UNSATURATED ZONE MONITORING BELOW SUBSURFACE WASTEWATER SYSTEMS SERVING INDIVIDUAL HOMES IN FLORIDA

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INTRODUCTION

As of 1986, 1.5 million families were served by onsite sewage disposal systems (OSDS) in Florida and over 60,000 new OSDS were being installed annually (Ayres Associates 1987). Many of the OSDS in Florida occur in subdivisions of over 200 homes on 1/2 to 1/4 acre lots. These numbers and densities of OSDS have caused concern as to whether past and present OSDS practices are having adverse impacts on the ground water resources of the State. (Sherman et. al., 1988, Anderson et. al., 1988). Since ground water is the source of approximately 90 percent of Florida's drinking water supply, this resource must be protected to ensure the public health and safety of residents and tourists in the State.

The concerns over ground water contamination from OSDS led to formation of the Florida Onsite Sewage Disposal System Research Project. The project is administered by the Florida Department of Health and Rehabilitative Services (HRS), Environmental Health Program. As part of the OSDS Project, the capability of Florida soils to renovate septic tank effluent (STE) is being investigated. Included in the study is an evaluation of potential viral and volatile organic compound (VOC) movement through the septic tanks and below the STE infiltration systems of several single family homes. This paper discusses the methods and preliminary results of this phase of the Florida OSDS Project.

OBJECTIVES AND SCOPE

The objectives of this aspect of the OSDS study were to investigate the presence of key contaminants in residential septic tank effluent and their occurrence in sandy soils below full-scale systems. Four septic systems serving single family homes have been studied. The septic tank effluent from these homes was characterized to include virus, VOC's and more conventional parameters. Soil samples were then taken below the subsurface wastewater infiltration areas and analyzed for the same parameters. These results were compared to soil samples taken from background locations unaffected by the septic system. One of the four septic systems studied was selected for presentation in this paper. A more complete discussion of the methods and results of the study can be found in a report by Ayres Associates (1989).

FIELD STUDY METHODS

Household OSDS Characteristics

The general characteristics of the study home were determined through a written questionnaire and personal interviews with the home owners.

The characteristics and layout of the OSDS were determined by interviews with home owners and health department officials and by subsurface probing at the site. The general characteristics of the home and its OSDS are listed on Table 1.

TABLE 1. Characteristics of individual OSDS monitoring site.[1]

Number Residents	4
Adults	2
Children	2
Age of Children	1, 5
Lot Size	0.47 Acres
Age of Home	11 Years
Occupancy	5 Years
Number of Bedrooms	3
Number of Bathrooms	2
Dishwasher	Yes
Clothes Washer	Yes
Garbage Disposal	No
Water Softener	No
Septic Tank Size	900 Gallon
Date Last Pumped	Never
Drainfield Area	210 Ft^2
Drainfield Type	2 Foot wide, gravel-filled trenches
Effluent Distribution	Gravity flow, 4" perforated pipe

1. Based on survey results returned during May 1987 and data gathered during study period.

Septic Tank Effluent Monitoring

To allow sample access to septic tank effluent (STE) over the study period, a small polyethylene basin (approximately 5 gallons) was installed in the drain line on the effluent side of the septic tank. A four inch diameter polyvinylchloride (PVC) riser pipe was fitted to the basin to bring the access point within 6 inches of ground surface. The 4 inch PVC pipe was fitted with a removable cap and the entire assembly was finished off at grade with the use of a plastic water meter box. STE flowed through the sampling basin and to the OSDS infiltration system, or drainfield. Upon arriving at the site to sample, the STE basin was pumped out and allowed to refill with fresh STE before taking grab samples. Samples for VOC's were always taken first by carefully dipping 250-mL Pyrex beaker into the STE without splashing, and then transferring the contents slowly to standard 40-mL volatile organic analysis (VOA) vials with Teflon lined caps. These vials were placed on ice in a sample cooler for shipment to the laboratory for analysis. After obtaining the necessary VOC aliquots, samples for conventional analyses were taken by pumping out of the STE monitoring basin with a small hand operated diaphragm pump. A 1-L polyethylene bottle was filled for subsequent laboratory analyses of BOD_5, TSS, TDS, NO_2+NO_3, Cl^- and MBAS. The aliquot was preserved by placing the bottle on ice in a sample cooler immediately after sampling and until arrival at the laboratory for analysis. A 0.5-L polyethylene bottle containing sufficient sulfuric acid to adjust the sample to pH<2 was filled for TKN and P analyses and also placed on ice in the sample cooler. Two sterile plastic bags (118 mL, Nasco Whirl-pak) were filled for fecal coliform analyses and also preserved by cooling on ice. A 0.5-L glass beaker was also filled and temperature, pH and conductivity were measured on that portion in the field.

STE samples for virus analyses were also collected from the sampling basin. Fifteen to nineteen liters of STE were pumped into a stainless steel pressure vessel in the field. Sufficient $MgCl_2.6H_2O$ was added to the specimen to render it 0.05M and pH adjusted to 3.5 with hydrochloric acid. Using positive pressure, the specimen was forced through a mixed esters of cellulose membrane, 293 mm diameter and average pore size 0.45 um, that had been overlaid with 30 grams of diatomaceous earth. Once filtration was complete, adsorbed virus was eluted by passing 500 mL of 1% buffered beef extract, pH 9.4 - 9.6 through the membrane under moderate pressure. The eluant was saved and kept refrigerated (4°C) until delivered to the laboratory for concentration using the method of Katzenelson (1976).

Sub-Infiltration System Soil Monitoring

To investigate the treatment of STE in the unsaturated zone, soil sampling was performed directly below the infiltration system. Basically, this part of the study was designed to provide preliminary insight into the downward vertical migration of contaminants in unsaturated soils beneath operating OSDS in sandy soils in Florida. It was desired to determine if potential contaminants were migrating downward to 2 feet or more below the infiltrative surface.

At two separate locations within the OSDS infiltration area and at one control location, soil samples were collected at two depths (Figure 1). The sample depths included the wastewater infiltrative surface and at approximately 2 feet beneath it. Analyses were conducted for a suite of physical, chemical and biological parameters which would enable determination of the recent exposure of the soil to wastewater effluent as well as the total contaminant concentrations remaining.

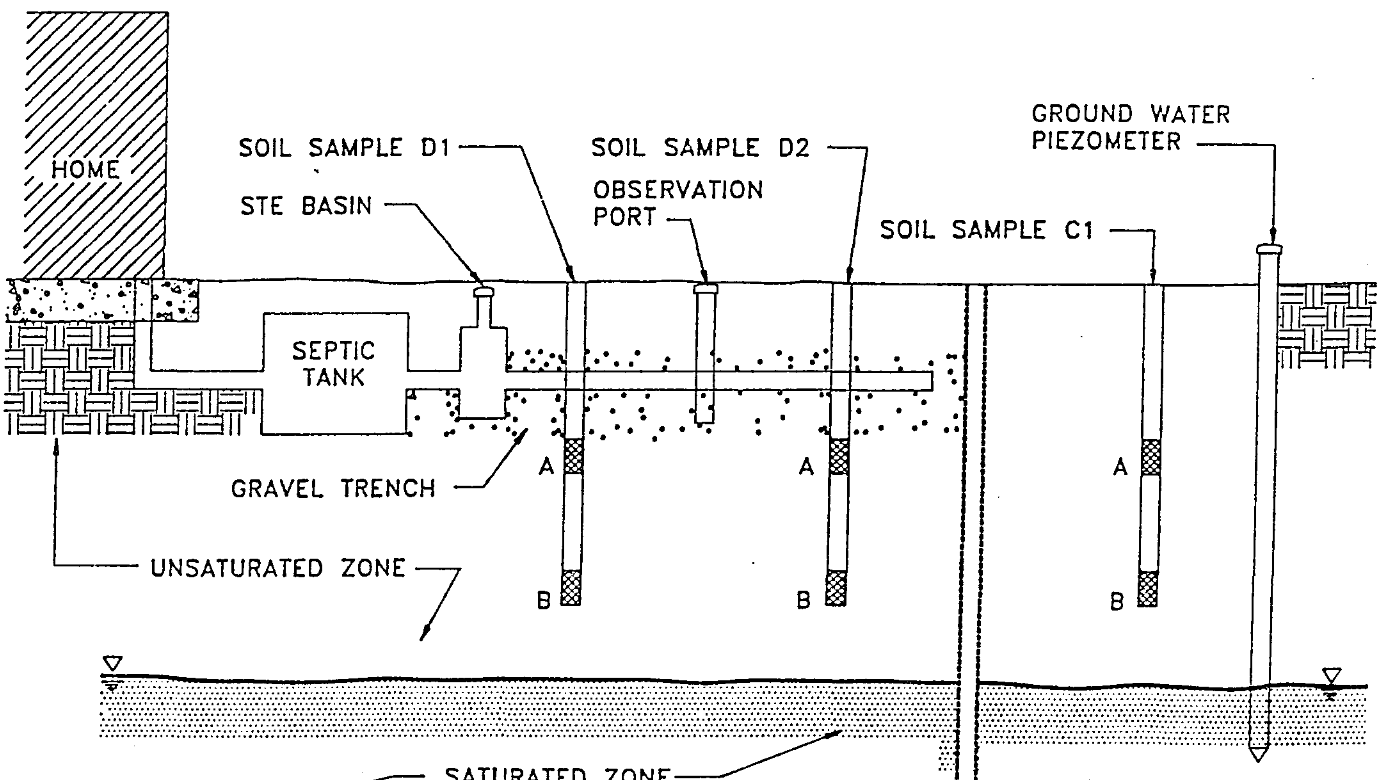

FIGURE 1. Profile schematic of sub-infiltration system sampling locations

The depth of 2 feet below the infiltrative surface was important as it was equal to the minimum depth to high ground water under which OSDS can be installed in Florida. If contaminants were detected at 2 feet, it could be interpreted to mean that the contaminants could have migrated into the ground water if it were present at the permitted 2 feet beneath the infiltrative surface.

Viral Monitoring of Stool Specimens

As part of the virus portion of the study, stool specimens were collected from the children in the study household and analyzed for enteric viruses. Collected feces were placed in a one (1) ounce screw capped bottle by a household member and held in the freezer portion of the household refrigerator. Subsequently the specimens were collected from the home owner on at least a monthly basis by a nurse epidemiologist and transported to the laboratory in a frozen state.

Viral Assays

Viral isolation attempts from sample concentrates were conducted by inoculation of BGM cell culture monolayers in 25 cm^2 flasks. The cultures were washed, inoculated, rocked for two hours at 36°C to enhance viral adsorption, washed again and overlaid with a liquid maintenance medium. Cultures were then incubated at 36° C and subjected to microscopic examination for fourteen (14) days post-inoculation. Cultures presenting a cytopathic effect were

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Human fecal and septic tank effluent isolates were serotyped using immune sera directed against human enteroviruses. Serum neutralization tests using pooled sera and at least thirty-two (32) tissue culture infective doses of the unknown virus were incubated, (37°C) for two (2) hours. The serum-virus mixtures were inoculated onto cell culture and observed for neutralization of the cytopathic effect of the virus. Each of the immune sera was common to one or more pools. Viral identity was then determined by the neutralization pattern. A more detailed description of viral analytical methods can be found in Standard Methods (APHA, 1985).

RESULTS

Septic Tank Effluent Quality

The results of septic tank effluent monitoring are listed in Tables 2 and 3. The conventional parameter results (Table 2) show typical values of septic tank effluent quality and compare well with literature values from other studies (SSWMP, 1978; Harkin et. a., 1979; Bowne, 1982; Brown et. al., 1977; Ayres Associates, 1989). Appreciable quantities of biodegradable organic material, solids, and nutrients were typically found in the septic tank effluent.

TABLE 2. Septic tank effluent quality summary, conventional parameters.

PARAMETER	UNITS	STATISTIC	VALUES
Temperature	°C	Mean	---
		Range	20.5 - 28.0
		Number of Samples	5
pH	Std. pH units	Mean	---
		Range	7.0 - 7.2
		Number of Samples	5
Conductivity	umho/cm.	Mean	712
		Range	640.0 - 880.0
		Number of Samples	5
Biochemical Oxygen Demand (BOD5)	mg/L	Mean	139
		Range	108.0 - 163.0
		Number of Samples	5
Total Dissolved Solids (TDS)	mg/L	Mean	415
		Range	330.0 - 498.0
		Number of Samples	5
Total Suspended Solids (TSS)	mg/L	Mean	93
		Range	74.0 - 122.0
		Number of Samples	5
Total Kjeldahl Nitrogen (TKN)	mg/L	Mean	36
		Range	16.0 - 53.0
		Number of Samples	5
Nitrate and Nitrite Nitrogen (NO2+NO3-N)	mg/L	Mean	0.06
		Range	0.01 - 0.17
		Number of Samples	5
Total Phosphorus (TP)	mg/L	Mean	15
		Range	12.0 - 17.0
		Number of Samples	5
Chloride (Cl)	mg/L	Mean	24
		Range	20.0 - 29.0
		Number of Samples	5
Fats, Oils, and Greases (FOG)	mg/L	Mean	25
		Range	15.0 - 36.0
		Number of Samples	4
Methylene Blue Active Substances (MBAS)	mg/L	Mean	5
		Range	3.0 - 8.2
		Number of Samples	4
Fecal Coliform Bacteria (FC)	Log #/100 ml	Mean	---
		Range	6.6 - 7.2
		Number of Samples	5

The volatile organic compound (VOC) analysis by EPA method 624 was capable of detecting over 30 different VOC's. The results of the STE monitoring at this home yielded detectable levels of toluene and 1,4 dichlorobenzene (Table 3). Toluene as detected in every STE sample at concentrations ranging from 25 to 34 ppb. Dichlorobenzene was detected in two of the four samples collected at concentrations of 21 and 33 ppb. Toluene was also found in STE from seven other homes in the Florida OSDS research project. These results were somewhat unexpected, but generally agreed with the limited data collected by other investigators (Greer and Boyle, 1988; Tomson et. al., 1984; and DeWalle et. al., 1985).

Sub-Infiltration System Soil Monitoring

As discussed in the Methods Section, soil samples were taken from two locations directly below the OSDS infiltration area and a control area unaffected by the OSDS (See Figure 1 schematic). A plan view of the OSDS at the study home is shown on Figure 2. The figure also shows the locations of the septic tank, STE sampling basin, infiltration trenches and soil sample locations.

TABLE 3. Septic tank effluent quality summary, volatile organic compounds.

COMPOUND DETECTED*	STATISTIC	VALUE
1,4 Dichlorobenzene	Mean	27 ug/L
	Range	21-33 ug/L
	Number**	2/4
Toluene	Mean	29 ug/L
	Range	25-34 ug/L
	Number	4/4

* Based on U.S. EPA Method 624 GC/MS scan.

** Positive samples/total samples.

A total of six soil samples were collected, representing two depths at each of three locations. Two sample locations (D1 and D2) were within the perimeter of the operating OSDS infiltration area. Background soil properties were assessed by sampling a control location approximately 210 feet away from the OSDS (C1).

Excavation and sampling in the background location (C1) revealed a zone of saturation at a depth of 4.6 feet below grade. Ground water was observed at the same elevation at piezometer AP2 nearby. (See Figure 2.) As a result of this shallow depth to ground water, only two samples were taken with depth at each location. The deepest samples taken were within the capillary fringe very near the saturated zone. The distance from the infiltrative surface to the saturated zone was approximately 2.5 feet (30 inches) at the time of sampling.

At the time of inspection, wastewater effluent was not present in the drainfield at either sampling location (D1 or D2). The

infiltrative surface zone was pale brown in color, and no signs of soil clogging were evident.
The soil textures observed were typically fine to very fine sand. Soil colors (moist Munsell color) were typically pale brown at a depth of 2.5 feet and light brownish gray at a depth of 4.5 feet below grade. Soil temperatures were in the range of 59° to 64°F.

The results of the soil analyses are presented in Figure 3. Concentrations of most parameters were highest in the soil samples closest to the septic tank outlet.

Soil moisture content in the samples near the infiltrative surface was significantly higher at D1 than D2, indicating that perhaps the majority of the effluent was infiltrating in the portion of the trenches closest to the septic tank. The shallow sample at D2 had a moisture content only slightly higher than the control, C1.

The significant increase in moisture content with depth is, of course, due to the proximity of the deeper samples to the saturated zone. As the results show,

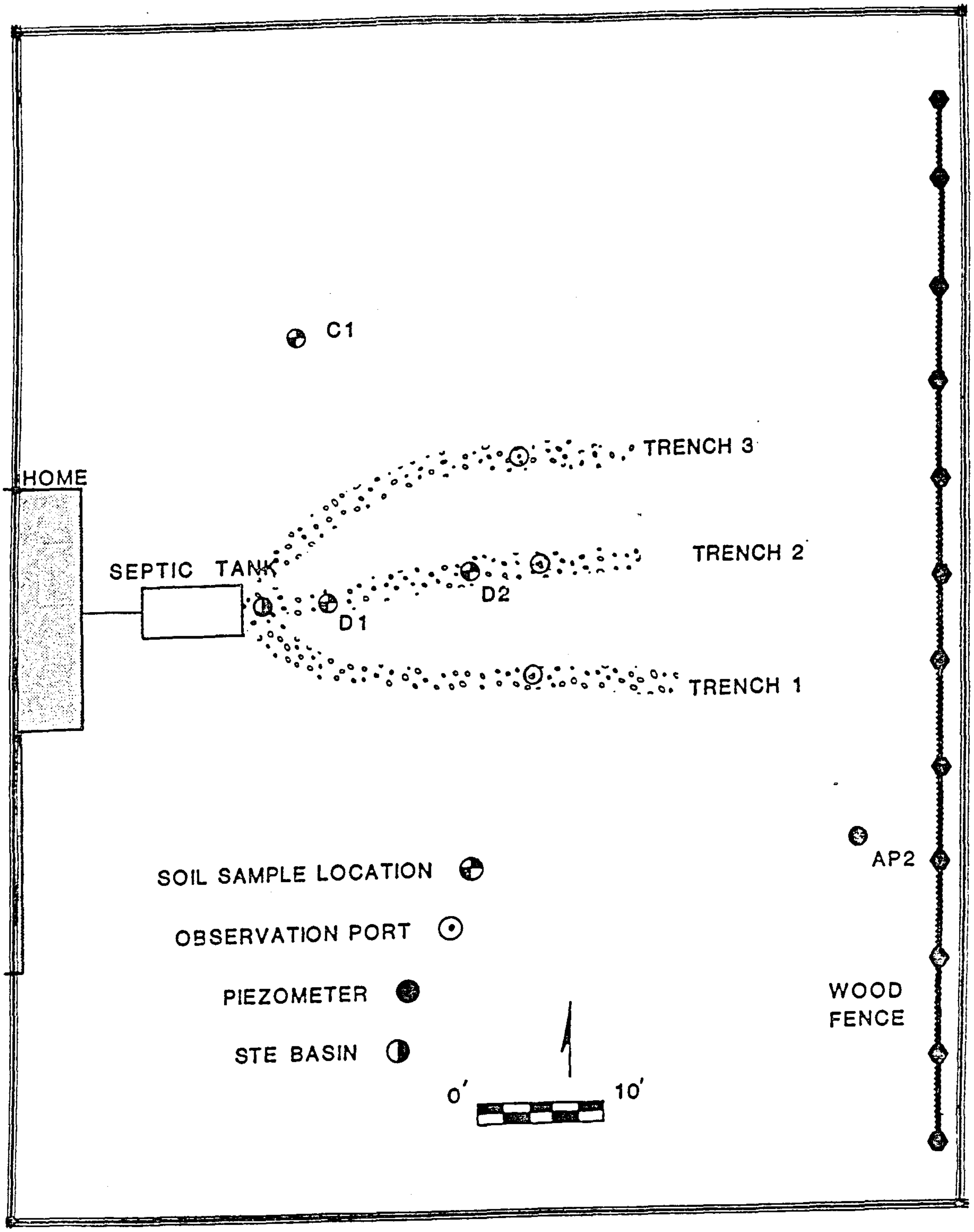
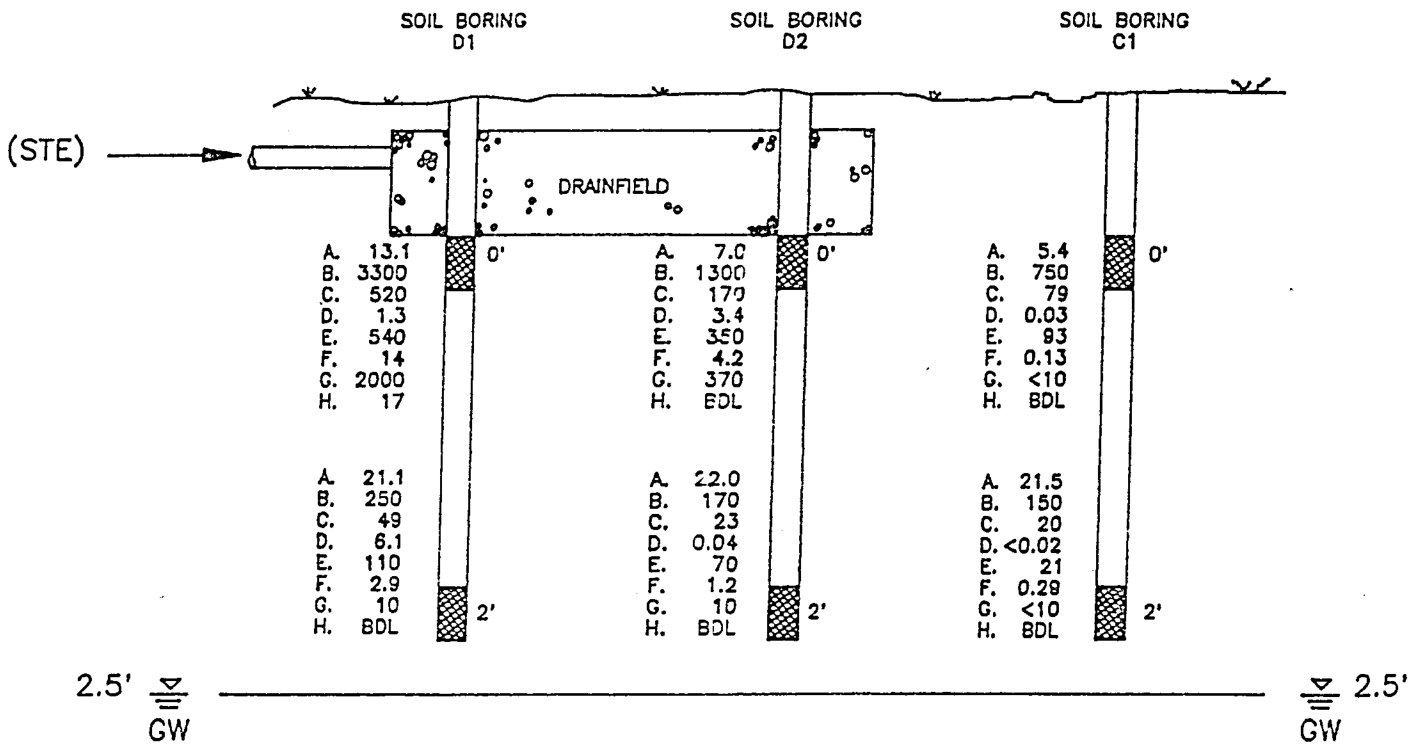


FIGURE 2. Plan view of OSDS and sampling locations at study home.

STE QUALITY

TOTAL ORGANIC CARBON (mg/L)	56
TOTAL KJELDAHL-N (mg/L)	36
TOTAL PHOSPHORUS (mg/L)	14.6
FECAL COLI BACT. (#/100 ml.)	10^6-10^7
VOLATILE ORGANICS (ug/L by EPA-624)	~56



NOTE : BDL = BELOW DETECTION LIMITS

SOIL ANALYSES

A. SOIL MOISTURE (%)
B. TOTAL ORGANIC CARBON (mg/kg SOIL)
C. TOTAL KJELDAHL-N (mg/kg SOIL)
D. NITRATE-N (mg/kg SOIL)
E. TOTAL PHOSPHORUS (mg/kg SOIL)
F. LEACHABLE ORTHO-P (mg/kg SOIL)
G. FECAL COLI BACT. (#/gm SOIL)
H. VOLATILE ORGANICS (ug/kg by EPA-624)

FIGURE 3. Profile schematic of soil sample locations and selected analytical results.

these samples were near or at saturation at all locations. This is significant because the samples were taken just over 2 feet below the infiltrative surface and approximately 2 feet of unsaturated soil existed at the time of sampling. One might suspect therefore, that certain STE contaminants present in the 2 foot samples at D1 could be transported to ground water at this OSDS site. Organic materials as measured by TOC, kjeldahl and nitrate nitrogen, phosphorous, and fecal coliform bacteria all occurred in the 2 foot samples at location D1 at levels considerably higher than the control, and may therefore be suspect for ground water contamination at this location.

Volatile organic compounds were found only in the shallow soil sample at location D1. Only 1,4 Dichlorobenzene was detected, at a concentration of 17 ug/kg soil. No VOC's were detected at two feet below the infiltration area.

Virus Monitoring Results

The viral monitoring phase of the study attempted to isolate and identify enteroviruses in stool samples from the home owners and correlate the results with enteroviruses identified in the septic tank effluent and soil samples below the infiltration area.

The results of the viral monitoring of fecal specimens and septic tank effluent are shown in Table 4. On several occasions over the study period, the same human enteroviral serotype found in fecal specimens from a resident child was also subsequently isolated from the household septic tank effluent. Coxsackievirus B5 was detected twice in stools of a child during December, 1988. The same enteroviral serotype was detected in the households septic tank effluent during November and December of 1988 and January of 1989.

TABLE 4. Virus monitoring results, fecal specimens and STE samples.

FECAL SPECIMENS			STE SAMPLES		
DATE	ENTEROVIRUS ISOLATIONS	RESIDENTS INITIALS	DATE	ENTEROVIRUS ISOLATIONS	MPN·IU / L
			8/24/88	Coxsackievirus B4	0.22
			9/14/88	Negative	--
			10/05/88	Negative	--
10/15/88	Negative	RF			
10/16/88	Negative	JF			
11/07/88	Negative	JF			
11/08/88	Negative	RF			
			11/16/88	Coxsackievirus B5	0.23
12/07/88	Coxsackievirus B5	RF			
12/09/88	Negative	JF			
			12/14/88	Coxsackievirus B5	>2.0
12/21/88	Poliovirus 1 and 3	JF			
12/21/88	Coxsackievirus B5	RF			
01/15/89	Poliovirus 3	JF			
01/16/89	Negative	RF			
			01/25/89	Coxsackievirus B5	0.15
02/09/89	Negative	JF			
			02/15/89	Negative	--
02/20/89	Negative	RF			

MPN·IU / L = Most probable number of infectious units per liter

These results confirm that human enteroviruses can indeed move through a septic tank and into the drainfield. In fact, similar findings were obtained with ECHO virus 14 and Poliovirus 1 at two other households being monitored as part of the Florida OSDS project. Also of interest in these results is the fact that Coxsackievirus B5 was isolated from septic tank effluent approximately 1 month after it was last isolated from a stool specimen. The virus was isolated from the stool sample of December 21, 1988 but the stool sample of January 16, 1989 was negative. Nevertheless, Coxsackievirus B5 was isolated from the STE sample taken on January 25, 1989.

These findings indicate a human enterovirus shed into an onsite wastewater system may remain viable for several weeks and exit the septic tank after detectable shedding by the household resident has ended.

Enterovirus analyses were also performed on the soil samples taken below the infiltration area. No enterovirus were isolated from any of the soil samples. However, these samples were taken at one point in time. The possibility of viable enterovirus availability cannot be assessed, since virus isolation attempts from either feces or effluents were not successful until several months later. Additional soil studies are envisioned immediately upon detection of enterovirus in the household septic tank effluent. This effort would be directed toward determining the fate of viable virus as it percolated downward through the unsaturated soil column.

SUMMARY AND CONCLUSIONS

This paper provides results of a study of septic tank effluent (STE) quality and its renovation in fine sandy soils below the infiltration area of an onsite sewage disposal system (OSDS) in Florida. Further sampling and analysis of OSDS systems in Florida are currently underway, therefore the results discussed here should be considered preliminary. Based on the results discussed herein, the following conclusions are offered.

- The septic tank effluent (STE) contained appreciable concentrations of organics, solids, nutrients, and bacteria. Additionally, trace levels (ppb) of several volatile organic compounds (VOC's) were measured. Toluene was found in four of four STE samples while 1,4 dichlorobenzene was found in two of four samples.

- Concentrations of various contaminants in soil samples collected beneath the OSDS infiltration area generally decreased considerably with depth. Several contaminants were suspected of being able to enter ground water if it were present at the two foot depth below the infiltration area, however. Fecal coliform bacteria were measured at the 2 foot depth, but in relatively low numbers. VOC's were not measured above detection limits in samples 2 feet below the infiltration system.

- Enterovirus isolations were identified in stool samples from children in the home. The same enterovirus was subsequently isolated from samples of septic tank effluent. No enterovirus was isolated from soil samples taken below the infiltration area. However, the soil samples were not taken during a time when enterovirus was known to be entering the wastewater system. Further work is planned in this area.

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