popular tubular samplers are ring-lined barrel samplers, split tube samplers, and thin-wall "Shelby tube" samplers. These samplers are commercially available in a variety of diameters. Brass cylindrical rings inserted inside a barrel sampler

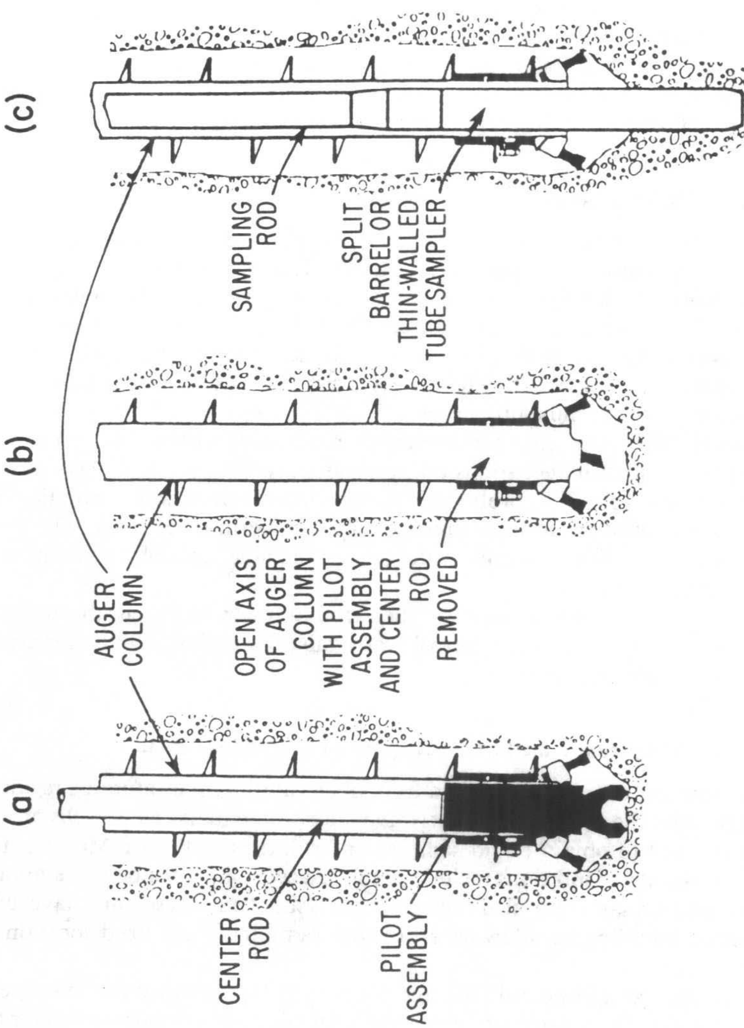

FIG. 3—*Hollow-stem auger, showing the method of sampling with sampling tubes* [11].