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Project Summary

Alternative Onsite Wastewater Treatment and Disposal Systems on Severely Limited Sites

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Several research and evaluation studies were performed on alternative onsite wastewater treatment and disposal systems at sites with severe limitations for conventional systems. The studies included systems that rely on the soil for treatment and disposal (including low-pressures pipe (LPP) systems, alternating soil absorption field systems, shallow conventional trenches, gravelless trenches, and mound systems) and systems that discharge to surface waters or to the atmosphere (including intermittent sand filters, upflow gravel filters, subsurface gravel beds, and evapotranspiration systems). These studies were performed on full-scale operating systems, scaled-down field systems, or laboratory columns.

The soil properties, soil moisture regime, and shallow groundwater table at the research locations were characterized to gain a better understanding of the ability of the soils to treat and dispose of wastewater. Several typical site evaluation techniques were assessed, and because of a seasonally high groundwater table present in the soils of this study, groundwater contamination was investigated.

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

Approximately 68 percent of the total land area in the United States is unsuitable for conventional onsite systems that utilize the soil for final treatment and disposal of wastewater. During the past several decades many alternative systems have been developed for use in these areas. Many of the successful newly developed alternative systems were custom-designed for the soil and site conditions at specific locations, and their use in other soil and site conditions is only slowly being evaluated. Many alternative systems have been demonstrated only in localized areas, and officals elsewhere are reluctant to approve their use because the alternative systems are unproved and untested under the conditions that pertain to their area.

The Cincinnati Center for Small Community Wastewater Systems Studies was established in 1980, in conjunction with the University of Cincinnati and the U.S. Environmental Protection Agency, to generate information relevant to onsite wastewater disposal options for areas with unfavorable soil and site conditions such as those typically found in southwestern Ohio.

Several alternative systems that had not been evaluated previously in southwestern Ohio were investigated by the Center. In several studies, existing systems that had failed were replaced with alternative systems. In other studies, alternative systems that had already been installed, but not yet proven as acceptable alternatives in southwestern Ohio were evaluated. Research was also performed in situ on several scaled-down alternative systems and in the laboratory on columns simulating alternative systems. The alternative systems studied included those that rely on the soil for the treatment and disposal of wastewater, and systems that do not rely on the soil for disposal, but which discharge either to surface waters or to the atmosphere.

Procedures

Study Site

The full-scale operating systems were installed at individual homes in Hamilton and Clermont Counties in southwestern Ohio, and the scaled-down field systems were installed at a field research station established in Clermont County, Ohio. The major limitations for conventional methods of onsite treatment and disposal in this area include slow permeability, a seasonally high water table, and limiting soil horizons. The majority of soils in the study areas formed in 40 to 100 cm of Wisconsinan loess and in the underlying weathered till of Illinoian age. The major soil types at the field station were the Avonburg silt loam (Aeric Fragiaqualf, fine-silty, mixed, mesic) and the Rossmoyne silt loam (Aquic Fragiudalf, fine-silty, mixed, mesic).

To describe the soil moisture regime of a typical site in southwestern Ohio, the groundwater table, soil moisture content, and soil moisture potential were measured in areas of the research site not affected by the addition of effluent. The free water surface was within 15 to 60 cm of the soil surface during the late fall, winter, and spring months, and receded to greater than 1.5 m during the summer months. The fragipan that was present in these soils did not greatly impede the downward movement of water.

The soil moisture content remained relatively constant during the late fall, winter, and spring and decreased only in the upper horizons of the soil profile during the summer months. Below approximately 1 m, there was very little change in the soil moisture content throughout the study.

Systems Studied

Table 1 lists the various systems evaluated in this project, and the major objectives for the individual studies. All systems utilizing the soil for disposal were monitored with trench observation wells to observe ponding depths. The soil absorption rates were determined by either preset loading rates, or by mechanisms in the trenches that controlled the amount of wastewater applied to the trench based on the amount of effluent the soil absorbed. The soil moisture regime surrounding the trenches was monitored with tensiometers, depth moisture gauge (neutron probe), and groundwater observation wells. The groundwater surrounding several of the systems was analyzed for contamination.

Influent and effluent samples from the systems that did not use the soil for disposal were analyzed for common wastewater parameters, including COD, BOD_5, fecal coliforms, Total-P, nitrogen species, and total suspended solids (TSS).

Site Suitability

Two common techniques to assess site suitability for onsite wastewater disposal, the use of 2-chroma mottles to predict the maximum height of the fluctuating high groundwater table, and the use of percolation tests and hydraulic conductivity tests to describe the hydraulic capacity of a soil, were evaluated. Soil colors described from core samples taken in areas where soil-water monitoring equipment was installed were compared with the groundwater table data. In situ hydraulic conductivity tests and percolation tests were performed in triplicate at four locations at the field research site representing two soil types. All of the tests were performed at a 50-cm depth to correspond with the depth of the infiltrative surface of a conventional soil absorption system. The values obtained were then compared to actual absorption rates obtained from two conventional trenches installed in an Avonburg soil.

Results and Discussion

Alternating Soil Absorption Field System

The installation of additional trench capacity prevented surfacing of effluent at a site with a failed soil absorption system during the 3-year period of the study. However, the alternating field concept could not be evaluated because the exisiting, failed system had been installed with only a few centimeters of soil between the infiltrative surface of the trench and bedrock. Consequently, when the groundwater table rose during the late fall, the trenches were inundated with groundwater. Therefore, during these periods, even when effluent was not being applied to the trenches, they were filled with water. The trenches could dry out during the summer months when effluent was directed to the alternate system, but the longest continuous resting period was only 90 days, and rejuvenation was insufficient to allow the system to dispose of the entire volume of wastewater produced. The importance of maintaining a suitable isolation distance between the trench bottom and an impervious horizon was clearly seen in this study.

Low-Pressure Pipe System

The LPP system was installed on a 10 percent side slope in a Rossmoyne soil, and consisted of 5 trenches that were 12.2 m long and spaced 1.5 m on centers. The trenches were 20 cm wide and approximately 28 cm deep and were installed with a trenching machine. Septic tank effluent was applied to the system by pressure distribution.

Throughout the 2-year study, effluent adsorption was variable and dependent on climatic factors. The loading rates ranged from 4 to 10 liters per day per square meter (Lpd/m^2) (based on the total surface area that the system covered), with the highest occurring during the first summer of operation. After the first year, the loading rate was kept constant at approximately 4 Lpd/m^2. However, occasional periods of surface seepage occurred at this loading rate. No freezing was detected during the one winter that the system was in continuous operation; however, during a second winter when system operation was interrupted for 4 weeks, the soil surrounding the trenches froze.

Alternative Trench Design System

Two alternative trench designs and a conventional trench were installed in duplicate in a nearly level Avonburg soil. The alternative designs included a gravelless trench that consisted of 25-cm diameter corrugated plastic tubing covered with a porous wrap and installed at a depth of 50 cm, and a shallow trench similar to a conventional trench except that it was installed at a depth of 30 cm. The trenches were 6 m long and were installed 6 m apart. A constant ponding depth of approximately 20 cm was maintained.

The average absorption rates varied greatly over the 2-year study. The shallow trench design had a statistically significant average absorption rate higher than the other two trench designs. There was no significant difference in the absorption rates of the conventional and gravelless trench designs throughout the study. During the summer months, all of the systems performed adequately. However, during the late fall, winter, and spring, absorption rates were much lower, and there were periods of time lasting for up to 5 months when no effluent was

Table 1. *Objectives of Individual Studies*

*System (Size, Discharge, Installation)**	*Objectives*
Alternating SAS⁺ (FS,S,I)	*Correct & rejuvenate existing failed conventional system.*
Low Pressure Pipe (SD,S,I)	*Evaluate performance in winter, and in a location that did not meet design site and soil requirements.*
Alternative Trench (SD,S,I) (Shallow, gravelless, conventional)	*Determine which of the 3 designs absorbed the most waste-water; evaluate gravelless and shallow trench systems.*
Mound (LC,S,Y)	*Determine effect of dosing schedule on effluent quality.*
Intermittent Sand Filter (FS,SW,I)	*Evaluate performance in a local where not commonly installed; determine effects of pretreatment on performance.*
Intermittent Sand Filter (LC,SW,I)	*Evaluate effect of hydraulic loading rate on performance.*
Recirculating Sand Filter (LC,SW,I)	*Evaluate effect of recirculation ratio on performance.*
Aerobic Unit/Upflow (FS,SW,E)	*Determine if effluent meets State discharge limits.*
Downflow Gravel Filter (FS,SW,E)	*Determine if effluent meets State discharge limits.*
Evapotranspiration/Absorption (FS,AS,E)	*Evaluate performance in a humid climate.*

**Size: FS = Full-scale; SD = Scaled-down; LC = Laboratory columns.*
Discharge: S = Subsurface discharge; SW = Surface water discharge; AS = Atmosphere/Subsurface.
Installation: I = Installed for this study; E = Existing system.
⁺SAS = Soil absorption system.

absorbed from the trenches. The shallow trenches, however, had significantly shorter periods of nonabsorption than the trenches installed at conventional depths, illustrating the value of the upper soil horizons for increased absorption capacity.

Perimeter drains were installed around the trenches during the second year of the study in an attempt to lower the groundwater table and improve soil absorption during those times of the year when the groundwater table was high. There was no apparent increase in the absorption rate of the soil as the result of the installation of the drains. Because the soils in this study had a high capillary potential, it is likely that only a small volume of water was removed from the soil profile by the drains, resulting in an insignificant increase in the percentage of pore space available for absorption.

Mound System

Soil columns simulating mound soil absorption systems were dosed at 3-, 6-, and 12-hour intervals at a rate of 10 Lpd/m². Nearly complete removal of Total-P, BOD_5, COD, fecal coliforms, and TSS occurred through all of the columns, and dosing frequency did not affect the treatment of septic tank effluent with respect to these parameters. However, the column dosed every 3 hour produced an effluent with significantly lower TKN, NH_3-N, and NO_3-N than those dosed every 6 and 12 hour. Although some nitrogen removal variation occurred, data from larger-scale mound systems are needed before design recommendations can be made concerning the optimum dosing frequency.

Intermittent Sand Filters

Two full-scale intermittent sand filters were designed and installed using conventional techniques. Influent and effluent composite samples from each filter were collected twice per week for 18 months. Pretreatment was provided by a septic tank at one location and an aerobic unit at the other. The hydraulic loading rates for each filter varied during the study, with an average loading rate for the filter receiving septic tank effluent of 150 Lpd/m², and 49 Lpd/m² for the filter receiving aerobic unit effluent.

The filters produced a high quality effluent with respect to BOD_5, TSS, and COD regardless of the type of pretreatment, and met the State of Ohio discharge standards for BOD_5 and TSS in 100 percent and 90 percent, respectively, of the samples tested. Fecal coliform numbers in the effluent exceeded 200 fecal coliforms per 100 mL, and disinfection of the sand filter effluent is recommended before it is discharged to surface waters.

The only maintenance required on the filters was the removal of a 13-mm thick crust that had formed on a section of one filter that was receiving a high load of effluent as the result of a temporary high overall hydraulic loading problem and a distribution problem. After the crust was removed, no crusting occurred on either filter for the remaining 10 months of the study.

In the laboratory intermittent sand filter study, 10 sand columns were used to test, in duplicate, 5 hydraulic loading rates ranging from 20 to 162 Lpd/m². Septic tank effluent was applied to the columns three times per day. Influent and effluent sand filter column samples were collected two or three times per week over a 6-month period. The results showed that the hydraulic loading rate did not affect effluent quality with respect to TSS or COD, but did affect Total-P and fecal coliform removal, which showed significantly less removal at higher loading rates.

In the laboratory recirculating intermittent sand filter study, septic tank effluents with recirculation ratios of 3 to 1, 4 to 1, and 5 to 1 (recirculated wastewater to septic tank effluent) were dosed onto columns at a loading rate of 122 Lpd/m². Column influent and effluent samples were collected twice per week for 11 weeks. The results showed that treatment of septic tank effluent for COD, TSS, and TKN was not affected by the recirculation ratio in the ranges tested.

Upflow Gravel Filters and Subsurface Gravel Beds

Two aerobic unit-upflow gravel filter-subsurface discharging gravel bed systems, that had been operating for approximately 3 years before the study, were evaluated. The upflow gravel filters were made specifically to treat aerobic unit effluent. The subsurface gravel beds were designed by the Department of Health in Clermont County, Ohio, and are required following aerobic unit-upflow gravel filter systems in that county. The average daily water use was 709 Lpd at one residence and 1474 Lpd at the other. Influent and effluent grab samples were collected twice per week for 16 weeks.

The average BOD_5 and TSS concentrations were reduced by all of the polishing units, but the effluent did not consistently meet the State of Ohio standards for the discharging of treated wastewater off of private property for these parameters. Fecal coliforms were reduced in numbers through all of the units, but the mean number exceeded the surface water standard for recreational use. Total-N and COD were inconsistently reduced through the units, and little reduction of Total-P occurred. The addition of the subsurface gravel bed to the aerobic unit-upflow gravel filter improved the quality of effluent, but the improvement was not consistent.

Evapotranspiration-Evapotranspiration/Absorption Systems

The performance of 11 evapotranspiration (ET) and evapotranspiration/absorption (ETA) systems that had been installed between 1978 and 1981 was evaluated during the spring of 1982 and winter of 1985. Information about each system was obtained through interviews with homeowners, health department personnel, plumbers, public water utilities, and onsite inspections.

Only 5 of the 11 systems were considered to be functioning properly. Both groups (failing and properly functioning) contained ET and ETA systems, had low and high flow rates, multiple and single trench designs, various fill materials, and were installed in suitable and unsuitable soils. Also, it is possible that the ET systems were actually operating as ETA systems as the result of faulty installation, and all modifications may not have been reported. Therefore, it could not be determined why a system did or did not work.

Systems that rely solely on evapotranspiration for the disposal of effluent should not be considered to be suitable alternatives for year-round use in southwestern Ohio because precipitation exceeds potential evaporation 6 months of the year. It is highly probable that the five functioning systems were not true ET systems and that other factors were involved in their satisfactory performance.

Groundwater Contamination

Groundwater was sampled from observation wells over a 1-year period in and around the LPP system, and from the perimeter drains surrounding the alternative trench design system to determine if groundwater contamination was occurring as the result of the added effluent.

The concentration of chloride was higher in the groundwater surrounding the systems than in areas not influenced by the addition of effluent. However, the other parameters tested (NH_3-N, NO_2+NO_3-N, TKN, Total-P, and fecal coliforms) showed little or no increase in concentrations for the time period they were monitored.

Although groundwater contamination did not appear to be a problem for most of the parameters measured during this study, the systems should be monitored for several years in soils with high water tables, such as those in this study, to fully evaluate the potential for groundwater contamination.

Soil Moisture Regime Surrounding Trenches

The soil absorption rates of the systems evaluated in this project suggest that the soils were able to absorb an adequate volume of wastewater during the summer months but during the winter months the absorption capacity was greatly decreased. This decrease most likely resulted from higher soil moisture contents, lower evapotranspiration rates, and a high groundwater table. Immediately surrounding the systems, however, the soil moisture régime remained relatively constant. Groundwater mounded below the LPP and alternative trench design systems throughout the year. No measurable change occurred in the soil moisture content below the elevation of the trench bottom to a horizontal distance of 75 cm between winter and summer, although low soil moisture tensions were present for a few weeks during the late summer. Above the elevation of the trench bottom, 90 cm from the trench, unsaturated conditions existed during the summer, but the tensions were much lower than in areas not influenced by wastewater addition. Also, after two years of operation, soil moisture potentials indicated that saturated conditions were present below the infiltrative surface of the monitored trenches, and in the trench sidewalls at the elevation of the trench bottom. Unsaturated conditions existed in the sidewall several centimeters above the trench bottom.

Site Evaluation Procedures

Using the presence of soil mottles with chromas of two or less to predict the depth to the fluctuating high groundwater table underestimated the height of the high water table rise in this study. Groundwater was observed for short periods in horizons that did not contain mottles with chromas of two or less, but did contain 3-chroma mottles and manganese nodules and cutans. Mottles with chromas of two or less were found in horizons that had extended periods of saturation. Soil morphological features such as 3-chroma mottles and manganese and iron nodules and cutans should be included in site evaluations on Avonburg and Rossmoyne soils to accurately predict the presence and duration of the high water table.

Percolation rates and saturated hydraulic conductivity values obtained from the auger-hole method and an in situ falling-head test overestimated the absorption capacity of the Avonburg and Rossmoyne soils in this study. No statistically significant difference occurred among the tests performed at four different locations. Percolation rates mathematically converted to saturated hydraulic conductivity values provided similar values to the auger-hole method and the in situ falling-head test in the soils in this study.

The geometric mean of the saturated hydraulic conductivity tests and the percolation rates mathematically converted to saturated hydraulic conductivity values ranged from 4 to 158 cm/day. Because no difference was found among the soils and tests in this study, an average saturated hydraulic conductivity of 33 cm/day was assumed. The average long-term acceptance rate for the conventional trenches in this project was 2.2 cm/day under optimum climatic conditions (i.e., summer). This loading rate was approximately 7 percent of the average saturated hydraulic conductivity value. When a subsurface soil absorption system is designed using a percolation rate, the infiltrative surface is sized with the use of empirically derived tables that correlate application rate to the percolation rate. Using standard tables, the maximum allowable loading rate (based on bottom area of trench) was 1.83 cm/day for the percolation rates in this study, which is similar to 2.2 cm/day, the long-term acceptance rate under optimum climatic conditions. The loading rates were much lower during the winter months, however, and the percolation rate greatly overestimated the absorption capacity of the soil during these time periods. Thus the percolation test approach for sizing appears to have serious inadequacies for the soils in this study.

Conclusions and Recommendations

None of the systems studied that rely on the soil for treatment and disposal of wastewater functioned properly when the groundwater table was high. The LPP system and the shallow-conventional trenches appeared to perform satisfactorily during most of the year, with only occasional surface seepage of effluent. Before they are recommended for use, however, further studies should be performed to determine if design modifications and reduced loadings could eliminate the occasional surface seepage since this is usually unacceptable for health and nuisance reasons. Recommended design modifications include increasing the trench spacing to provide as large a lateral absorption area as possible, and installing the trenches as close to the soil surface as possible to use the more permeable topsoil horizons and to provide the greatest possible spacing between the high groundwater table and the infiltrative surface. The potential for freezing and methods of prevention in these shallow systems should be further investigated.

Because of the lack of centralized sewer systems and suitable soils in many areas of southwestern Ohio, the LPP and shallow trench systems are possible alternatives for wastewater disposal in areas where soil absorption is the only option available. Areas should be further evaluated on a site-by-site basis to determine what loading rates and design modification are required to eliminate seasonal failure.

The intermittent sand filters consistently produced a high quality effluent with respect to BOD_5, COD, and TSS when pretreatment was provided by either a septic tank or an aerobic unit. This process would be considered to be a good alternative to subsurface disposal in southwestern Ohio if an appropriate receiving water is available for surface discharge, and if the regulatory agencies permit such a discharge. The additional expense of pretreating the wastewater with an aerobic unit was not justified. Disinfection of the effluent should be required before discharge.

An overview of project conclusions with regard to the applicability of specific technologies to soils with generally low permeabilities, high groundwater tables, and limiting soil horizons, such as those present in southwestern Ohio, is presented in Table 2.

The full report was submitted in fulfillment of Cooperative Agreement No. CR-808168 by the Cincinnati Center for Small Community Wastewater Systems Studies under the sponsorship of the U.S. Environmental Protection Agency.

Table 2. *Summary of Onsite Alternative Wastewater Treatment and Disposal Systems on Severely Limited Soils*

Technology	Suitability for Use in SW Ohio	Remarks
Alternating Soil Absorption System (ASAS)	*Possibly High Potential*	*This concept could not be evaluated because of high groundwater in the original trenches (built prior to these studies directly on bedrock). However, if used with trenches which incorporated sufficient volume to store flows during low absorption periods, this system might be successful.*
Low Pressure Pipe	*Limited Potential*	*Ponding in trenches was likely for long periods. Thus no advantage other than for summer homes or where trenches are higher than septic tank. Freezing potential needs more evaluation.*
Shallow Trench	*High Potential*	*Lower costs and increased absorption during low absorption periods of the year. Combined with other concepts (e.g. ASAS), it represents part of the most potentially successful system designs. Potential freezing problems/solutions and most cost-effective trenching methods need more evaluation.*
Gravelless Trench	*Limited Potential*	*Has no advantage over conventional trenches unless cost of gravel is high enough to justify economics. Shallow installation and freezing problems/solutions need more evaluation.*
Conventional Trench	*Low Potential*	*Since shallow trench is superior in absorptive capacity, the only advantage could be greater storage capacity during low absorption periods on small lots.*
Mound	*Not Known*	*Not evaluated at full-scale, but inability of soils to absorb effluent even from shallow trenches for long periods causes doubts about applicability. More frequent dosing improves nitrogen removal.*
Intermittent Sand Filters	*Very Suitable Where Surface Discharge Allowed*	*Superior performance over other surface discharge technologies. Pretreatment beyond septic tank not justified, and post-disinfection is required to meet indicator organism limits. Very reliable effluent quality and low maintenance features.*
Aerobic Unit/Upflow-Gravel Filters	*Low Potential*	*Unacceptable effluent quality with wide fluctuations; increased maintenance may improve somewhat. High annual costs.*
Downflow Gravel Filters	*Limited Potential*	*Used to upgrade aerobic/upflow-gravel system to produce a better, but not fully acceptable, effluent. Total capital costs high for complete package.*
Evapotranspiration Beds (ET)	*Not Suitable*	*Non-discharging ET systems are not possible in SW Ohio because humidity and precipitation outweigh evapotranspiration potential.*
ET/Absorption Beds (ETA)	*Low Potential*	*Because of the low ET potential in SW Ohio, the ETA systems that worked depended heavily on absorption. (The shallow trench system is, in effect, an ETA system because it maximizes both soil absorption and ET.)*
Highest Potential Subsurface System		*A shallow trench system with sufficient volume to accommodate either a low loading rate or storage capacity for low absorption periods. Although ASAS could not be evaluated in these studies, the use of shallow ASAS's could potentially be highly successful.*
Highest Potential Surface Discharge System		*Intermittent sand filters preceded by a septic tank and followed by disinfection, as required.*

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The complete report, entitled "Alternative Onsite Wastewater Treatment and Disposal Systems on Severely Limited Sites," (Order No. PB 87-140 992/ AS; Cost: $24.95, subject to change) will be available only from:
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