New regulations concerning the management of underground storage tanks (USTs) have resulted in increased awareness of environmental contamination resulting from leaking USTs. The objective of the typical underground storage tank investigation is to determine if any subsurface contamination has occurred as a result of tank or product line leakage, fuel spills or overfills. Soil contamination at underground storage tank sites is usually discovered during the removal and replacement of USTs. Techniques that can be used to detect the presence of soil contamination adjacent to existing USTs include soil vapor analysis, exploratory boring, and soil and ground water sampling.

The lateral and vertical extent of contamination must be determined at any site which contains detectable quantities of contamination. Two common methods for determining the extent of contamination are over-excavation and borehole drilling and sampling. Boring design and location considerations include number of borings, borehole depth and spacing, and site sub-surface conditions. Differentiation between perched sub-surface water and aquifers is critical. Once an appropriate boring plan has been established, then a sampling and analysis plan must be adopted that meets the needs of the particular investigation. The determination of the extent of contamination at an underground storage tank site is the first step leading to site closure and remediation.

Introduction

There are currently millions of underground storage tanks (USTs) in the United States that contain hazardous constituents such as petroleum products and other chemicals. It is estimated that as much as 25 percent of all USTs may currently be leaking (Evans, 1988). New regulations established by the Environmental Protection Agency (EPA) have resulted in an increased awareness of environmental contamination caused by leaking USTs. The new regulations were developed by the EPA to protect human health and the environment with much of the emphasis placed on the nations ground water resources. The EPA regulations have placed the burden of regulatory authority on each state and local agency. It is the responsibility of each state to establish a program which either meets or is more stringent than the federal regulations.

The focus of the new regulations is to locate all leaking tanks, clean-up existing contaminated tank sites and prevent future leaks or spills. These regulations have had an immediate impact on the tank owner. Because of the new regulations, all USTs installed prior to December 1988 must be retrofitted to contain corrosion protection and spill and overfill prevention devices. In addition, leak detection monitoring must be conducted on each tank periodically. Many tank owners have opted simply for replacing the old tank systems to comply with the new regulations. In any case, many of the existing problems were discovered during the process of replacing or upgrading the UST system.
When a UST leak has been discovered, the first step is to report the incident to the proper regulatory authorities, who will request that a site investigation be conducted to evaluate the extent of the problem. In areas where shallow ground water is encountered, it may be necessary to first remove free product that may be encountered prior to determining the extent of contamination.

**Site Investigation Methods**

Several methods can be utilized to determine the extent of contamination. One of the simplest methods can be employed during the excavation and removal of the tanks. This method involves over excavating the tank pit to remove all or as much of the contamination as possible. This method is very effective in situations where limited contamination has occurred. Soil is monitored during the excavation with a hand held photo-ionization detector (PID) or flame-ionization detector (FID) to detect the presence of potential contamination. Based on the levels indicated by the instrument, contaminated soil is segregated from non-contaminated soil. Contaminated soil can either be placed on plastic sheeting and remediated on-site or be removed from the site and disposed of in a hazardous waste facility.

There are several limitations to over-excavation as a means of determining the extent of contamination. One limitation is that the depth of the excavation is limited to the vertical reach of the excavation equipment on hand. Another limitation is that space needed for stock piling contaminated soils or expanding the size of the tank pit laterally may be limited. If contaminated soil cannot be treated on-site, it is usually very expensive to dispose of off-site.

Another method that can be used to determine the extent of contamination is through the analysis of soil vapor. Volatile compounds from a UST leak in most cases will leave a traceable "signature" in the soil profile that can be mapped using field analytical instruments. The soil vapor survey can be used to delineate the lateral extent of contamination, and is also useful in determining appropriate locations for borings or monitoring wells.

At each soil vapor sample location, a stainless steel probe is driven or pushed into the subsurface to the depth of interest. The probe is then connected to the gas chromatograph in the mobile laboratory by a sampling line. Soil vapor is withdrawn from the ground by a peristaltic pump and is injected into the gas chromatograph where it is then analyzed. A PID is generally used when lower concentrations are encountered and an FID is used when higher concentrations occur (Water Resources Associates, 1989).

The use of soil vapor analysis is limited in that it may be difficult to determine the vertical extent of contamination. Depending on the subsurface conditions encountered, the soil probes generally can only be driven to depths averaging approximately ten to fifteen feet below ground surface. It is also sometimes difficult to extract soil vapor from tight clay bearing formations.

One of the most common and widely accepted methods used to determine the extent of contamination is the drilling and sampling of boreholes. There are several different drilling methods that can be used. The selection of the drilling method is based on the subsurface
conditions expected to be encountered at the site. Selection of the proper drilling method is probably the most important part of planning a drilling program. Other important points that need to be addressed during the development of a drilling plan include the number of borings needed to determine the lateral extent, the depth of the borings and available site access.

In most cases, approximately six to ten borings are needed to determine the lateral extent of contamination. Borings are terminated whenever the vertical extent of contamination has been determined or when auger refusal occurs. When two sample intervals show non-detectable concentrations of contamination with use of the field instrument, the boring is discontinued. Site access can be affected by the existence of overhead power lines or subsurface structures such as USTs, product lines and private or public utilities. All underground structures are located using professional locating instruments prior to drilling at each site.

If it is determined during the drilling program that groundwater has been contaminated, then a series of groundwater monitoring wells would need to be installed. In most cases, at least three wells are needed to determine the extent of groundwater contamination and the groundwater flow direction. By measuring the static water level in each monitor well, a plane depicting the surface of groundwater can be constructed by plotting the measurements of at least three wells, and contours can be drawn which show the direction and gradient of flow. This information is useful in determining the potential for lateral migration of contaminated groundwater. Samples can be collected from the monitor wells to determine the extent of free product or dissolved contaminants in the ground water.

Drilling Methods

**Hollow-Stem Auger Method.** As stated before, the drilling method is selected based on the conditions expected to be encountered at each site. In situations where finer grained materials, such as silt, sand and clay are expected to be encountered, one of the best drilling methods is with the use of a hollow stem auger drilling rig.

Hollow-stem augering is one of the most effective and cost efficient drilling techniques used to determine the extent of contamination. This drilling method is accomplished by rotating the augers into the soil thereby advancing the boring. Sections of augers are added at the surface to the downhole string in order to advance the boring to the desired depth. Sampling at depth is facilitated by using augers with hollow centers. This system allows sampling devices to be lowered down through the auger string to the bottom of the boring where relatively undisturbed samples can be collected. The sample device is attached directly to a smaller diameter steel rod and is either driven or pushed ahead of the auger bit into the undisturbed soil to collect a sample. When Bedrock or course grained sediments such as gravel and cobble are encountered in the borehole, drilling with the use of a hollow stem auger rig is no longer practical and in most cases auger refusal will occur. Alternate drilling methods must be used in these situations.

**Dual Wall Hammer Method.** In unconsolidated course grained deposits, the dual wall hammer drilling method is commonly employed. This method is accomplished by physically driving a dual-wall or triple-wall temporary casing into the subsurface. Compressed air is circulated down into the outer wall of the casing and up through the inner wall carrying the drill
cuttings to the surface. The cuttings are discharged at the surface through a flexible hose and cyclone. Down-hole sampling can be conducted to obtain relatively undisturbed samples similar to the sampling techniques utilized with a hollow stem auger rig. However, soil sample recovery is usually poor when attempting to sample from course grain deposits.

One advantage to this method is that monitor wells can be installed inside the temporary casing which eliminates the risk of borehole collapse associated with other methods. This method also limits the vertical migration of contaminants during the drilling process and needs little or no drilling additives, which may potentially effect the quality of groundwater in the vicinity of the boring.

Disadvantages of this method are that it is significantly more expensive than hollow-stem augering and since the percussion hammer is diesel powered, there is a potential for introducing diesel oil to the air compressor and eventually into the formation. (Sale and Rhoades, 1987)

Core Drilling. When drilling and sampling into consolidated bedrock formations, a core rig is typically used. Relatively undisturbed insitu soil samples can be collected using this method without removing the drill string. Samples can be collected at intervals or continuously.

In most situations, a temporary stabilization casing must be installed in the upper unconsolidated formation prior to core sampling. Drilling fluids are circulated during the core drilling process to remove the drill cuttings. Core samples are collected using a core barrel sampler which is wirelined into place through the drill string. The inner core barrel sampler locks into place ahead of the drill bit and accepts the representative sample as the drill string is advanced. When the drill string has advanced the proper distance, the core barrel sampler is wirelined to the surface.

Core drilling is a time consuming process that involves extensive preparation and set-up. Due to these considerations, this method can be considerably more costly than other site investigation methods.

Rotary Drilling. Rotary drilling methods are less commonly used for the investigation of UST leaks. However, when the installation of monitor wells is necessary, and the water bearing unit is relatively deep, rotary drilling is a viable method.

Rotary drilling is accomplished by circulating either a drilling fluid or air through the center of the drill string and bit. Drill cuttings are transported to the surface through the annulus between the drilling string and borehole wall. A major disadvantage of this method for the investigation of a UST leak is that down-hole sampling is not easily accomplished.
Sample Collection and Preservation

Several steps must be taken during the collection of samples to ensure the quality of each sample and prevent the loss of volatile constituents. When the sample device is retrieved from the subsurface, the sample is sealed and labeled and placed into a cooler containing ice for preservation. Excess soil sample from each interval is monitored at the surface with a hand held field instrument to detect and document the presence of contamination. Samples are generally collected at 5-foot intervals to develop an adequate profile of subsurface conditions and contamination concentrations. Logs are maintained to document the lithology encountered and the field instrument readings at each boring location. Each sample is listed on a chain-of-custody form, which is a detailed record of the history of each collected sample. When the samples are transferred from one party to another, the transaction is documented on the chain-of-custody form.

Analytical Test Methods For Soil Samples

The type of analytical method used to quantify the contaminant concentration depends on the type of product that was lost from the leaking UST. For gasoline leaks, the soil sample is usually analyzed by the modified EPA Method 8020 for benzene, toluene, ethylbenzene and xylenes (BTEX) and the EPA Method 8015 for total petroleum hydrocarbons (TPH). Soil samples contaminated with diesel can be analyzed by the EPA Method 8015, modified for diesel or the modified EPA Method 418.1. Both of these analysis methods quantify TPH in the soil sample. To properly quantify waste oil contamination, several analysis methods must be conducted. Samples contaminated with waste oil need to be analyzed for TPH and BTEX by the methods listed above and also for metals and solvents. A typical analysis method for solvents is the EPA method 8010.

Summary

The implementing of current regulations which have required many tank owners to remove or upgrade their UST systems have resulted in the discovery of numerous leaking USTs that were previously undetected. Inventory discrepancies were either discounted or ignored in the past. With an estimated twenty-five percent of all UST systems currently leaking, site investigations at leaking tank sites need to be conducted in order to evaluate the nature and extent of the problem so that remedial measures can be adopted and site clean-up can be accomplished. As previously stated, the most important phase of the site investigation is the delineation of the contamination plume. Several techniques can be utilized to accomplish this task including over-excavation and soil gas analysis. However, the most effective method is through the drilling and sampling of boreholes. At sites where groundwater has been contaminated, monitor wells are installed to evaluate the extent of groundwater contamination. Once the site investigation has been completed, a site remediation plan can be developed and implemented.
REFERENCES CITED

1. Evans, J., 1988, Musts for USTs, A summary of the new regulations for Underground Storage Tank Systems, Environmental Protection Agency (EPA).
