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Project Summary

Technical Assessment of Low-Pressure Pipe Wastewater Injection Systems

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The purpose of this study was to review all technical and practical experience with Low-Pressure Pipe Waste Injection Systems (LPP systems) and to characterize typical systems and their field performance. A rigorous review of available information on LPP systems is presented in this report. To augment these data, 12 typical LPP facilities were monitored over the winter-spring stress period from October 1982 to July 1983. Detailed system design specifications, soil conditions, flow estimates, background and in-trench moisture conditions, and numerous other performance indicators are reported in this technical assessment. Study methods are presented, results are discussed and summarized, with conclusions, and recommendations are made for further research.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, 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

The LPP system combines several innovative subsurface wastewater absorption system concepts into a unique onsite design package. Most important among the features of LPP systems are very shallow placement, very narrow trenches, pressure-dosed distribution, loading on a system area basis, and rather flexible site criteria. This system was developed in North Carolina in response to intense growth and development in unsewered areas with soils unsuitable for conventional systems. Since about 1977, approximately 1500 LPP systems have been installed in North Carolina, and continued rapid proliferation is anticipated.

Unfortunately, only limited documentation of these systems' performance, other than general observations, is available from the first several years of field experience. Further, based on the recommended sizing procedure for these systems and their trench configuration, it is apparent that LPP systems have somewhat different operational characteristics from conventional systems.

The purpose of this study was to assess available information and perform field studies of the LPP system of onsite wastewater disposal that is now used extensively in the southeastern United States in areas where soil and site conditions exist that preclude the use of conventional soil absorption systems. The LPP system incorporates placement of a pressure-dosed distribution network in shallow, narrow trenches. The term "LPP" derives from the use of low pressures in the range of 2 to 4 ft of water, as measured at the distal end of the network. The septic tank effluent flows by gravity to a pumping chamber, where a submersible pump conveys it to the trenches in controllable doses approximately 2 to 3 times per day.

The following basic components of the LPP system are illustrated in Figure 1:

- two-compartment septic tank
- pumping chamber

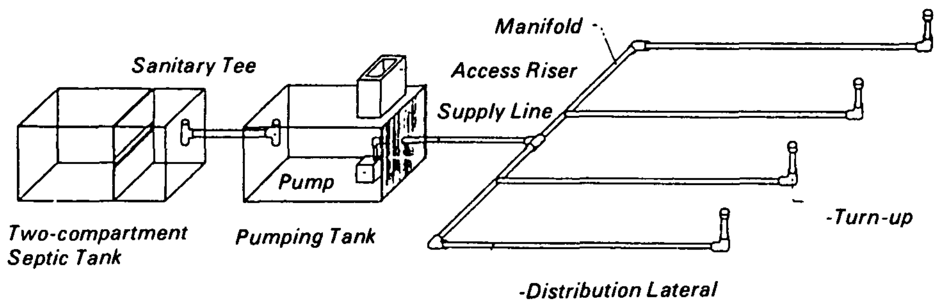

Figure 1. *Basic components of a typical low-pressure pipe wastewater absorption system.*

- submersible effluent pump, with high and low level controls
- high water alarm system
- supply line and manifold
- perforated distribution laterals
- trenches installed in soil of suitable area, depth and morphology.

The trenches, spaced 5 ft or more apart, are excavated by a continuous trenching machine and are typically 6 in. wide. Depth of excavation varies with site and soil conditions, but 6- to 18-in.-deep trenches are most common. In the case of very shallow applications, appropriate fill material may be required for cover, with final grading to enhance runoff away from the absorption area. In other situations LPP systems have been installed entirely in fill.

Where site and soil conditions preclude the use of a conventional system, alternatives to include LPP or mound systems may be proposed. North Carolina Code requires that LPP systems must have at least 2 ft of suitable or provisionally suitable soil and maintain a vertical separation distance, from trench bottom to limiting condition, of at least 1 ft. This is significantly less than the 2 to 4 ft of separation generally recommended to achieve proper renovation.

Sites on which LPP systems have been successfully applied include the following:

- soils with seasonally shallow or perched groundwater
- soils with hydraulically restrictive horizons at shallow depths
  - —clayey subsoils with slow permeability
  - —compact or cemented horizons
  - —bedrock
  - —saprolite
- sandy soils with rapid permeability
- sites with steep slopes

If natural soil conditions will support use of an LPP system, this is usually the system of choice, as opposed to a mound that may cost approximately three times as much as an LPP. Where less than 2 ft of suitable native soil is available, LPP systems have been installed partially or totally in fill materials, a common practice in replacement situations.

Shallow system placement offers several advantages over deep placement. The most obvious, and the primary application of LPP systems, is the utilization of the best soil available at shallow depths while maintaining maximum vertical separation above a limiting condition such as groundwater or a flow-restricting horizon. Shallow placement also introduces the wastewater into the soil's best aerated, most permeable, and most biologically active zone. Especially in thermic climates such as North Carolina's, shallow systems offer an important advantage in enhanced evapotranspiration. This may contribute significantly to the system's hydraulic function by increasing the hydraulic gradient away from the absorption trench, allowing for trench zone drying and breakdown of accumulated organic material during dry summer periods.

History

The use of LPP systems in North Carolina has enjoyed rapid growth over the past few years. Approximately 1,400 LPP systems were in operation in North Carolina by the end of 1983.

As promoted and endorsed by the N.C. Division of Health Services and North Carolina State University, the LPP concept is appropriate for a wide range of site-limiting conditions. More than half of North Carolina is unsuitable for conventional septic systems according to the North Carolina Administrative Code (NCAC) guidelines. Given its apparent successful performance thus far, and the widespread demand for such a solution, it is clear that LPP technology will eventually enjoy use throughout the state. Equally important, these systems will be constructed on sites that would otherwise not be utilized for onsite waste systems owing to combinations of any or all of the following site limitations:

- high groundwater
- shallow bedrock
- impermeable soil
- periodic flooding
- excessive slope

The State of New Mexico has adopted the North Carolina LPP system comprehensively in its 1981 onsite waste guidelines. The design and installation procedures specified by New Mexico are substantially the same as those employed by North Carolina. As yet, very few LPP systems have been constructed in New Mexico.

Virginia has adopted the general concept of a shallow, narrow-trench, dosed wastewater absorption system in their 1982 revised code. However, the Virginia Low-Pressure Distribution (LPD) systems do differ from LPP systems in several important ways. The LPD systems are designed on the basis of trench bottom area as opposed to system area for LPP systems and have a much more conservative loading schedule. Also the trench configuration and the distribution specifications of the LPD system vary somewhat from the LPP system.

During 1983 a community rehabilitation project (the Harney Project), sponsored by the U.S. Department of Housing and Urban Development, was initiated in Carroll County, Maryland. As part of this project alternative, individual onsite wastewater systems are being constructed. Because of shallow bedrock and seasonal perched groundwater conditions, the alternative selected for about 35 homes in the community was the LPP system. About 15 LPP systems were constructed and put into operation in fall 1983, with completion of the remainder expected in spring 1984. LPP systems have not been approved for general use by the State of Maryland.

Study Approach

The study involved an amalgamation of two forms of engineering assessment.

The first was an intensive search of readily available and fugitive literature sources, personal contacts and other sources of information to assess the state of the art. The second was a field monitoring program designed to assess the subjects least defined by the former effort, e.g., interactions of wastewater flows, trench loading rates, and background conditions. This evaluation involved the instrumentation and monitoring of 12 LPP systems over the stress period of winter-spring 1982-83 (10 mo).

All but one of the sites had been in operation for more than 1 yr. All available site information was evaluated and verified in the field, and each was retrofitted with flow monitoring devices and monitoring wells around and in the trenches. System monitoring activities typically included examination of the pumping chamber and flow counter, determination of water levels in each well, and inspection of general system conditions. Based on observed wastewater production, efforts were made to conduct monitoring at a time of day when the system would be ready for a pumping event. In any case, evidence of recent pumping events was noted to aid in interpretation of the well data. At least twice during the monitoring period, the wells' response to a pumping event was measured by observing, for an extended period, the rate of water level change after the pump had shutoff. This provided an estimate of trench outflow dynamics. Water meter data was collected where available. Precipitation was estimated from data available from nearby National Weather Service reporting stations.

To assist in data analysis, plan and section view layout plots were constructed for each of the 12 systems. Likewise, background and in-trench well levels were plotted over the monitoring period. Also, trench well dosing response curves were developed. These data are presented for four representative systems to demonstrate typical system features and performance. Selected operational and performance indicators were summarized for all systems.

Results and Conclusions

Technical Review

1. Shallow placement of the LPP trenches utilizes the most permeable and biologically active soil horizons, accentuates evapotranspiration, and permits use on sites that have insufficient suitable soil depth for conventional systems, and thereby increases useful land area and improves system performance.

2. Narrow trenches permit inexpensive construction techniques, reduce site disturbance, and minimize soil compaction.

3. Design hydraulic loadings are approximately 3.8 times that of conventional systems on a total land area basis, but are less than conventional on a trench-bottom-area basis.

4. LPP trench volumes result in decreased storage capacity compared to conventional trenches during stress periods, but also reduce gravel requirements.

5. Previous surveys have documented a success rate of over 90% for LPP systems installed on sites considered unsuitable for conventional systems.

6. Monitoring studies have reported excellent reductions of all wastewater pollutants 2 ft below LPP trenches, including viruses.

Field Study

1. LPP trench location in the shallow horizons result in extreme sensitivity to soil moisture, resulting in their functioning as shallow groundwater injection systems during periods of high groundwater.

2. LPP systems dry out very rapidly when groundwater levels recede and rainfall ceases, displaying minimal clogging effects on trench interfaces owing to the combined effects of pressure dosing, shallow placement, and narrow trenches.

3. Mechanical problems of LPP systems were significant, primarily with level control switches, and excessive pumping owing to infiltration problems will likely result in shortened pump service life.

4. Almost half of the systems displayed temporary surface outbreaks during saturated periods in the course of the pumping cycle.

Overall

Although the LPP systems have been shown to be a successful alternative to conventional onsite systems under site conditions that would prohibit the latter, the LPP design parameters employed and site conditions recommended for their proper application need better definition. Also, the LPP technology should be evaluated in colder climates to determine its applicability in locations with more severe winter conditions.

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The complete report, entitled "Technical Assessment of Low-Pressure Pipe Wastewater Injection Systems," (Order No. PB 88-107 222/AS; Cost: $13.95, subject to change) will be available only from:
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Project Summary

Nondestructive Testing (NDT) Techniques to Detect Contained Subsurface Hazardous Waste

Arthur E. Lord, Jr. and Robert M. Koerner

A systematic and comprehensive study was conducted to detect buried containers with nondestructive testing (NDT) remote-sensing techniques. Seventeen techniques were considered but only four were ultimately selected. Those four were electromagnetic induction (EMI), metal detection (MD), magnetometer (MAG), and ground penetrating radar (GPR). The containers — both steel and plastic — varying in size from 5 gal to 55 gal were buried in known distributions in a wide variety of soils; also, some were submerged in water. Five diverse field sites were used.

As a result of the work at the five field sites, a relatively complete picture has emerged concerning the strengths and weaknesses of the four NDT subsurface container location techniques. GPR is the only reliable method to detect plastic containers, but it has limitations. GPR, EMI, and MD all suffer severe loss of detection ability when the background electrical conductivity exceeds 40 millimhos/meter. In dry sandy soil EMI, GPR, and MAG are all capable of picking up a single 55-gal steel drum to a depth of at least 10 feet. The MAG method works well for steel under all subsurface conditions, and GPR can usually pickup the side walls of the excavations where waste is dumped. Application of signal enhancement techniques (background suppression) can be expected to enhance NDT utility.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio, 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

Since there is a vast amount of hazardous waste buried below the surface of the soil, it is important to clean up these wastes before they do additional damage to the environment. The first step in any cleanup procedure is to detect the waste and then determine its spatial extent. As in any subsurface exploration, many techniques can be brought to bear. Test borings and limited excavations are very valuable but are not without their problems. The information obtained is not continuous and the destructive nature of the test makes it possible that waste could inadvertently be released during the probing phase. Therefore, there is an interest in probing from the surface with nonintrusive methods.

The goal of this project is to identify and assess the best possible NDT techniques for detecting and delineating hazardous waste. Since another EPA laboratory was performing the same type task for monitoring hazardous waste leachate plumes, this work concentrated on the detection of steel and plastic containers buried beneath the surface of soil and water bodies.

Literature Phase

The first phase of this project consisted of identifying as many NDT techniques as possible which could have possible application to a broad spectrum of hazardous waste problems. Seventeen such techniques were identified. They were:

- Microwave-pulsed — also called ground penetrating radar (GPR)
- Microwave-continuous (CWM)
- Eddy current - also called metal detection (MD)
- Magnetometer (MAG)
- Seismic reflection
- Seismic refraction (SR)
- Electrical resistivity (ER)
- Penetrating radiation (x-rays, gamma-rays, neutrons, etc.)
- Acoustic emission
- Liquid penetrant
- Infrared radiometry
- Pulse-echo ultrasonics
- Sonar
- Very low frequency electromagnetic — also called electromagnetic induction (EMI)
- Induced polarization
- Self-potential
- Optical techniques.

A detailed report was prepared on each of these techniques. (These are available from the authors.) Information was sought from the literature, company brochures and personal communications. The literature search eliminated a number of the techniques from further experimental evaluation. Some of the reasons for eliminations were:

- prediction of very little chance of success
- high cost of equipment
- no indication from literature search of success for container detection
- inaccessibility of equipment.

As a result of this first phase of the project, the number of techniques considered was further reduced from seventeen to seven. The remaining techniques were ground penetrating radar, microwave-continuous, metal detection, magnetometer, seismic refraction, electrical resistivity, and electromagnetic induction.

Field Tests

Each of the NDT methods will operate "ideally" under a prescribed set of soil types and man-made interferences. The typical sites where most waste material containers are buried are far from those "ideals." Rather than burial in dry granular soils, drums are usually dumped in swamps, mudflats, water and the like. Furthermore, the most successful methods we have worked with are based on measuring electrical or magnetic effects. High electrical conductivity areas, e.g., near equipment storage areas, junk yards, or ocean water, can severely influence the techniques. Soil homogeneity and water conductivity are major issues. Quantities of ferromagnetic material (e.g., steel objects) can severely affect the MAG method. With these thoughts in mind, test sites were obtained, containers of various sizes were carefully placed at different depths and geometric arrangements, backfilled, and then located using the various NDT methods.

The first field site was a nearly ideal dry sandy soil in an open field, free of man-made interference. This site provided an excellent starting point and essentially narrowed the selection (after careful literature review) from seven of the possible NDT methods to the four mentioned previously. The surviving methods were MAG, EMI, GPR, and MD. Steel containers buried to 10-ft depths were accurately located and could possibly have been located deeper if stable burial pits could have been excavated. Various steel container arrays and the boundaries of a "metal trash dump" were accurately located. Some plastic containers were also located, but with poorer results.

The second site was more formidable. Here a saturated silty clay soil overlying shallow shale rock was used. Detection depths with the four methods indicated techniques were much shallower, approximately 4 ft, and the results were influenced by the large amount of background metal in the areas (e.g., trailers, equipment, fences, etc.).

The fact that containers are sometimes dumped directly into water and that the salinity of the water can range from fresh to brine, the third study was directed at drums under water. Containers were submerged in water and placed on the bottom sediments at four different sites. The salinity of the water ranged progressively from fresh to ocean. (The work was actually performed at various positions along the Delaware River.) To depths of 3 ft of water above the containers, the detection and delineation results were "excellent" to "no good" in direct proportion to the increase in water salinity, i.e., electrical conductivity of the water.

Bearing directly on the above three studies is the extent to which ground salinity can influence the detecting capability of the NDT methods used. At this point, studies were made at a fourth site with steel containers buried in a soil of varying electrical conductivity. The ocean was used as an electrical conductivity extreme and the conductivity decreased substantially as the survey moved inland. The soil was a medium-to-fine granular sand indigenous to the coastal area. The sand density ranged from loose (near the surface) to intermediate (at a depth of 6 ft).

Background conductivities greater than 40 millimhos/meter seriously impaired the use of those methods based on electrical conductivity measurements, i.e., MD, EMI and GPR. The MAG method worked much better since it is a method based on magnetic measurements and not on electrical conductivity. The boundaries of a "trash dump" containing metal objects were observed with all methods even though the background conductivity varied from 25-60 millimhos/meter.

Site 5 was the same location as Site 4 but, in this case, plastic containers were used instead of steel. The MD, EMI and MAG did not detect any of the plastic containers even when these were filled with salt water. The ability of GPR to pick up the water table, as well as the containers, was demonstrated.

Conclusions

Table 1 presents the results obtained at all five field sites and should be considered the final results of the project and can serve as a guide for the practitioner. Some additional remarks are in order to help assimilate all the results of these studies.

In a dry, granular soil with medium interference, individual typical steel containers can easily be seen to a depth of at least 10 ft with all methods except MD, which detects to 6 ft. Deeper detection is probably possible, but 10 ft was the limit of our burial ability. As the soil water electrical conductivity becomes larger, the detection ability of the MD, EMI, and GPR methods suffers. When the background conductivity rises to 40 millimhos/meters or above, the detection ability is seriously impaired. The MAG method works well under all granular soil conditions for it is not affected by high background electrical conductivity.

In cohesive soils (clays), there are definite problems with MD, EMI, and GPR due to the usual high water content and soil inhomogeneities. A logistical problem arose with respect to the MAG data, since work in cohesive soils was performed in the presence of magnetic interfering materials (trucks, fences, etc.). Research should be conducted in an interference-free cohesive soil using the MAG method. The use of MD, EMI, and GPR in relatively uniform, dry cohesive soils is of interest.

When steel containers were submerged under water, the MD, EMI and GPR

Table 1. *General Acceptability of Using Various NDT Methods to Locate Typical Sized Buried Containers (Maximum Penetration Depth Achieved in Parentheses)*

Subsurface Material (Reference)	Saturation	Type of Void Water	Metal Detector (MD)	Electromagnetic Induction (EMI)	Ground Penetrating Radar (GPR)	Magnetometer (MAG)
			Steel Containers			
Granular (sand)	0% - 20%	fresh	excellent (6')	excellent (10')	excellent (10')	excellent (10')
	20% - 50%	intermediate	excellent (2')	average (4')	excellent (3')	excellent (4')
	50% - 100%	ocean	not good	not good	poor (2')	excellent (10')
Cohesive (clay)	50% - 100%	fresh	moderate* (4')	moderate* (4')	moderate* (4')	poor (4')**
Water	100%	fresh	excellent (3')	excellent (3')	excellent (4')	excellent (3')
	100%	intermediate	poor	not good	not good	excellent (3')
	100%	ocean	not good	not good	not good	excellent (3')
			Plastic Containers			
Granular	10% - 50%	intermediate	not good	not good	excellent - if contents conductive (4') fair — if contents non-conductive	not good
	50% - 100%	ocean	not good	not good	poor	not good

*Excellent in dry clay.
**Many interfering magnetic objects. Excellent in absence of interference.

methods are only of value in relatively fresh water. When the water conductivity rises above 60 millimhos/meter, the three methods are quite useless. The MAG method functions well in water of all conductivities.

Plastic containers are more difficult to detect than steel containers. The MD, EMI and MAG methods are useless in detecting buried plastic containers. The GPR method works well for typical size plastic containers, especially if the containers are filled with electrically-conductive material. However, the method still works with non-conductive contents. These results for plastic containers apply only for granular soil with relatively low electrical conductivity. If the granular soil has high conductivity material in its voids or if the soil is a wet, non-uniform cohesive material, then the same limitations apply to GPR as were mentioned earlier.

While this is a systematic and comprehensive study of NDT methods, it is not complete and a few additional situations still remain to be studied.

As a brief bottom line, it can be stated:

- MD, EMI, and MAG all work extremely well in detecting buried steel containers in dry, granular soil to any typical depth.
- The MAG method works well under all subsurface conditions.
- MD, EMI, and GPR will suffer severe loss of detection ability when the soil's electrical conductivity rises above about 40 millimhos/meter. The same conductivity limitations also apply to the detection ability for containers submerged under water.
- GPR is the only reliable method to detect buried plastic containers.
- GPR can "see" excavation boundaries. This is an extremely important point.
- For a preliminary survey of a metal-container dump site, the MD (instrument costs about $500) is a good first method, followed closely by the MAG method (cost about $4000). More detailed surveys can use the more expensive instruments: EMI (cost about $8000) and GPR (cost about $30,000).

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The complete report, entitled "Nondestructive Testing (NDT) Techniques to Detect Contained Subsurface Hazardous Waste," (Order No. PB 88-102 405/AS; Cost: $13.95, subject to change) will be available only from:
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