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Project Summary

A Guide to the Selection of Materials for Monitoring Well Construction and Ground-Water Sampling

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The project was initiated to supplement and update existing guidance documents for effective ground-water monitoring efforts. The areas of primary concern were the potential sources of errors in chemical analyses of subsurface samples caused by well construction and sampling materials, techniques or procedures. A critical review of the literature was conducted on monitoring natural waters, materials' performance, data and unpublished information on the success of various ground-water monitoring techniques. The results of the literature review were collected and reviewed by a panel of experts from government agencies, private hydrological consulting firms, the manufacturing industry and national standards organization. The publication consists of a thorough discussion of ground-water monitoring strategies, requirements, and pitfalls. It concludes with a detailed treatment of the costs and benefits of recommended monitoring design criteria.

The principal conclusions of the work support the use of proven noncontaminating well construction and sampling procedures employing materials' selection appropriate to the information needs of the monitoring plan. It further demonstrates that the use of more sophisticated techniques and more expensive, sturdy materials for well construction and sampling can be cost-effective even for short-term (5-year) monitoring projects. The penalties involved in sample reanalysis or generating unreliable information can be eliminated through careful planning and design. The second phase of the project, in progress, consists of field performance tests of the materials' recommendations in the selection guide.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, and the Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Ground-water monitoring techniques drew little scientific attention until the mid 1970's. Frequently, research on subsurface processes and chemical monitoring adopted procedures or practices developed for surface-water monitoring applications. The inherent difficulties in obtaining "representative" samples of aquifer materials or ground water have compounded the interpretation of analytical data. Improvements in the sensitivity and performance of analytical methods, particularly for organic compounds increased the demand for reliable sample collection. In the past decade the scientific basis for collecting reliable ground-water data has improved and it remains an active area of research.

Various aspects of ground-water monitoring network design and implementation have been treated in detail in a number of publications as well as in the open literature. However, the biases introduced into analytical data by various drilling or sampling techniques and the choice of materials used in these applications have not been systematically reviewed. Since much of the available information was unpublished or scattered, the project plan included the use of letter solicitations to active researchers in ground-water monitoring or research. A panel of representatives from government, industry, private enterprise and a national standards organization was assembled to develop guidance for monitoring personnel, regulatory agency staff and interested scientists. The major objective was to identify proven non-contaminating drilling, well construction, and sampling techniques for ground-water monitoring.

The literature review included all English-language and selected foreign publications in a variety of data-bases, including: Chemical Abstracts, Selected Water Resource Abstracts, Pollution Ab Abstracts, Enviroline, Compendex (Engineering), Metadex (Metals Abstracts/Alloys Index), Rapra (Rubber and Plastics Research Association), and the National Ground Water Center Data Base. Approximately 600 references were received in full version for evaluation purposes. The limited response received from the letter solicitation proved to be fruitful in uncovering important unpublished findings relevant to the study.

The literature on monitoring network design, well construction, and sampling techniques was critically reviewed with emphasis on techniques that cause minimal disturbance to the subsurface environment and permit faithful sample collection and transfer mechanisms. A short discussion of the nature of the subsurface environment was included to establish some of the demands that must be met in order to obtain representative water samples.

Materials' chemical compatibility data under various types of exposures were categorized for potential effects on the integrity of water samples in contact with well casing, pump parts, and transfer tubing. Exposures were categorized in four groups, approximating the types of ground water or contaminated ground-water mixtures that have been encountered in monitoring efforts. These categories were inorganic buffered water at pH 5, organic-acid anion buffered water at pH 5, high dissolved solids acidic ground water and various organic/water mixtures. The potential for deleterious effects on materials used for well construction or sampling applications was scored as unlikely, likely under some conditions, or probable (that is, material is not recommended on a three-point scale). Rigid materials and flexible materials were rated relative to Teflon®, which was considered the ideal material for critical applications.

The literature data on potential materials' effects on analytical data were supplemented by documented field results for various well casing, pump, and tubing types. Further, analytical method performance (accuracy and precision) for common monitoring parameters and priority pollutant determinations were compiled to serve as benchmarks for the potential magnitude of sample collection errors.

Costs of conducting ground-water monitoring programs were analyzed from the perspective of both the information needs and the selection of rigid, well casing materials. A sample monitoring effort consisting of one- and five-year operation of four well networks employing rigid PVC, Teflon® and stainless steel casing materials with increasing analytical detail was included. A resulting analysis was discussed to support the use of recommended materials for the specific goals of the monitoring plan.

Conclusions

Ground-water monitoring is conducted in response to major governmental legislation (RCRA, CERCLA, etc.) and agency regulations. Source monitoring may be categorized as detective or interpretive, depending upon information needs before or after a contaminant release has been detected. Monitoring for specific research into subsurface phenomena and ambient monitoring for resource evaluation also are purposes for which sampling networks are implemented. Regardless of the information needs, recommended minimum planning and design details must be considered before network implementation. For good program performance, the involvement of professional hydrogeologists, chemists, laboratory and field personnel and the director of the monitoring effort should be encouraged. The monitoring design should be planned with careful consideration of the hydrogeologic conditions and analytical parameters of interest in all subsequent decisions. Flexibility is the most important aspect of the design. It is necessary to maximize the usefulness of preliminary data collection and allow for future expansion if the goals of the monitoring program are expanded.

Well Installation

Well drilling and construction technologies are available to establish sampling points with minimal disturbance of the subsurface or interferences with analytical determinations. Hollow-stem auger, air-rotary, cable tool or inorganic mud rotary drilling techniques are preferred. Careful well completion methods and proper well development procedures should be used in conjunction with an appropriate drilling method. The time necessary for proper well development can save considerable time and effort by reducing difficulties in pumping and filtering turbid samples. Manufactured screen materials of proper slot sizes are recommended over hand-sawn slits.

Sampling

Sampling gear should be selected so that disturbance of the actual concentrations of chemical constituents of interest is reduced. Pumps or other collection mechanisms are available which minimize gas exchange and faithfully transfer water samples to storage vessels. Materials' selection for components that contact the water in sampling operations is critical to the elimination of bias, imprecision or interferences in subsequent analytical results. Simple mechanisms that reduce the potential for human error should be chosen and manufacturers' claims or recommendations must be carefully evaluated for each specific application. No-gas contact bladder pumps and various grab-sample mechanisms are preferred for sampling ground water for volatile chemical constituents as well as pH and oxygen sensitive analytes. Sampling errors are not correctible through field blanks, standards, or procedural standards. Research on sampling methods and procedures is needed.

Rigid Materials

Materials for well casing, pump and sample transferlines must be chosen for specific hydrogeologic conditions and the analytes of interest. Well casing materials must retain their structural integrity and maintain a low analytical error rate for long periods of time. Exposure conditions can vary in time or by location. Compatibility with natural ground-water conditions, as well as waste/groundwater mixtures, should be carefully evaluated. The order of preference for various rigid well casing materials is shown in Table 1 with recommendations for specific applications. Although PVC well casing is durable and inexpensive, the potential for interference from leaching or adsorption of organic

Table 1. *Recommendations for Rigid Well Casing Materials (In decreasing order of preference)*

Material	*Recommendations*
Teflon® (flush threaded)	*Recommended for most monitoring situations with detailed organic analytical needs, particularly for aggressive, organic leachate impacted hydrogeologic conditions. Virtually an ideal material for corrosive situations where inorganic contaminants are of interest.*
Stainless Steel 316 (flush threaded)	*Recommended for most monitoring situations with detailed organic analytical needs, particularly for aggressive, organic leachate impacted hydrogeologic conditions. Virtually an ideal material for corrosive situations where inorganic contaminants are of interest.*
Stainless Steel 304 (flush threaded)	*May be predisposed to slow pitting corrosion in contact with acidic high total dissolved solids aqueous solutions. Corrosion products limited mainly to Fe and possibly Cr and Ni.*
PVC (flush threaded) other noncemented connections, only NSF approved materials for well casing or potable water applications*	*Recommended for limited monitoring situations where inorganic contaminants are of interest and it is known that aggressive organic leachate mixtures will not be contacted. Cemented installations have caused documented interferences. The potential for interaction and interferences from PVC well casing in contact with aggressive aqueous organic mixtures is difficult to predict. PVC is not recommended for detailed organic analytical schemes. Recommended for monitoring inorganic contaminants in corrosive, acidic inorganic situations. May release Sn or Sb compounds from the original heat stabilizers in the formulation after long exposures.*
Low-Carbon Steel *Galvanized Steel* *Carbon Steel*	*May be superior to PVC for exposures to aggressive aqueous organic mixtures. These materials must be very carefully cleaned to remove oily manufacturing residues. Corrosion is likely in high dissolved solids acidic environments, particularly when sulfides are present. Products of corrosion are mainly Fe and Mn, except for galvanized steel which may release Zn and Cd. Weathered steel surfaces present very active adsorption sites for trace organic and inorganic chemical species.*

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compounds makes it a less desirable material for organic compound investigations when aqueous/organic mixtures may be encountered. Teflon® and stainless steel are preferred in these situations, as well as for corrosive, high dissolved solids' solutions. PVC also may be expected to function well under these conditions. The use of galvanized, low-carbon or carbon steel is not recommended in corrosive, acidic environments, since these will corrode much faster than stainless steels. Corrosion of these materials results in the formation of active sites for adsorptive interactions with both organic and inorganic chemicals.

Flexible Materials

Similarly, the flexible materials for pump components (bladders) and sample transfer lines must be carefully chosen in relation to the exposures expected and the analytes of interest, because, compared to well casing, these materials are in close contact with the water samples (after well purging).

Table 2 contains a list of preferred flexible materials and recommendations for their use. Teflon® again is the material of choice for most situations, due to its inertness and its freedom from nonpolymeric additives. Polypropylene and linear polyethylene are recommended over flexible polymer formulations (PVC), since these polyolefins have better chemical resistance and very low levels of additives or plasticizers that will bias detailed organic analytical procedures. The use of the remainder of the materials in the table should be approached carefully, particularly for prolonged contact with aqueous organic mixtures. Additional controlled sorption or leach testing is needed for these materials using the same analytical procedures employed for actual ground-water monitoring analytical work.

Cost Analysis

Analysis of the cost of implementing a four well ground-water monitoring network supports the cost-effective use of appropriate well construction materials. Because additional drilling is needed if ground-water conditions require more chemically-resistant, non-contaminating monitoring wells, it makes good sense to choose sturdy proven materials in preliminary work. The cost of a single sample reanalysis (when doubtful analytical results are obtained) alone clearly outweighs the choice of less expensive materials. The cost savings in cheaper materials actually results in greater

Table 2. *Recommendations for Flexible Materials for Sampling Applications (In decreasing order of preference)*

Materials	*Recommendations*
Teflon®	*Recommended for most monitoring work, particularly for detailed organic analytical schemes. The material least likely to introduce significant sampling bias or imprecision. The easiest material to clean in order to prevent cross-contamination.*
Polypropylene *Polyethylene (linear)*	*Strongly recommended for corrosive high dissolved solids solutions. Less likely to introduce significant bias into analytical results than polymer formulations (PVC) or other flexible materials with the exception of Teflon®.*
PVC (flexible)	*Not recommended for detailed organic analytical schemes. Plasticizers and stabilizers make up a sizable percentage of the material by weight as long as it remains flexible. Documented interferences are likely with several priority pollutant classes.*
Viton® *Silicone (medical grade only)* *Neoprene*	*Flexible elastomeric materials for gaskets, O-rings, bladder and tubing applications. Performance expected to be a function of exposure type and the order of chemical resistance as shown. Recommended only when a more suitable material is not available for the specific use. Actual controlled exposure trials may be useful in assessing the potential for analytical bias.*

penalties as the degree of analytical detail increases. Viable alternatives to Teflon® or stainless steel alone in specific monitoring applications may be the use of either less expensive material in the unsaturated zone, coupled to better materials at depth or paired PVC/SS wells to obtain high quality, unbiased inorganic and organic analytical data, respectively, from nested installations.

It is generally concluded that more careful documentation of well siting, construction, completion and sampling procedural detail is called for. This information is vital to unequivocal interpretation of the resulting analytical data. Complete documentation would further facilitate the timely transfer of proven technology and practice to various user communities.

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The complete report, entitled "A Guide to the Selection of Materials for Monitoring Well Construction and Ground-Water Sampling," (Order No. PB 84-141 779; Cost: $11.50, subject to change) will be available only from:

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