專 論

地下水的監測技術

Ground Water Monitoring Technologies

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摘 要

地下水是水文循環的一部份，也是人類重要的天然資源，95 %的飲用水存儲在地下水水層內，只有5 %存儲在地表的河川和湖泊內。

地下水在地表面下流動，地下水污染不如地面水污染那麼明顯，地下水污染的來源很多，包括工業廢水、農藥、石油、垃圾和海水入侵等，一旦污染物進入地下水系統，清理是相當困難的步驟，有時需要幾十年的時間才能達到清理的目標。

為了保護這個重要的天然資源，我們一定要用有效的監測系統和技術，希望能夠及早發現問題，馬上清理污染物。

地下水監測一向是測量水位和收集水樣送到水質實驗室分析，現在漸漸進展到實地測量水質，馬上可以知道結果，不需要等待實驗室的分析報告，大量減少時間和費用。
關鍵詞：地下水，監測技術，污染。

ABSTRACT

Groundwater is part of the hydrologic cycle and is a major natural resource for the majority of the human population. In fact, approximately 95 % of the Earth fresh-water is stored in aquifers, with only 5 % stored in rivers, lakes and streams as surface water.

A large percentage of the population believes ground water is naturally protected from contamination. The layers of clays, sands and gravels are thought to act as filters. Especially, groundwater contamination is not nearly as visible as surface water pollution or air pollution. This lack of visibility of contamination, however, is deceptive and misleading.

The leakage from waste landfills, infiltration of pesticides and fertilizers from agricultural activities, drainage from septic tanks, leakage from petroleum and chemical storage tanks and pipes, accidental spills of chemicals and sea water intrusion due to over pumping of groundwater along coastal areas all have the potential of contaminating subsurface soil and water.

Government regulatory agencies recognize that groundwater contamination is a serious problem. It may take years to discover contamination and then decades to clean up. These regulatory agencies have therefore provided guidelines and monitoring requirements for groundwater resources. The groundwater monitoring technologies, usually requiring the monitoring of groundwater levels and groundwater quality, have come a long way from the labor intensive, less accurate approaches to the current, reliable, on-site,real-time analysis.
Keywords : Groundwater, Monitoring technologies, Contamination.

INTRODUCTION

Environmental site monitoring usually requires taking samples and submitting them for laboratory analysis. However, this method of analysis can be expensive and lengthy.

Costs include sampling equipment, containers, time, transportation and a persample fee for each test conducted. The time lag, which can be as long as six weeks (including time spent preparing for the sampling trip, the sampling itself and the analysis), contributes to the delay in achieving an expedited remediation effort, if needed.

This situation has generated substantial interest in achieving rapid,real-time, cost-effective field analysis and in situ monitoring methods. Field screening of soil and water samples for appropriate indicator parameters can be used to indicate the presence of contamination. This approach allows the responsible party to make more infcrmed decisions as to whether or where a sample should be collected for laboratory analysis and to define the boundaries of contamination. [1]

SITE CHARACTERIZATION

Understanding the geology, hydrology and geochemistry of the contaminated formation is the first major step in obtaining the required information for remediation design. In general, the following information is required. [2]

Shallow unconfined aquifers are highly vulnerable to contamination compared with deep aquifers that are protected by overlying impermeable layers. The following table shows the methodologies in obtaining geologic, hydrologic and geochemical data.

Geology	Hydrology	Geochemistry
• Geologic cross-sections • Lateral continuity of saturated zones • Hydraulic communication between adjacent formations • Recharge areas • Discharge areas	• Hydrologic properties of aquifer • Water level in wells • Wellhead elevations • Dispersivity values • Regional groundwater use inventory • Primary contamination migration peak	• Adsorption characteristics • Biodegradation information

1. Geology

Information	Method
Geologic cross-section	Drill wells, cores, log
Recharge and discharge areas	Field reconnaissance

2. Hydrology

Information	Method
Hydrologic properties	Aquifers
Water level	Measurements
Dispersivity	Tracer test
Effective porosity	Tracer test
Water quality	Water sampling analyses

3. Geochemistry

Information	Method
Adsorption	Literature search, lab test
Biodegradation	Literature search, lab test

We are interested not only in detecting hazardous subatances migrating out of the site, but also in detecting substances reappearing on site. Monitoring network including sampling points:

1. Within the bonds of the site:

One may select wells previously used for injection or production during remediation and add some new wells.

2. Surrounding the site (plume monitoring)

A minimum of three down gradient wells spaced according to the size of the site and the dispersivity and flow rate of the aquifer. One up gradient well provides background reference.

BASELINE WATER QUALITY

In order to define the degree of the contamination, the baseline water quality in the formation of concern must be established. The groundwater system is under dynamic conditions and the groundwater quality is constantly changing. Fortunately, the movement of groundwater is slow. In most cases,groundwater movement is less than 100 meters per year. The variation of groundwater quality at most locations is generally small.

Baseline information comes from determination of water quality in the affected aquifer, either:

- prior to suspected contamination events, or
- spatially outside the contaminated region.

The information is most useful if it has been collected over an extended period of time and at different seasons of the year. This enables the user to properly incorporate possible temporal fluctuations in water quality. Of course it is assumed that all information incorporated into the baseline study is based on the use of proper technologies of sampling, handling, storage and analysis of aquifer waters. [2]

WHAT TO MONITOR

There are basically two approaches to examining and selecting what to monitor. These include:

- Monitor for all substances relevant to the waste type, or
- Apply key indicators which give early warnings of leakage.

Selectivity, sensitivity and ability to screen out potential interferences are important considerations. For simplicity in comparison, analytical methods and devices can be placed into any of the following three classes of performance: [1]

- Class 1 - The simplest method. It indicates a change or the presence of a contaminant.
- Class 2 - These devices provide some information on an analyte of interest in a simple matrix.
- Class 3 - These devices are capable of identifying and measuring specific parameters in a relatively complex matrix.

There are basically two ways to monitor water quality:

- analyze for each substance which may possibly be troublesome (an entire suite of components).
- select key indicator substance which give early awarning of problems.

For example, R. Plumb studied 500 contaminated sites within the United States and concluded volatile organic compounds (VOC_S)are the most significant contaminants in groundwater associated with disposal sites. Rather than conduct a complete water-quality analysis for organic contaminations, which can cost up to thousands of dollars, Plumb suggested that monitoring for VOC_S alone is a useful early warning system for excursions which indicate the need for more extensive laboratory analysis for organic constituents. [3]

Some key indicators being advocated are: [2]

- Volatile organic compounds (VOC_S) for organics priority pollutants
- pH for acid mine waters
- Specific conductivity (SC) for inorganic contamination
- Total hydrocarbon content (THC) for petroleum in soil
- Total nitrogen and phosphates for agricultural contamination
- Total organic halogen (TOX) for pesticides
- Total organic carbon (TOC) for general organic substances
- Flame ionization detection (FID) or photo ionization detection (PID)responses of soil vapor for volatile organic components of gasoline.

HOW TO MONITOR

Aquifers may be monitored by periodic water level measurement and periodical sampling by pumping, or continuously by remote sensors.

1. Periodic water level measurement and water quality measurements (pumping and taking water samples from the wells).
   a.) well head measurements:
   - water level
   - pH
   - temperature
   - specific conductance

   b.) Samples:
   - preserve properly for storage and transport to the analytic facilities

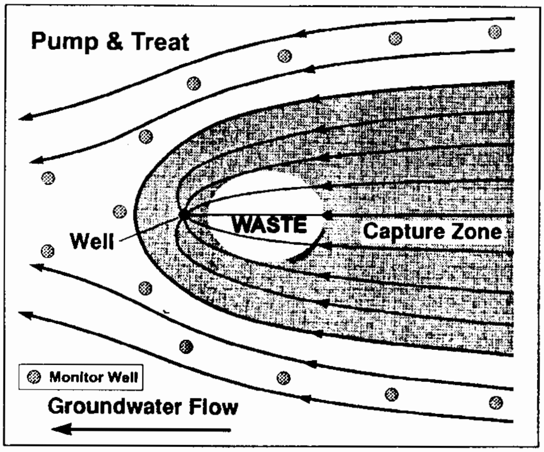
   c.) Strengths:
   - Calibration of instruments
   - One set of instruments serve many wells

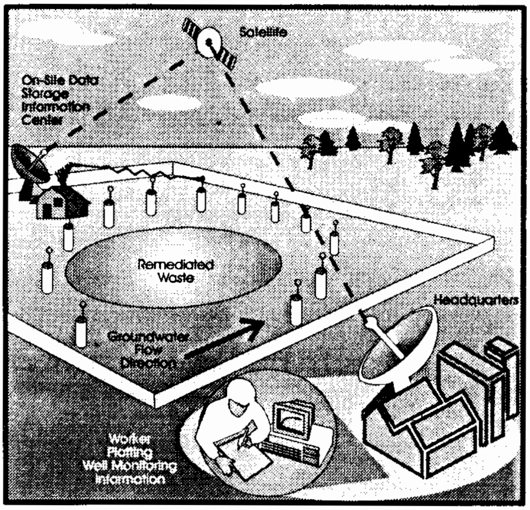
   d.) Weakness:
   - data not continuous available
   - time lag for results
   - pumping, sampling, transportation and lab analyses can be expensive
2. Remote sensors (down hole monitoring).
   a.) Periodic (portable) down hole monitoring (move from one well to another well).
   b.) Continuous down-hole monitoring
   c.) Strengths:
   - Convenience
   - Does not disturb water flow
   - Give continuous readings

   d.) Weakness:
   - Long term stability of the measurements (drift)
   - Calibration

The following figure shows the use of in-situ monitors to detect waste leakage from a hydrologically confined pump and treat system. [1]

Advance command and control systems which employ sophisticated communications technology will be used extensively in the future. Remote analysis and monitoring systems at sites throughout the world will be controlled by a limited number of highly trained personnel at a few central facilities. Excursions from confined areas will be detected in real time by these systems. The computer programs can contain instructions for notifying regulatory agencies and key site personnel, or trigger alarms to address various situations which may arise. [2]





NEW TECHNOLOGIES EMERGE

Emerging technologies in micro-robotics and intelligent control systems will be combined to develop the emerging generation of chemical monitoring instrumentation for field screening and in situ monitoring.[1] These instruments will be able to identify and measure specific parameters in our environment.

Work is under way in many phases to develop cost-effective in situ monitors. It is currently expected that development will require another three to five years.[1]

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