ONSITE TREATMENT AND DISPOSAL OF RESTAURANT WASTEWATER

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ONSITE TREATMENT AND DISPOSAL OF RESTAURANT WASTEWATER

by

Robert L. Siegrist, Damann L. Anderson, James C. Converse 1/

INTRODUCTION

In unsewered areas throughout Wisconsin and other states private facilities must be utilized for wastewater treatment and disposal. These facilities most commonly include a septic tank for pretreatment of the raw wastewater followed by a subsurface soil absorption system for final treatment and disposal of the effluent. Wastewater facilities such as these have been used not only for households, but also for a myriad of commercial establishments including restaurants, taverns, bowling alleys, motels, and service stations.

The design practice of household systems is often directly applied to commercial systems with little modification except for an adjustment of the design daily flow. Design and operation of commercial systems generally does not account for wastewater flow variations, organic loading, problem wastewater constituents or other factors commonly considered in engineering other non-soil absorption wastewater facilities.

In Wisconsin during the early 1980's, concern developed over the design and performance of private wastewater systems serving restaurant establishments. At least two large restaurant systems designed according to conventional practice (Wis. Adm. Code 1980) had failed hydraulically within months of their being put into operation. Their rapid failure could not be attributed to obvious design or construction deficiencies. As other similar malfunctions occurred, the need for a careful investigation became evident.

The overall objective of this work was to investigate the design and performance of septic tank-soil absorption systems for restaurant wastewaters. The specific objectives were to:

- Identify the current design practice utilized for restaurant systems,
- Characterize restaurant septic tank effluent in terms of daily flow and composition,
- Determine the operation status and infiltration capacity of a sample of restaurant soil absorption systems,

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PRELIMINARY FIELD SURVEY

MATERIALS AND METHODS

A preliminary field survey of restaurant systems was conducted during the summer of 1982 by representatives of the Wisconsin Department of Industry, Labor and Human Relations (DILHR). A total of 42 restaurants were visited and inspections were made to assess in general the operation status of the systems. The soil surface in the vicinity of the wastewater absorption system was inspected to identify any sogginess or seepage. The observation vents typically installed into the system's gravel bed were inspected to determine the occurrence and magnitude of any effluent ponding.

A summary of the systems inspected by location and system type is shown in Figure 1. Of the 42 systems inspected, 10 were conventional subsurface systems and 32 were alternative systems, either subsurface systems utilizing pressure distribution or mound systems (Wis. Adm. Code, 1980).

RESULTS AND DISCUSSION

Of the 42 systems inspected, 14 exhibited significant effluent ponding in the absorption system. Of these 14, 3 were conventional and 11 were alternative systems. Approximately 30 percent of the conventional systems inspected were ponded compared to 34 percent of the alternative systems.

The results of the survey for District 7 (Figure 1) were of special interest since major problems with restaurant wastewater systems in that area had been reported previously. Eleven systems, all of alternative design, were inspected. At the time of the inspection, all systems had been in operation for less than eighteen months. Significant effluent ponding was noted in the absorption beds of seven of the eleven systems, with two of the seven classified as hydraulically failing due to surfacing effluent. For the two failing systems, ponding reportedly occurred shortly after the systems were put into operation with surfacing effluent occurring less than a year later.

It is difficult to interpret these survey results and draw any conclusions regarding the performance of restaurant wastewater systems as compared to household systems. Continuous ponding of wastewater within household soil absorption systems commonly develops after one year of operation and has traditionally not been considered to be a malfunctioning condition (Bouma, 1972; Hargett, et al., 1982). Of the 42 systems inspected in this survey, only 33 percent were ponded. This might be interpreted to indicate good performance at least as far as infiltration capacity is concerned. Further, approximately the same percentage of conventional and alternative type restaurant systems were found to be ponded suggesting little difference in the infiltration performance between the two types. However, interpretations such as these would be ill-founded due to the small sample size as well as the lack of data regarding important factors affecting operation including system age, actual operating flow, and wastewater composition. To provide these important data and facilitate evaluation of restaurant system performance, a detailed investigation of a selected number of systems was undertaken.

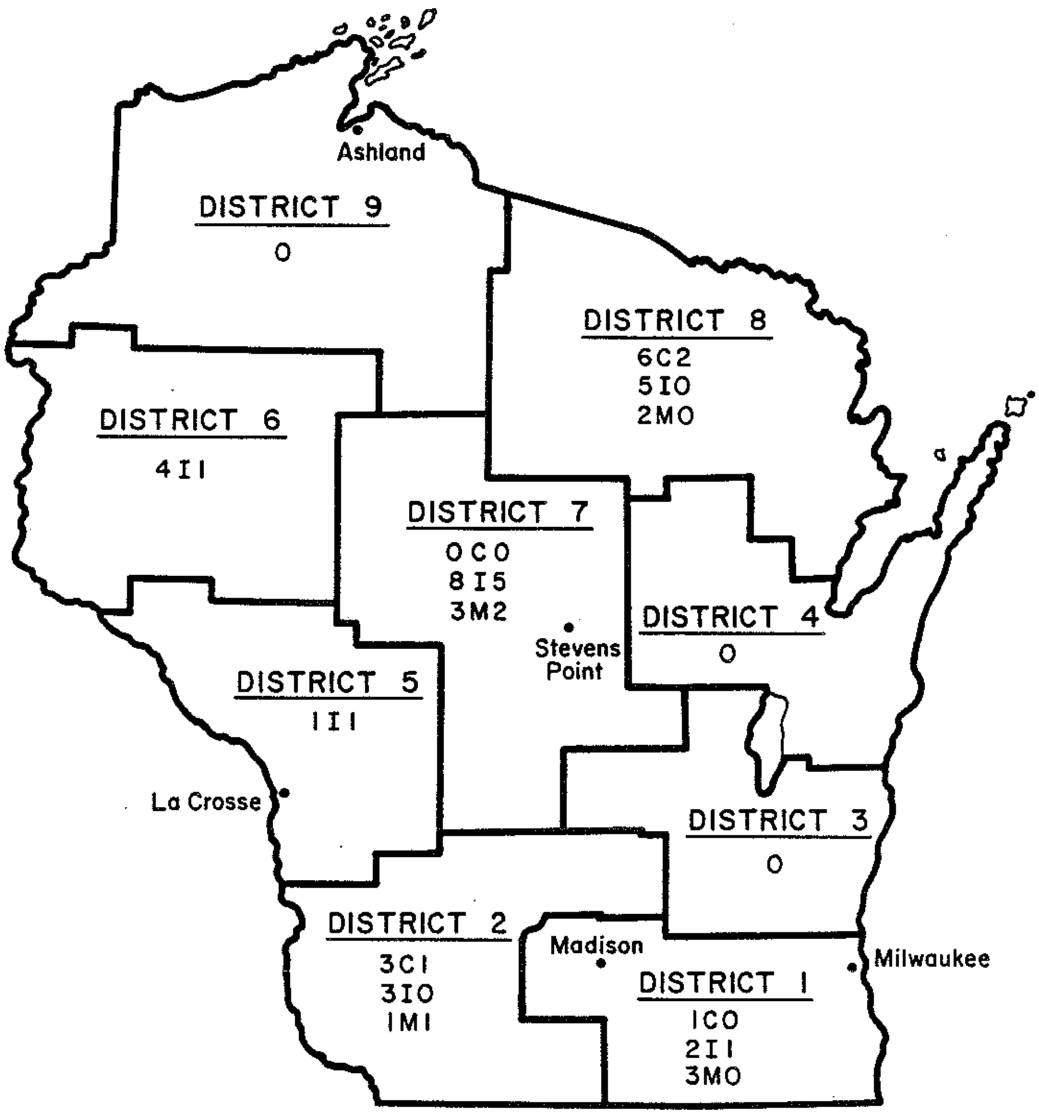


Figure 1. Summary of Restaurant Systems Surveyed

(C = Conventional, I = Inground Pressure, M = Mound, 3C1 Means 3 Conventional Systems Surveyed, 1 of 3 ponded)

FIELD INVESTIGATION

A more detailed field investigation of restaurant wastewater systems was carried out between March and September, 1983 by staff of the Small Scale Waste Management Project (SSWMP) of the University of Wisconsin-Madison. The objectives of this phase of the study were to characterize the daily flow and composition of restaurant STE and to determine the operation status and infiltration capacity of restaurant soil absorption systems.

MATERIALS AND METHODS

Restaurant Characteristics

Based on the results of the preliminary field survey, 12 restaurants were selected for further investigation. The characteristics of the restaurant establishments are summarized in Table 1 and their respective locations are shown in Figure 2. The establishments studied were characterized generally and included one bar and grill, six restaurants, two large restaurant/lounge/motel complexes, and three restaurant/golf clubs (Table 1). All but one of the restaurants served full-course dinners. Many also served lunches, but few served breakfasts. Several restaurants offered banquet seating and were used for business meetings, parties and weddings.

Restaurant seating capacity varied from 40 to 240 while associated bar/lounge seating capacity ranged from 0 to 150 seats. Two large establishments included motels with 100 and 120 rooms each, substantial banquet seating, and swimming pools. Three restaurants were associated with golf country clubs where locker rooms and shower facilities were used seasonally.

Restaurant Wastewater Facilities

The characteristics of the restaurant wastewater facilities are summarized in Tables 2 and 3. The restaurant facilities were designed to handle design daily wastewater flows of 1890 to 25000 gpd. The systems included one or more septic tanks for pretreatment of the raw wastewater. Many of the restaurants (8 of 12) also had a grease interceptor through which certain kitchen waste streams passed prior to entry to the septic tanks. All except restaurant No. 5 employed a pumping system to deliver septic tank effluent (STE) to the soil absorption system. The STE was distributed within each of the five conventional soil absorption systems with a distribution box whereas within the alternative systems (inground pressure and mounds), pressurized distribution networks were utilized. Ten of the soil absorption systems were of bed geometry, ranging in size from 1600 ft^2 to 21000 ft^2. All but one of the restaurant systems were installed in soils of sand texture with reported percolation rates of less than 10 minutes per inch (MPI) (Figure 2). Restaurant No. 5 was located in less permeable soils, with a reported percolation rate of 20 to 30 MPI. This latter restaurant was utilized as the wastewater source for the laboratory study described in the following section.

Table 1. Characteristics of the Restaurant Establishments *

Site No.	Type	Meals**	Service+	Rest. Seats	Bar Seats	Motel Units	Employees	Other
1	Supper Club	FC	D	70	22	0	5	-
2	Supper Club	FC	D	68	32	0	12	3 Apt. (5 br)
3	Supper Club	FC	L,D,S	125	62	0	13	-
4	Restaurant/Bar/ Motel	FC	B,L,D,S	160	150	120	70	Banquets, Pool
5	Supper Club	FC	D,S	210	22	0	30	Dances
6	Restaurant/Bar/ Motel	FC	B,L,D,S	240	100	100	40	500 Banquet Seating, Pool, Showers
7	Supper Club	FC	D	80	30	0	10	-
8	Restaurant/ Golf Club	FC	L,D,S	70	96	0	16	Locker Room, Showers
9	Supper Club	FC	B,L,D,S	160	35	0	6	300 Banquet Seating, Dances
10	Restaurant/ Golf Club	FC	L,D,S	108	65	0	12	Locker Room, Showers
11	Restaurant/ Golf Club	FC	L,D,S	100	20	0	9	Locker Room Showers
12	Bar/Grill	S	L,D	40	34	0	4	2 BR Home

* Refer to Table 2 and 3 for the characteristics of the restaurant wastewater facilities.

** FC = Full Course, S = Sandwiches

+ B = Breakfast, L = Lunch, D = Dinner, S = Special Events (Meetings, Parties,...).

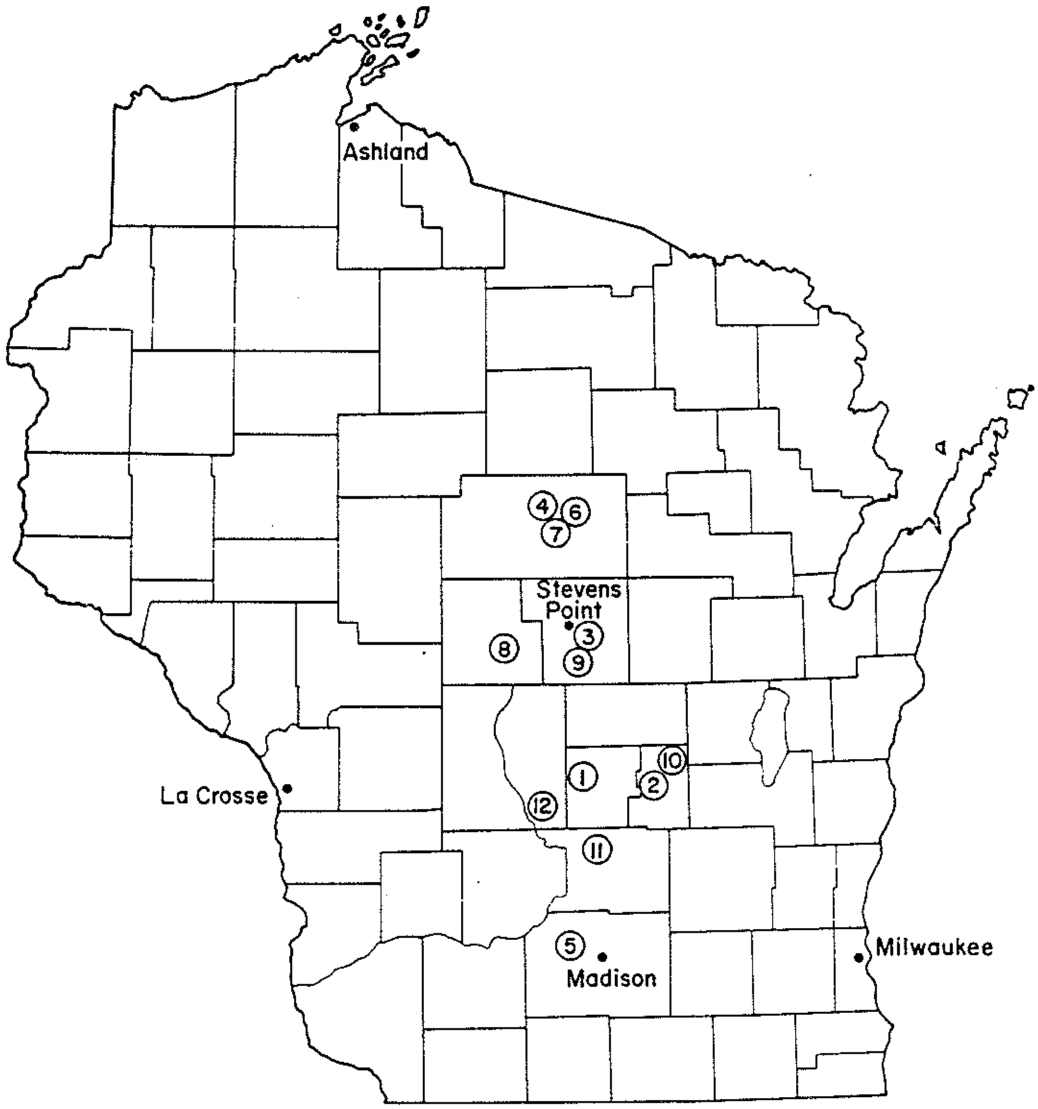


Figure 2. Location of 12 Restaurant Systems Monitored in the Field Investigation

Table 2. Restaurant Wastewater Pretreatment Facilities *

Site No.	Design Flow (gpd)	Grease Trap	Septic Tanks+ (gal) 1st	2nd	3rd	4th	Pump Chamber (gal)	Installation Date
1	3400	None	1900	1000	580	-	300	1980
2	4520	None	1300	1000	1000	1000	1000	1979
3	4940	Inhouse	6750	-	-	-	6750	Fall, 1982
4	-	Yes	14315	25750	-	-	-†	1975
5	-	Inhouse	1000	1570	1570	-	-	1974
6	25000	1000 gal	20000Φ	20000Φ	50000Φ	-	6000	Oct, 1980
7	3110	1000 gal	2500	2500	-	-	1000	May, 1983
8	4500	None	4500	-	-	-	1200	Fall, 1980
9	3160	800 gal	1000	1000	1000	1000	4600	Spring, 1981
10	5260	Inhouse	4000	1500	-	-	2500	Dec., 1981
11	4000	500 gal	500**	500**	2000**	2000**	1000	Fall, 1979
12	1890	None	1500	1250	-	-	2500	Fall, 1981

* Based upon data from as-built plans and field inspection. Refer to Tables 1 and 3 for additional facility characteristics.

+ Septic tanks installed in series as shown unless otherwise noted.

† Septic tank 2 plus pump chamber = 25750 gal. Pump chamber size unknown.

Φ 2, 20000 gal septic tanks in parallel serving restaurant/bar. 50000 gal septic tank serving motel.

**Two 500 gal septic tanks in series serve locker rooms; two 2000 gal septic tanks receive effluent from the two 500 gal tanks plus kitchen wastewater from grease trap.

Table 3. Restaurant Soil Absorption System Characteristics +

Site No.	Design Flow (gpd)	Site: Slope (%)	Site: Soil Texture	Site: Perc. (MPI)	Site: GW* (in)	System: Type#	System: Geometry	System: No.	System: W (ft)	System: L (ft)	System: D (ft)	Area† (ft^2)
1	3400	0-1	lfs	-	>72	Conv	Trench	13	5	100	2.5	6500
2	4520	4-6	sl	2-5	>78	Conv	Bed	1	65	145	≥ 3.0	9425
3	4940	1	ls	8	>60	Conv	Bed	1	100	156	2.4-3.0	15600
4	-	0-1	ls	<10	-	Conv	Bed	1	76	270	-	20500
5	-	-	-	20-30	-	Conv	Bed	1	-	-	-	13500
6	25000	0-1	ls	<1	>75	IGP	Bed	2	100	105	-	21000
7	3110	0-1	sl	9	>72	IGP	Bed	1	48	56	≥2.5	2680
8	4500	2-5	s	-	>75	IGP	Bed	1	35	100	2.4	3500
9	3160	0-1	s	<2	>72	IGP	Bed	1	36	100	3.0	3600
10	5260	5	ls	1-3	-	IGP	Trench	7	5	120	2.2(1.7)Ψ	4200
11	4000	0-1	s	2-7	>96	IGP	Bed	1	42	82	2.0	3000
12	1890	1-2	s	-	36	M	Bed	1	16	100	M#	1600

+ Based upon data from soil test reports and as-built plans. Refer to Table 1 and 2 for additional facility characteristics.

* Depth below ground surface to groundwater.

Conv = Conventional, IGP = Subsurface system utilizing pressure distribution of STE; M = Mound.

† Horizontal soil infiltrative surface area.

Ψ Depth below final ground surface after adding cover over system (depth below original ground surface).

Monitoring

Monitoring of each wastewater facility included a variety of activities. Water use was monitored at each of nine sites utilizing a water meter installed on the water supply line serving the establishment. Since there was little or no exterior use, water use data were utilized to estimate the wastewater flows. Water meter readings were taken approximately monthly by project staff and utilized to compute the average daily wastewater flow.

At each of six sites, the frequency of wastewater application to the soil absorption system was monitored. Electrical event counters were installed in the electrical circuitry of the pumping systems serving each soil absorption system. Each time a dosing event occurred, it was recorded by the counter. Counter readings were taken approximately monthly and utilized to determine the average number of doses per day and the average volume of wastewater per dose.

Qualitative characterization of the septic tank effluent at each facility was accomplished using grab samples collected from the pump chamber, except at Restaurant No. 5 where samples were obtained at the outlet end of the last septic tank. Samples were collected using a specially constructed apparatus consisting of a 4-liter, wide-mouth polyethylene bottle mounted onto a portable aluminum frame (Figure 3). The bottle was capped with a rubber-gasketed lid which could be remotely opened and closed by pulling or releasing a wire attached to it. The sample bottle was submerged so that the lid was approximately two feet below the liquid surface and then the lid was raised and a 4-liter sample was collected. The bottle lid was closed prior to removing the bottle from the liquid. Sampling in this manner excluded any scum or floating debris from the sample collected.

The contents of the 4-liter sample bottle were divided among three smaller sample bottles: a 1-liter glass jar with a teflon-lined cap for subsequent analysis for oils and grease; a 1-liter polyethylene bottle for subsequent physical and chemical analyses; and a 1-liter glass jar for subsequent microbiological analyses. The remaining sample volume was utilized for onsite determination of pH and temperature. The three sample containers were stored on ice during transport back to Madison, Wisconsin where analyses were performed according to Standard Methods (1980) for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total organic carbon (TOC), total kjeldahl nitrogen (TKN), total phosphorus (TP), solids, oil and grease (OG), and total and fecal coliform bacteria.

The characterization of the soil absorption system operation and performance addressed only infiltration capacity. Due to time and budget limitations, purification capacity could not be investigated, although it is recognized to be of equal importance. A general inspection of the wastewater facility at each establishment was made by project staff during each monthly site visit. At each facility the pump chamber was opened and the contents were observed. Floating scum and solids were noted as was the general condition of the chamber. The land surface over and around the subsurface soil absorption system was inspected for sogginess, wet areas, odor, and so forth. The 4-inch diameter observation vents which extended through the gravel-filled bed to the soil infiltrative surface, were inspected and the occurrence and magnitude of any wastewater ponding was noted. The owner or operator of each establishment was consulted regarding system operation and maintenance since the last site visit.

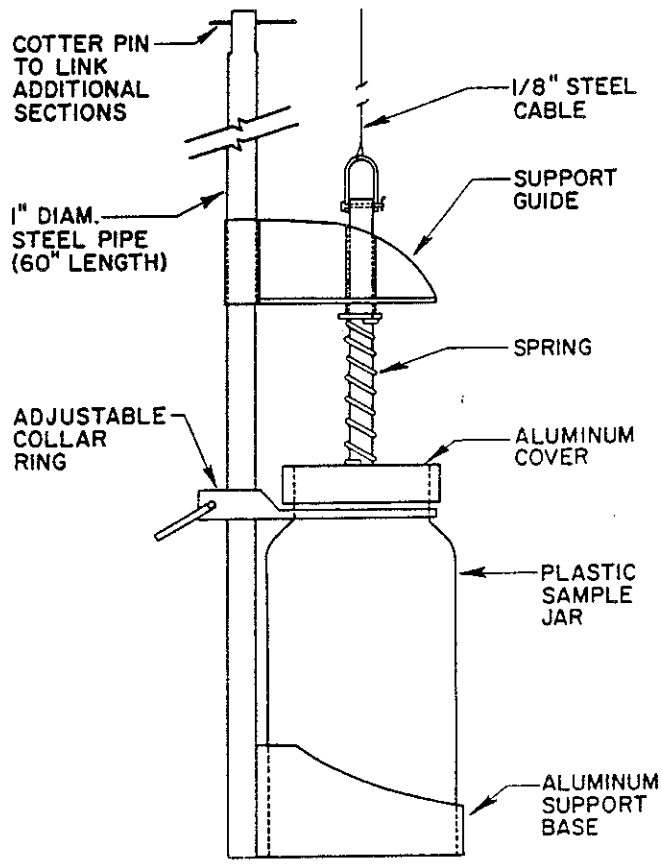


Figure 3. Septic Tank Effluent Sampling Apparatus

RESULTS AND DISCUSSION

Wastewater Flow

The results of flow monitoring at nine of the restaurant facilities are summarized in Table 4. The average daily wastewater flow at six of the nine facilities was measured to be less than 50 percent of the design flow. These results confirmed the conservative nature of design flows as predicted according to current practice (Wisc. Adm. Code, 1980). Previous investigators have reported similar findings for other Wisconsin homes and establishments (Siegrist et al., 1976; Otis, 1978, Harkin et al., 1979).

The average daily flow per restaurant seat for five establishments ranged from 7.5 to 13.1 gpd/seat (Table 4). These flows are substantially lower than the current design flow requirements of 30 gpd/seat (Wisc. Admn. Code, 1980).

Table 4. Restaurant Wastewater Flow Characteristics

Site No.+	Design Flow (gpd)	Average Daily Flow (gpd)		(gpd/seat*)	Data Period (Days)	From	To
1	3400	528	(16)#	7.5	169	July 21, 1983	January 6, 1984
3	4940	1642	(33)	13.1	67	July 21, 1983	September 26, 1983
4	-	14120	(-)	-	393	March, 1982	June 14, 1983
6	25000	13950	(76)	-	365	May, 1982	May, 1983
7	3110	780	(25)	9.8	230	May 25, 1983	January 10, 1984
9	3160	1564	(49)	9.8	168	July 21, 1983	January 6, 1984
10	5260	3750	(71)	-	202	March 3, 1983	September 26, 1983
11	4000	836	(21)	-	89	July 28, 1983	October 25, 1983
12	1890	445	(24)	11.1	110	August 10, 1983	November 28, 1983

+ Refer to Table 1 for Restaurant Characteristics.

* Based upon Restaurant Seating Only. "-" Indicates Measured Flow Included Non-Restaurant Contributions.

Approximate Percent of Design Flow.

Wastewater Pretreatment

The raw wastewater generated at each restaurant establishment was treated, often in a grease interceptor, but always in one or more septic tanks prior to discharge to a soil absorption system. Characterization of the raw wastewater was not accomplished as part of this investigation. The results of previous studies have demonstrated that raw restaurant wastewater contains substantially higher levels of organic matter, solids and grease compared to household wastewater (SSWMP, 1978). This suggests the possibility that sludge and scum accumulation in restaurant septic tanks may be accelerated over that of household units. This may necessitate septic tank servicing more frequently than every three years as typically recommended for household systems. It may be prudent to remove the sludge and scum in restaurant septic tanks quarterly during the initial period of operation. After the rate of accumulation is known, the pumping schedule could be adjusted as appropriate.

The compositions of the final septic tank effluents at each establishment are delineated in Tables 5 to 7. The measured compositions of organic materials, nutrients, and physical parameters varied between the different restaurant establishments. However, temporal variations in measured parameters at a given site were relatively small as evidenced by coefficients of variation which were typically less than 0.40 (Table 5-6).

Table 5. Composition of Restaurant Septic Tank Effluent - Organics and Nutrients*

Site No.	Statistic	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	TKN (mgN/L)	TP (mgP/L)
1	X (n)	582(7)	1196(7)	401(7)	82(7)	24(3)
	S.D.	134	244	59	11	6
	Range	392-705	870-1445	365-512	62-92	19-30
2	X	245(4)	622(4)	208(4)	64(4)	14(2)
	S.D.	93	78	60	9	-
	Range	109-316	559-723	129-257	52-74	9-18
3	X	880(7)	1667(7)	530(7)	71(7)	23(3)
	S.D.	160	465	56	9	11
	Range	670-1058	963-2414	453-616	62-86	11-33
4	X (n)	171(7)	381(7)	140(7)	34(7)	20(3)
	S.D.	46	69	32	3	-
	Range	109-247	280-468	111-195	29-37	19-21
5	X (n)	377(9)	772(9)	270(6)	30(7)	15(2)
	S.D.	121	225	64	12	-
	Range	155-532	444-1070	170-350	14-48	11-18
7	X (n)	693(3)	1321(4)	470(4)	78(4)	28(2)
	S.D.	93	34	34	3	
	Range	595-781	1286-1360	430-511	74-80	27-29
8	X (n)	193(3)	416(3)	116(3)	36(3)	13(2)
	S.D.	54	189	50	10	4
	Range	156-259	270-630	75-172	25-44	10-15
9	X (n)	261(7)	586(7)	220(6)	73(7)	19(3)
	S.D.	64	127	63	9	2
	Range	187-351	440-770	144-300	63-89	17-20
10	X (n)	333(6)	620(6)	231(6)	63(6)	17(2)
	S.D.	64	59	105	13	-
	Range	251-409	542-711	153-440	48-83	11-23
11	X (n)	101(4)	227(4)	93(4)	36(4)	10(2)
	S.D.	49	138	87	28	-
	Range	61-171	95-365	20-211	11-60	4-16
12	X (n)	179(5)	449(5)	152(5)	61(5)	7(2)
	S.D.	48	29	47	11	-
	Range	104-218	424-495	110-230	46-76	4-10
All Sites+	X	365	751	257	57	17
	S.D.	248	451	147	19	6
	Range	101-880	227-1667	93-530	30-82	7-28

* Based upon grab samples.
\+ Statistics based upon individual site averages.

Table 6. Composition of Restaurant Septic Tank Effluent - Physical*

Site No.	Statistic	pH	Temp. °C	TS mg/L	TVS mg/L	TSS mg/L	VSS mg/L	Oil/Grease mg/L
1	X (n)	-(7)	-(7)	1001(5)	507(5)	187(7)	170(7)	101(6)
	S.D.	-	-	101	55	39	36	25
	Range	5.6-6.4	8-22	836-1088	447-589	146-268	132-244	66-132
2	X (n)	-(4)	-(4)	1438(4)	374(4)	65(4)	53(4)	40(4)
	S.D.	-	-	470	71	22	23	7
	Range	6.6-7.0	8-22	935-2018	320-477	41-92	25-80	34-49
3	X (n)	-(7)	-(7)	2130(5)	784(6)	372(6)	324(6)	144(7)
	S.D.	-	-	249	114	119	99	56
	Range	5.8-6.3	13-23	1857-2450	648-962	248-582	224-480	89-256
4	X (n)	-(7)	-(7)	596(5)	219(5)	66(7)	60(7)	45(7)
	S.D.	-	-	71	37	13	12	17
	Range	6.5-7.1	20-28	512-690	188-283	48-84	46-84	21-74
5	X (n)	-(7)	-(2)	-	-	247(8)	173(8)	101(4)
	S.D.	-	-	-	-	120	67	29
	Range	5.7-6.8	16-21	-	-	115-439	99-273	71-140
6	X (n)	-	-	-	-	108(1)	88(1)	66(1)
7	X (n)	-(6)	-(6)	1771(2)	854(2)	125(4)	105(4)	65(4)
	S.D.	-	-	-	-	53	32	23
	Range	5.5-6.9	4-25.5	1829-1913	822-886	81-192	71-134	40-94
8	X (n)	-( )	-(3)	558(3)	233(3)	56(3)	43(3)	24(3)
	S.D.	-	-	170	54	16	17	10
	Range	6.5-6.8	6-20	387-728	183-291	38-66	26-59	15-34
9	X (n)	-(7)	-(7)	844(5)	348(5)	66(7)	60(7)	47(7)
	S.D.	-	-	116	119	34	36	18
	Range	5.8-7.0	7-25	707-1002	269-552	28-126	16-118	26-72
10	X (n)	-(6)	-(6)	1505(4)	438(4)	121(6)	106(6)	46(6)
	S.D.	-	-	387	99	34	40	16
	Range	6.2-6.8	13-26	1160-1898	366-584	72-176	50-170	24-73
11	X (n)	-(4)	-(3)	617(3)	211(3)	44(4)	38(4)	33(4)
	S.D.	-	-	261	110	35	30	32
	Range	6.2-7.4	10-23	422-914	137-337	9-78	9-69	11-81
12	X (n)	-(5)	-(5)	515(4)	257(4)	79(5)	67(5)	49(5)
	S.D.	-	-	63	31	36	30	28
	Range	6.0-7.0	8-22	467-607	225-300	42-132	38-100	2.9-96
All Sites+	X (n)	-	-	1097	422	130	109	63
	S.D.	-	-	576	231	102	85	37
	Range	5.5-7.4	4-28	515-2130	211-854	44-372	38-324	24-144

* Based upon grab samples.

+ Statistics based upon individual site averages excluding Site 6.

Table 7. Composition of Restaurant Septic Tank Effluent - Total and Fecal Coliform Bacteria, Organisms/100 mL

Site No.	Total Coliforms 1*	Total Coliforms 2	Fecal Coliforms 1	Fecal Coliforms 2
1	2.9×10^7	2.7×10^7	1.9×10^7	2.3×10^7
2	1.1×10^9	5.8×10^8	5.4×10^6	1.2×10^7
3	4.1×10^6	3.8×10^6	1.1×10^6	2.3×10^6
4	8.0×10^6	1.3×10^7	5.2×10^6	6.0×10^6
7	3.2×10^6	1.8×10^6	1.8×10^6	1.8×10^6
8	-+	6.5×10^8	-	2.8×10^5
9	6.9×10^6	3.0×10^6	1.5×10^6	3.0×10^6
10	1.2×10^7	4.2×10^6	1.4×10^6	1.6×10^6
12	5.2×10^7	2.4×10^7	1.0×10^6	6.5×10^5

* Sample Number: Sample 1 Collected March 7 or 8, 1983. Sample 2 Collected April 13 or 14, 1983.
+ Indicates no analyses performed.

Inspection of the STE characteristics at the 12 establishments suggested that differences in effluent quality may have been associated with the type of restaurant establishment (Table 1). As shown in Table 8, the STE concentrations measured at the six restaurants (Sites 1, 2, 3, 5, 7, 9) were generally substantially higher than those measured at the other six establishments. In particular the organics and solids concentrations measured at four supper club establishments (sites 1, 3, 5, 7) were extremely high (Table 8). The non-restaurant functions at the other establishments most likely contributed substantial quantities of wastewater containing lower contaminant concentrations.

Table 8. Average Concentration of Selected Constituents in Restaurant Septic Tank Effluent *

Type**	Site No.	BOD_5 (mg/L)	COD (mg/L)	TKN (mg-N/L)	TP (mgP/L)	TSS (mg/L)	TVSS (mg/L)	Oil/ Grease (mg/L)	Temp. (°C)
Restaurant	1	582	1196	82	24	187	170	101	8-22
	2	245	622	64	14	65	53	40	8-22
	3	880	1667	71	23	372	324	144	13-23
	5	377	772	30	15	247	173	101	16-21
	7	693	1321	78	28	125	105	65	4-26
	9	261	586	73	19	66	60	47	7-25
Restaurant/ Motel	4	171	381	34	20	66	60	45	20-28
Restaurant/ Golf Club	8	197	416	36	13	56	43	24	6-20
	10	333	620	63	17	121	106	46	13-26
	11	101	227	36	10	44	38	33	10-23
Bar/Grill	12	179	449	61	7	79	67	49	8-22
Average	-	365	751	57	17	130	109	63	-
Minimum	-	101	227	30	7	44	38	24	4
Maximum	-	880	1667	82	28	372	324	144	28

* Based upon grab sampling between March and September, 1983. (See Tables 5-6).
** Refer to Tables 1 - 3 for additional site characteristics.

The characteristics of the pretreatment facilities utilized at each establishment are summarized in Table 9. In some establishments, kitchen wastes were passed through grease interceptors prior to discharge into the building sewer leading to the septic tanks. Small inhouse interceptors as well as large exterior units were utilized. The size, number and configuration of septic tank facilities varied between establishments. Anywhere from one to four tanks in series were utilized.

Table 9. Pretreatment System Characteristics Versus Effluent Quality

Type	Site No.+	Pretreatment System: Grease Trap	Septic Tanks in Series	θ_T * (days)	STE†: BOD_5 (mg/L)	TSS (mg/L)	Oil/Grease (mg/L)
Restaurant	1	None	3	6.4	582	187	101
	2	None	4	–	245	65	40
	3	Inhouse	1	4.1	880	372	144
	5	Inhouse	3	–	377	247	101
	7	1000 gal	2	7.7	693	125	65
	9	800 gal	4	3.1	261	66	47
Restaurant/ Motel	4	Yes	2	2.8	171	66	45
	6	1000 gal	1	4.7/4.9#	–	–	–
Restaurant/ Golf Club	8	None	1	–	197	56	24
	10	Inhouse	2	1.5	333	121	46
	11	500 gal	2	6.6	101	44	33
Bar Grill	12	None	2	6.2	179	79	49

\+ Refer to Tables 1 - 3 for establishment characteristics.
* Approximate average hydraulic detention time (θ_T) estimated from the average daily flow and the total grease trap and septic tank capacity.
† Average effluent quality based upon data shown in Tables 5 and 6.
\# Restaurant septic tanks followed by lodge septic tanks.

The hydraulic detention time of the pretreatment facilities at a given establishment was estimated based upon the liquid capacity of the septic tank(s) and grease interceptor (if any) and the average daily flow. As shown in Table 9, the average θ_T calculated for nine of the systems varied from 1.5 to 7.7 days. For seven of the nine systems, the average θ_T was greater than 3.0 days. The average θ_T values measured were all greater than that typically recommended for design (Wisc. Adm. Code, 1980; U.S. EPA, 1980).

It is difficult to correlate septic tank effluent quality with pretreatment system characteristics for many reasons. The characteristics of the pretreatment system are known only approximately. Further, the operation and maintenance practices associated with the grease interceptors and septic tanks are unknown. Finally, the composition of the raw wastewaters are unknown. Recognizing these limitations, a cursory review was made of the STE composition data versus the number of septic tanks in series. For the supper club establishments the data suggest that three or more tanks in series produced an effluent with lower BOD_5 and TSS concentrations (Table 9).

The average composition of restaurant STE is compared to that of domestic STE in Table 10. The concentrations of organic materials and solids in STE at six restaurants, particularly supper clubs, were found to be substantially higher than that in domestic STE while other parameters were similar. Biodegradable organic matter content as measured by BOD_5, was approximately 380 percent higher in restaurant STE as compared to domestic STE (Table 10). Total organic content as measured by COD, was approximately 230 percent higher. The discrepancy between these two ratios suggests a higher percentage of biodegradable organic material in restaurant STE. This seems logical since there is likely a substantial contribution of biodegradable organics from kitchen activities and a lack of potentially more resistant organics from bathing and laundry activities.

Table 10. Comparison of Restaurant STE Versus Domestic STE

Parameter	Unit	Restaurant STE *		Household STE	Community STE#
		Restaurant Only	Restaurant With Other Facilities		
BOD_5	mg/L	506 (3.83)+	196 (1.48)	132	118-189
COD	mg/L	1027 (2.31)	419 (0.94)	445	228-284
TSS	mg/L	177 (2.03)	73 (0.84)	87	41-50
TKN	mgN/L	66 (0.80)	46 (0.56)	82	-
TP	mgP/L	20 (0.91)	13 (0.59)	22	-
pH	-	5.5-7.0	6.0-7.4	7.3	6.4-7.8
Fecal Coli	Log#/L	7.0-8.4	6.4-7.8	6.45	-
Oil/Grease	mg/L	83	39	-	16-65
Source		Sites 1,2,3,5,7,9	Sites 4,8,10,11,12	Harkin et al., 1979	Bowne, 1982

* Average results of establishment averages shown in Tables 5-7.
\+ Ratio of restaurant STE to household STE shown in parentheses.
\# Range of average values measured at three small communities.

The characteristics of STE at establishments involving a combination of facilities, not only a restaurant but also a motel or country club, are also compared to domestic STE in Table 10. The biodegradable organic contents of these restaurant establishments' STE were approximately 148 percent higher than that of domestic STE but the concentrations of the other measured parameters were similar or even somewhat lower.

Subsurface Soil Absorption

Operation Status--

The operation status of each soil absorption system was determined during periodic site visits. Monitoring efforts addressed the occurrence and magnitude of any effluent ponding within the system and whether the daily flow could be infiltrated by the system without plumbing backups or surfacing effluent. The results of the monitoring are highlighted in Table 11 and briefly discussed below.

Table 11. Operation Status of the Soil Absorption Systems

Type	Site No.*	Design Flow (gpd)	Actual Flow (gpd)	Hydraulic Loading # (gpd/ft^2)	Operation Status
Restaurant	1	3400	528	0.08+	Continuous ponding in 1 trench (11 to 15") All others dry
	2	4520	-		No ponding
	3	4940	1642	0.11	No ponding
	5	-	-	-	Intermittent ponding
	7	3110	780	0.29	First bed hydraulically failed. New bed ponded after two months. (0 to 3")
	9	3160	1564	0.43	Continuous ponding (7 to 11") Surcharges during dose
Restaurant/ Motel	4	-	14120	0.70	Continuous ponding (5 to 12") Surcharges during dose
	6	25000	13950	0.90	Beds hydraulically failed
Restaurant/ Golf Club	8	4500	-	-	Beds hydraulically failed
	10	5260	3750	0.82	Continuous ponding in 5 trenches (2 to 10") Others dry
	11	4000	836	0.24	No ponding
Bar/Grill	12	1890	445	0.28	Intermittent ponding in part of bed (0 to 2")

* Refer to Tables 1 to 3 for establishment characteristics.
\# Actual hydraulic loading based upon actual flow and bottom area only (Tables 3-4).
\+ Hydraulic loading with entire flow to Trench 1 equals 1.04 gpd/ft^2.

<u>Restaurant 1</u> - This restaurant was a supper club serving full course meals and open evenings only. The soil absorption system was a 6500 ft^2 conventional trench system consisting of 13 trenches, each 5 feet wide. Operation of the system was excellent according to the owners and they had experienced no problems during approximately three years of operation, unlike their previous system (2780 ft^2 bed) which had failed after a year and a half of use. Inspection of the system revealed that most of the wastewater flow was going to one trench. This trench was continuously ponded (11 to 15 inches) during this study, while the remaining twelve trenches were dry. The overall operation of the system did not appear affected by this distribution problem.

Restaurant 2 - Restaurant 2 was also a supper club type restaurant serving full course meals (evenings only). Three apartments with a total of five bedrooms were also served by the same wastewater system. The soil absorption system was a 9425 ft^2 conventional bed, 65 ft wide by 145 ft long. This system was installed as a replacement system for a smaller, failed system. No problems were noted over the course of this study and system ponding was never observed.

Restaurant 3 - This was a new supper club type restaurant serving luncheons and dinners. The soil absorption system was a conventional bed, 100 ft. wide by 156 ft. long, and had only been in operation about 6 months when monitoring began. No problems were noted during the study and ponded effluent was never observed in the observation vents.

Restaurant 4 - Restaurant 4 was a motel-restaurant-lounge complex. Meals were served throughout the day and large banquets were frequently served as well. A swimming pool, sauna, and locker rooms with showers were also present in the establishment, although pool waste was not discharged to the wastewater system. The soil absorption system was a large conventional bed (20000 ft^2) which had been in operation for about eight years. According to the manager, the bed had been fully ponded for 6 to 8 months at the outset of this study and a commercial additive, Liquid Live Micro-Organisms (LLMO), was being used in an attempt to rejuvenate the system. During the first site visit it was noted that ponded effluent backed up into the distribution box with backflow to the pump chamber after a dose. Continuous ponding of the system existed throughout the study at depths of 12 to 13 in. in the east end and 6 to 8 in. in the west end.

Restaurant 5 - This was a supper club establishment serving meals evenings and weekends only. The soil absorption system was a 13500 ft^2 conventional bed and gravity distribution of STE was utilized. The system was fairly old and details of its design were unavailable. No problems with its operation were noted during this study.

Restaurant 6 - Restaurant 6 was a large motel-restaurant-lounge complex serving meals throughout the day. Banquet facilities were available for up to 500 people. Pool, sauna, whirlpool, and locker room facilities were also present, but swimming pool waste was not discharged to the wastewater system. The soil absorption system consisted of two beds totalling about 21000 ft^2 and utilizing pressure distribution of STE. The absorption system had experienced problems since shortly after its start-up in late 1980. This system replaced an older conventional system. Ponding of effluent in the beds occurred almost immediately after system start-up. No reason was found for this and according to the restaurant's engineer and local health department authorities, the system had been designed and installed according to existing codes. At the start of this study the facility had been plagued by surfacing effluent and plumbing back-ups and wastewater was being hauled and disposed of offsite. This practice continued throughout the study period. An additive (LLMO) was tried without measurable success.

Restaurant 7 - This restaurant was a small supper club establishment serving full-course meals, evenings only. The soil absorption system consisted of a 2700 ft^2 in-ground pressure bed. This bed had been installed in the autumn of 1980 and developed ponding shortly thereafter. At the outset of this study surfacing effluent and plumbing back-ups had occurred from time to time and the bed was continuously ponded. A substantial portion of each dose would drain back to the pump chamber after dosing. An additive (LLMO) was tried in an attempt to rejuvenate the bed, but no change in performance was noted.

In May of 1983, a new absorption field was installed in the same location as that of the previous system but approximately 8 in. lower in elevation. Project staff were present during construction to observe the condition of the failed bed. The gravel above the infiltrative surface was black in color and a black layer was present at the infiltrative surface. Gravel was pressed into the infiltrative surface for 1 to 2 in. Below this a dense, brownish-gray layer of 1 to 8 in. thick was noted. Beneath this layer, natural soil material was present, a clean reddish-brown colored medium sand. Soil samples taken at various depths were analyzed for volatile solids, total Kjeldahl nitrogen, and moisture content. Results were variable but showed higher values of all parameters in the top 1 in. layer of soil. Two months after start-up of the new system, approximately 2 in. of ponded effluent were observed in two of the three observation vents. This condition varied from 1.8 to 3 in. during the remainder of the study.

Restaurant 8 - Restaurant 8 was a country club establishment serving lunches and dinners. Locker room facilities were also present. This facility was used seasonally only, generally from April to October. The soil absorption system consisted of a 3500 ft^2 bed with STE distribution accomplished by a pressure distribution network. Ponding reportedly developed in the second season of operation and surfacing effluent occurred towards the end of that season. At the start of the third season, also the beginning of this study, the bed was completely dry but ponding developed within 3 weeks of opening. The depth of ponded effluent increased to about 23 in. by early summer, indicating a surcharged condition. A fire in midsummer caused the facility to close and monitoring ceased.

Restaurant 9 - This restaurant consisted of a 24-hour cafe on one side and a restaurant-lounge open evenings only on the other side. The soil absorption system consisted of a pressure distribution network and a 3600 ft^2 bed which had been in operation about 2 years at the beginning of this study. Although no surfacing or plumbing backups to the building had occurred, the bed was continuously ponded at 7 to 8 in. in one end and 10 to 11 in. in the other. A major portion of the STE discharged to the bed flowed back into the pump chamber after each dose. This condition persisted throughout the study.

Restaurant 10 - Restaurant 10 was a country club establishment serving lunches and dinners. Lockerroom facilities were also present. Although open year round, business peaked during the summer months. The soil absorption system was an in-ground pressure system consisting of 7 shallow trenches on a sloping site and had been in operation just over a year at the start of this study. The manager of the club reported good operation of the system. Monitoring of the observation vents showed five of the seven trenches ponded from 0.5 to 5.5 in. during winter and early spring increasing to 2 to 10 in. during late spring and summer. No ponded effluent was observed in the other two trenches. This condition was consistent throughout the study.

Restaurant 11 - This was also a country club with locker room facilities serving lunches and dinners. This restaurant was open seasonally, generally April to October. The soil absorption system was a 3500 ft^2 bed with pressure distribution of STE and had been in operation three seasons at the beginning of this study. Excellent operation was reported by the manager. No problems were evident during this study and ponded effluent was never observed in the bed.

Restaurant 12 - Restaurant 12 was a small bar and grill establishment serving mostly sandwiches and fast food items. The soil absorption system was a mound system with a 1600 ft^2 infiltrative area. This system had been in operation one and one half years at the outset of this study. The owners considered its operation satisfactory. Monitoring revealed that one end of the mound absorption bed was ponded with 0 to 2 in. of STE whereas the other end was dry.

Effluent Loading and Performance--

The average hydraulic loading rates measured in this study ranged from 0.08 to 0.90 gpd per ft^2 of total horizontal soil infiltrative area (Table 12). These rates were less than typically recommended according to current practice (Wisc. Adm. Code, 1980; U.S. EPA, 1980). Despite this fact, five of the twelve systems studied were judged to have performed poorly based upon substantial ponding and system surcharging during a dose with three of these exhibiting surfacing effluent (Sites 7, 9, 4, 6, 8).

The reasons for this apparently poor performance of five systems are not entirely clear, but potential contributing factors have been suggested. Inspection of the hydraulic loading data versus infiltration capacity suggested that an operating hydraulic load in excess of approximately 0.4 gpd/ft^2 may be too high to facilitate long-term successful operation of restaurant systems. However this interpretation may be overly simplistic. Perhaps more important than hydraulic loading rate are the wastewater constituent mass loadings. High mass loadings of organic matter and suspended solids may overload the soil system's capacity to degrade these materials. Severe soil clogging may result and effluent ponding may develop to the point where surfacing effluent or plumbing backups occur. The organic loading rates measured in this study ranged from 8.8 to 99.8 lb BOD_5/acre/d. Four of the systems performing poorly were loaded with BOD_5 at rates in excess of 40 lb/acre/d. This rate is more than twice as high as that typically applied to soil absorption systems for domestic STE (Table 12). Average suspended solids loadings ranged from 3.8 to 36.1 lb ss/acre/d. At most sites, the suspended solids loadings were similar to those applied in domestic systems (Table 12), suggesting that suspended solids may not be a critical factor affecting infiltration capacity of these restaurant systems.

Another potential factor adversely affecting performance of the systems studied may have been that all but two of the twelve were beds, mostly characterized by low length/width ratios (Table 3). The five poorly performing systems were all beds. One of the two trench systems studied (site 10) was loaded at very high hydraulic and mass loading rates but performed satisfactorily (Table 12). The trench design may have provided better performance than that which would have been experienced with a bed design. Trenches generally offer greater infiltrative surface area and improved system aeration as well as other advantages in comparison to beds.

Table 12. Summary of Soil Absorption System Loading and Performance

Type	Site No.*	System Type+	System Size (ft^2)	System Loading: Hydraulic (gpd)/(ft^2)	System Loading: Organic (lb BOD_5)/(d acre)	System Loading: Solids (lb SS)/(d acre)	Infiltration Performance#
Restaurant	1	CT	6500	0.08	17.1	5.5	2
	2	CB	9425	–	–	–	3
	3	CB	15600	0.11	33.7	14.9	3
	5	CB	13500	–	–	–	2
	7	IGPB	2680	0.29	73.1	13.2	0–2**
	9	IGPB	3600	0.43	40.8	10.3	1
Restaurant/ Motel	4	CB	20500	0.70	43.5	16.8	1
	6	IGPB	21000	0.90	–	–	0
Restaurant/ Golf Club	8	IGPB	3500	–	–	–	0
	10	IGPT	4200	0.82	99.8	36.1	2
	11	IGPB	3000	0.24	8.8	3.8	3
Bar/Grill	12	MB	1600	0.28	18.1	8.0	2
Domestic†	–	MB	410	0.38	18.2	12.0	–

* Refer to Tables 1 to 3 for establishment charactertistics.

\+ CT = Conventional Trench design; CB = Conventional Bed; IGPB = Pressure distribution of STE in a bed; IGPT = Pressure distribution of STE in a trench; MB = pressure distribution of STE in a mound bed.

† Single-family home STE (Harkin et al., 1979).

\# Rating Scale: 0 = hydraulically failed; 1 = mostly flooded but handling daily flow; 2 = intermittent ponding or partial system ponding; 3 = no ponding.

** First bed failed, replacement system ponded after 2 mon.

LABORATORY INVESTIGATION

Subsurface soil absorption of restaurant wastewater was investigated in the laboratory utilizing small lysimeters. The objective of this phase of the study was to compare under controlled conditions, the infiltration capacities and treatment efficiencies of sand media dosed with STE from a typical restaurant versus that from a single-family home. This experiment was carried out in laboratories of the Civil Engineering Department at the University of Wisconsin between July and December, 1983.

MATERIALS AND METHODS

Experimental Design

The experimental design established for this investigation is shown in Table 13. Wastewater type and hydraulic loading were the variables studied with two versions and levels of each considered, respectively. The anticipated response variables included infiltration capacity and effluent quality.

Table 13. Experimental Design of the Laboratory Study

Lysimeter No.	Wastewater Source (STE)	Hydraulic Loading (gpd/ft^2)
H1, H2	Home	2.25
H3, H4	Home	1.25*
R1, R2	Restaurant+	2.25
R3, R4	Restaurant+	1.25*

* Indicated hydraulic loading was equal to that required by Wis. Adm. Code (1980) for in-ground pressure distribution systems installed in soils of sand texture and also for mound systems.

\+ Restaurant STE was obtained from restaurant No. 5 of the field investigation (see previous section).

Lysimeter Characteristics

The experiment was conducted using small lysimeters to simulate conventional subsurface soil absorption systems. The soil material utilized was a filter sand with an effective size of 0.6 mm and a uniformity coefficient of 1.6. The bulk density of the sand was determined to be 1.64 gm/cm^3 and the porosity was calculated to be 38 percent at a particle density of 2.65 gm/cm^3. This material was selected in preference to naturally occurring sand to minimize differences in media characteristics between different hand-packed lysimeters which might have confounded the experimental results.

Each lysimeter consisted of sand media hand-packed in a 4-in. diameter length of clear acrylic pipe (Figure 4). The columns were carefully prepared according to the following procedures. The interior walls of each pipe section were treated with an epoxy cement and a coating of sand to minimize STE channeling along the sidewalls. Approximately 200 lb of sand were first mixed in a plastic basin. After removing approximately 10 lb for characterization purposes, 0.8 gal of tapwater were added and thoroughly mixed with the sand. Meanwhile, approximately 2 in. of coarse gravel (1 in.) were placed in the bottom of each lysimeter, followed by 2 in. of fine gravel. The moist sand was then added in 4-in. layers to a total depth of approximately 31 in. A 6 in. layer of coarse gravel was then placed on the sand surface to simulate the gravel bed typically found in a soil absorption field.

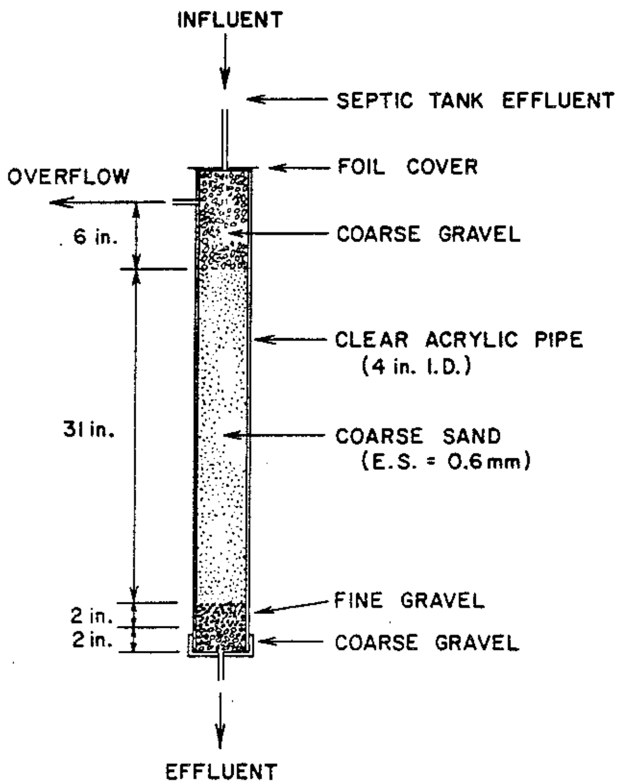


Figure 4. The Lysimeters Used for the Laboratory Study.

The initial infiltration capacity of the sand media in each lysimeter was measured. Tapwater was applied to the gravel over the surface of each lysimeter and allowed to pond to approximately 6 in. depth during infiltration and percolation into and through the sand media. After an initial three to five minutes of flow, the outflow rate from each lysimeter was measured over a three minute period. Two measurements were made for each lysimeter. The infiltration capacities so measured for the four home lysimeters averaged 3,490 gpd/ft^2 with a standard deviation of 297 gpd/ft^2. Those for the four restaurant lysimeters averaged 3,430 gpd/ft^2 with a standard deviation of 113 gpd/ft^2.

The lysimeters were mounted in the laboratory and maintained in darkness, except during routine servicing and monitoring. The air temperature within the lab was not controlled and during the experiment gradually decreased in response to seasonal decreases from approximately 30°C to 20°C. A photograph of the lysimeters and associated wastewater feed apparatus is shown in Figure 5.

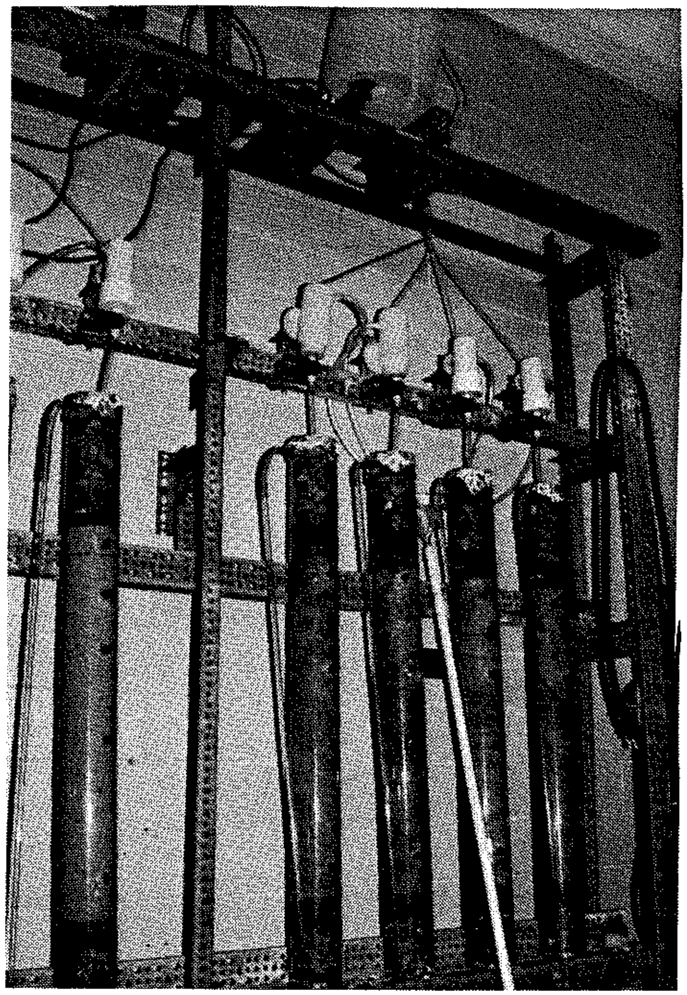


Figure 5. Lysimeter Apparatus.

Each lysimeter was dosed twice daily with the specified volume of wastewater effluent as follows. Septic tank effluent (STE) was manually collected from a local restaurant and single-family home approximately every three days throughout the course of this study. After collection, the effluents were transported back to the University of Wisconsin and refrigerated at 5° to 8°C. Each afternoon approximately 2 gal. of each STE were transferred to 5-gal. reservoirs feeding an automatic dosing system. The outlet from each reservoir was connected directly to an electrically operated solenoid valve. Each valve was connected to a small chamber which distributed the appropriate STE between four lysimeters. A polyethylene vessel was provided for each lysimeter with an overflow port at a specified level to yield a given vessel liquid volume. The outlet from each vessel was connected to an electrically operated solenoid valve which directed effluent into the gravel layer on the surface of a lysimeter. The dosing of the lysimeters was controlled by a specially designed timing mechanism. Twice daily at approximately 10 AM and 8 PM, STE was applied to each lysimeter.

Monitoring

The operation of the lysimeters was monitored on a daily basis. The number of wastewater doses to each set of lysimeters (home, restaurant) was automatically recorded using electrical event counters wired into the circuitry of the dosing system. The accumulated value of each counter was recorded on a data form each day.

The occurrence and magnitude of any wastewater ponding was monitored at least once daily. Once continuous ponding occurred to a depth of 6 in. (15 cm) excess wastewater exited each lysimeter via the overflow port. This overflow was collected and its volume measured each day.

The compositions of the two septic tank effluents were determined periodically throughout the study. Samples of each effluent were taken from the volumes collected for feeding the lysimeters and analyzed for selected physical and chemical parameters according to Standard Methods (1980). On two occasions during the study, the effluent compositions of each collected STE were monitored with time during refrigeration to identify any effects due to storage. These measurements revealed insignificant changes in all measured physical and chemical parameters with 24 and 48 hours of storage at 5^{o} to $8^{o}C$. After 72 hours of storage, the BOD_5 concentrations were reduced by 5 to 30 percent compared to the fresh STE concentrations although no other significant changes were noted.

The compositions of the effluent from each lysimeter were determined on two occasions, 15 and 35 days after start-up. The effluent from each lysimeter was collected following a wastewater dose and analyzed for selected chemical and physical parameters.

RESULTS AND DISCUSSION

Influent Wastewater Composition

The composition of the two septic tank effluents (STE) applied to the lysimeters (Table 14) were representative of household and restaurant STE. The household STE was similar to that measured at other Wisconsin homes by Harkin, et al. (1979) while the restaurant STE was within the range of values determined at restaurants in the field investigation phase of this study (Table 8).

The average concentrations of organic materials (BOD_5) and suspended matter (TSS) in the restaurant STE were approximately 2.7 to 2.8 times higher than that in the household STE (Table 14). As a result, the average mass loadings were similarly higher (Table 15). The BOD_5 and TSS mass loadings in 1.25 gpd/ft^2 of household STE were equal to those in approximately 0.45 gpd/ft^2 of restaurant STE.

Infiltration Capacity

The infiltration capacities (IC's) of the lysimeters receiving household STE were reduced by 9 to 37 percent after 67 days of effluent application (Table 16). Final IC's remained in excess of 2,300 gpd/ft^2. Throughout the study each dose of STE rapidly infiltrated into the media and the sand surface remained exposed to air. After 67 days of operation, effluent application to the household lysimeters was terminated.

Table 14. Compositions of Septic Tank Effluents Applied to Soil Lysimeters*

Parameter	Units	Home			Restaurant			Ratio** X_R/X_H
		n	X_H	SD	n	X_R	SD	
BOD_5	mg/L	9	140	30	9	377	121	2.69
TOC	mg/L	7	196	73	6	270	64	1.38
COD	mg/L	9	356	43	9	772	225	2.17
TSS	mg/L	8	88	41	8	247	120	2.81
TVSS	mg/L	8	61	30	8	173	67	2.84
TKN	mgN/L	7	48	8	7	30	12	0.63
NH_4N	mgN/L	5	42	7	5	16	9	0.38
NO_3N	mgN/L	4	0	-	3	1	1	-
P	mgP/L	2	12	1	2	15	5	1.22
Oil/Grease	mg/L	4	38	8	4	101	29	2.69
pH	-	7	6.6-7.4	-	7	5.7-6.8	-	-

* n = number of data points, X = average, SD = standard deviation.

** Ratio of the restaurant average concentration to that of the home.

Table 15. Average Mass Loadings of Selected Constituents

Parameter	Units	Home		Restaurant	
		Low*	High	Low	High
Flow	gpd/ft^2	1.25	2.25	1.25	2.25
BOD_5	lb/d/Acre	63	114	171	308
TSS	lb/d/Acre	39	72	112	202
NH_4N	lb/d/Acre	19	34	7	13
Lysimeter No.	-	3,4	1,2	7,8	5,6

* Refers to hydraulic loading (Table 13).

Table 16. Infiltration Capacity Characteristics

Parameter	Units	Home				Restaurant			
		H1	H2	H3	H4	R1	R2	R3	R4
Hydraulic Loading	gpd/ft^2	2.25	2.25	1.25	1.25	2.25	2.25	1.25	1.25
Time to Continuous Ponding	d	>67	>67	>67	>67	21	8	23	23
Time to Hydraulic Failure*	d	-	-	-	-	22	9	29	29
Initial** Infiltration Capacity	gpd/ft^2	3663	3700	3535	3055	3332	3317	3506	3528
Final** Infiltration Capacity	gpd/ft^2	2472	2337	2511	2781	<2.25	<2.25	<1.25	<1.25
% Reduction	%	32.5	36.8	29.0	9.0	99.93	99.93	99.96	99.96

* Time until the ponding depth surpassed 6 in. and overflow occurred.

**Measured under a 6 in. hydraulic head.

Shortly after initiation of the experiment, drastic reductions occurred in the infiltration capacity (IC) of the restaurant lysimeters. Within eight days of effluent application, the IC's of the two lysimeters receiving 2.25 gpd/ft^2 of restaurant STE (R1, R2) were reduced to less than 0.2 percent of initial capacities. Continuous inundation or ponding of the sand surface occurred in R2 after only eight days of loading and in R1 after 21 days (Table 16). Continuous ponding in the two restaurant lysimeters receiving 1.25 gpd/ft^2 of STE occurred after 23 days of loading.

Once the sand surface of a lysimeter became continuously ponded with STE, the IC soon decreased to the point where the entire volume of STE applied would not infiltrate into the lysimeter, even under a 6 in. hydraulic ponding head. At this point STE would exit the column via the overflow port. Hydraulic failure was considered to occur when the ponding depth surpassed 6 in. and lysimeter overflow first occurred. For all four restaurant lysimeters, hydraulic failure occurred after only 29 days of operation or less (Table 16).

Purification Capacity

Infiltration and percolation of STE through the sand media in all lysimeters achieved substantial reductions in organic materials and suspended solids and near complete nitrification of the applied ammonia nitrogen (Table 17). The effluent from the restaurant lysimeters was not markedly different from that of the household lysimeters. This indicated that the restaurant lysimeters achieved greater removals of organic matter and suspended solids. Accompanying greater removal, however, is the need for greater degradation and stabilization of the removed materials. If the soil system is overloaded with organic matter and suspended solids, system failure may result. This undoubtedly was a major factor in the early hydraulic failure of all four restaurant lysimeters (Table 16).

Table 17. Lysimeter Effluent Composition*

Parameter	Units	Home					Restaurant				
		STE+	H1	H2	H3	H4	STE+	R1	R2	R3	R4
COD	mg/L	356	88	102	56	24	772	132	85	22	44
TOC	mg/L	196	66	68	55	40	270	80	66	64	84
TSS	mg/L	88	12	22	26	50	247	14	26	19	21
TVSS	mg/L	61	10	4	12	8	173	1	4	8	12
NH_4N	mg-N/L	42	2	1	1	1	16	1	1	1	1
NO_3N	mg-N/L	0	46	58	55	52	1	26	31	34	24

* Average of two samples collected after 15 and 35 days of effluent loading.

+ Average STE composition as presented in Table 14.

SUMMARY AND CONCLUSIONS

A field and laboratory study was conducted to investigate the onsite treatment and disposal of restaurant wastewater. A preliminary field survey of 42 restaurant wastewater systems occurred during 1982 followed by a detailed investigation of 12 systems during 1983. A comparative study of soil absorption of restaurant wastewater versus household wastewater was conducted under laboratory conditions between July and December, 1983.

The results of the field and laboratory investigations clearly demon-demonstrated that the performance of onsite wastewater treatment and disposal systems receiving wastewater from restaurant establishments was markedly different from that of systems receiving household wastewater. Even after treatment in grease interceptors and multiple septic tanks, restaurant wastewater effluent contained substantial concentrations of biodegradable organic materials, suspended solids, grease as well as nutrients and bacteria (Table 10, Figure 6). Septic tank effluent (STE) at supper club type restaurants was especially concentrated. Compared to typical household STE, supper club STE contained far greater concentrations of organic matter (506 mg/L BOD_5) and suspended solids (177 mg/L TSS) (Table 10). These concentrations were approximately 380 percent and 200 percent higher than those of household STE.

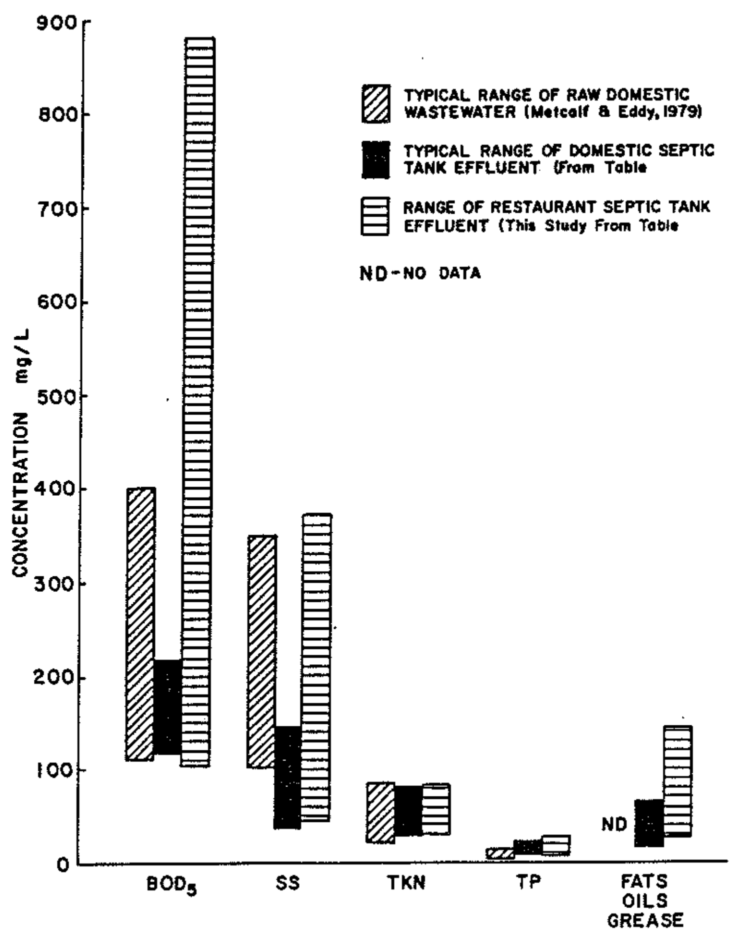


Figure 6. Comparison of Wastewater Compositions.

Restaurant establishments with substantial non-restaurant wastewater sources (e.g. motel, lockerrooms) exhibited less concentrated STE compared to supper clubs. With the exception of organic matter concentration (196 mg/L BOD_5), these establishments exhibited STE concentrations similar to or lower than household STE.

While not specifically investigated in this study, the issue of sludge and scum accumulation in restaurant septic tanks was briefly considered. Due to the elevated concentrations of organic matter, solids and grease associated with raw restaurant wastewater compared to household wastewater, quarterly pumping of restaurant septic tanks may be a prudent practice during initial system operation. Once the rate of sludge and scum accumulation is known, the pumping schedule can be adjusted accordingly.

Acceptable performance of subsurface soil absorption systems is characterized by a long-term infiltration capacity greater than the applied hydraulic loading and advanced treatment of the applied wastewater as it percolates through the soil to the groundwater. The results of this investigation revealed that the long-term infiltration capacity of restaurant soil absorption systems is substantially lower than that of household systems. For systems installed in soils of sand texture with percolation rates of less than 10 minutes per inch, current design practice typically consists of system sizing based on a design hydraulic loading rate of 1.2 gpd/ft^2 (e.g. U.S. EPA, 1980). Five of eleven systems so installed in Wisconsin were found to be performing poorly as regards their infiltration capacity though their operating hydraulic loading rates were equal to no more than 75 percent of this value, and typically much less. In addition they had generally been in service less than three years. Three of the systems monitored had hydraulically failed within two years of start up, requiring major system rehabilitation or replacement.

Many of the malfunctioning systems encountered in this study were alternative inground pressure systems according to Wisconsin Adm. Code (1980). These systems are similar in most respects to conventional subsurface soil absorption systems. The notable exception in their design is that septic tank effluent is distributed within the absorption system through a network of pressurized pipe, rather than by gravity flow. Investigation of the design criteria required for sizing restaurant systems in Wisconsin revealed significant differences between conventional and alternative system sizing criteria (Wisc. Adm. Code, 1980). As illustrated in Table 18, the required infiltrative surface for a restaurant soil absorption system is drastically lower for an alternative versus a conventional system. Consequently, the design hydraulic loading rate utilized for an alternative system is 200 to 450 percent higher than that for a conventional system (Table 19). The basis for this increased hydraulic loading for alternative soil absorption systems is unknown and the practice appears inappropriate based upon the results of this study.

Table 18. Infiltrative Surface Requirements for a 100-Seat Restaurant*

Percolation Rate (MPI)	Conventional System		Alternative System	
	Trench (ft^2)	Bed (ft^2)	Inground Pressure (ft^2)	Mound+ (ft^2)
0 - 10	9350	11900	3142	3142
10 - 30	14025	17425	4713	-
30 - 45	17000	21250	5236	-
45 - 60	18700	23800	9425	-

*Horizontal infiltrative surface area required per Wis. Admn. Code (1980) for a 100-seat restaurant with a 30-seat bar and 10 employees.

+Size of the infiltrative surface of absorption bed in Wisconsin Mound systems.

Table 19. Implicit Design Hydraulic Loading Rates for a 100-Seat Restaurant*

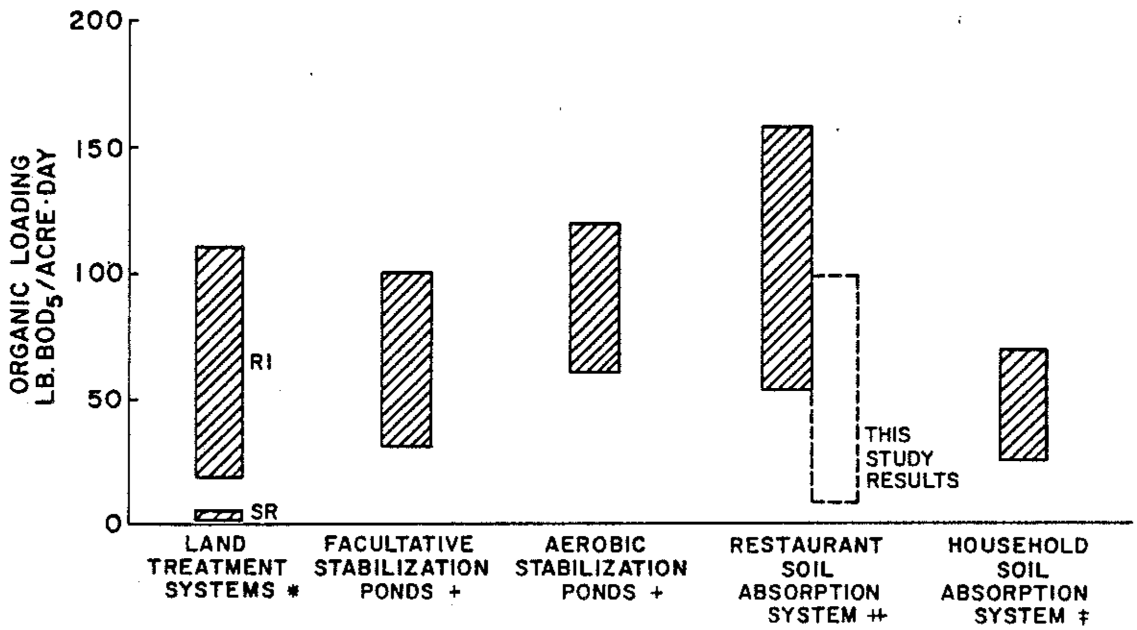
Percolation Rate (MPI)	Conventional System		Alternative System	
	Trench (gpd/ft^2)	Bed (gpd/ft^2)	Inground Pressure (gpd/ft^2)	Mound (gpd/ft^2)
0 - 10	0.40	0.32	1.20	1.20
10 - 30	0.27	0.22	0.80	-
30 - 45	0.22	0.18	0.72	-
45 - 60	0.20	0.16	0.40	-

*Based upon the data shown in Table 18 and a design flow of 3770 gpd per Wis. Adm. Code (1980).

Further consideration of the design practice for subsurface soil absorption systems was made for systems in general and restaurant systems in specific. The design and operation of conventional and alternative subsurface soil absorption systems has largely evolved from the laboratory and field experiences gained with household systems. Current design practice typically consists of soil system sizing based solely on established hydraulic loading rates for soils of different characteristics. The concentrations or mass loadings of other constituents such as BOD_5 or suspended solids are generally not considered in design. This is in sharp contrast to the design and operation of surface land treatment systems and mechanical treatment plants.

This lack of consideration for constituent loading rates can result in alarmingly high values based upon sizing for hydraulic loading rate alone. For example, recommended organic loading rates (BOD_5) for design of several types of treatment systems are shown in Figure 7 along with the organic loading rates associated with subsurface soil absorption systems. As illustrated, the organic loading rates potentially encountered in restaurant soil absorption systems designed based on hydraulic load can exceed those generally recommended for land treatment systems, facultative stabilization ponds and even aerobic stabilization ponds.

Of particular interest is the comparison of subsurface systems and land treatment systems (Figure 7). Slow-rate irrigation and rapid infiltration systems are typically designed to receive average hydraulic loadings of primary municipal wastewater effluent in the range of 0.5 and 2.5 gpd/ft^2, respectively, not dramatically different than many subsurface systems.



* Typical Range of Values for (EPA, 1981) Rapid Infiltration (RI) and Slow-Rate (SR) Systems.

\+ Typical Range of Design Values (Metcalf & Eddy, 1972).

Range of Design Values Based on Hydraulic Loading of 0.4 - 1.2 gpd/ft^2 and Average Wastewater Quality Measured in This Study. Range of Values Measured in This Study.

Range of Design Values Based on a Hydraulic Loading of 0.4 - 1.2 gpd/ft^2 and Average Wastewater Quality from Table 10.

Figure 7. Comparison of Design Organic Loading Rates for Various Wastewater Treatment Systems

However, to facilitate long-term operation, the design of these land treatment systems limits organic loading as well as other constituent loading rates and system operation allows for resting intervals as well as periodic maintenance of the soil infiltrative surface (U.S. EPA, 1981). In contrast, subsurface system design does not explicitly limit organic loading and system operation doesn't generally allow for resting intervals or periodic maintenance. These practices appear questionable since organic and other constituent loading rates potentially encountered in restaurant systems may exceed the limits of the soil system to degrade the materials applied. The result may be an inadequate long-term infiltration and purification capacity.

The results of the field investigation suggest that hydraulic loading rate is likely not the sole important design parameter. The mass loading of other parameters such as BOD_5 and solids may also be critical. Maximum loading rates for these parameters may be dependent on soil morphology and system geometry. For systems of bed geometry installed in sands, maximum rates may be in the range of 0.70 gpd/ft^2, 40 lbs. BOD_5/d/acre and 15 lbs. TSS/d/acre (Table 12). Substantially higher hydraulic loadings may be potentially utilized successfully as regards infiltration as long as applied organic and solid loadings are maintained below acceptable levels. Higher hydraulic and mass loading rates may be appropriate for systems of shallow narrow trench design due to the increased infiltrative capacity and system aeration afforded by this type of design.

A commercial additive, Liquid Live Micro-Organism (LLMO), was utilized by the managers at three hydraulically malfunctioning restaurant systems in an attempt to restore their infiltrative capacity and prevent outright system failure. The use of the additive appeared to have little or no marked effect on the operation of these systems.

The purification capacity of subsurface soil absorption systems for restaurant septic tank effluent was investigated under laboratory conditions using soil lysimeters. A limited data base collected over a short period of operation indicated that the composition of restaurant effluent after percolation through approximately 2.5 ft. of medium to coarse sand was generally similar to that of household effluent after the same soil treatment. The purification capacity actually achieved under field conditions over the long-term are currently unknown.

RECOMMENDATIONS

1. Efforts should be made to educate the managers of restaurant establishments regarding appropriate interior water use and waste disposal habits, proper use of cleansers and additives, and system operation requirements.

2. Flow monitoring equipment (e.g. water meters) should be included in commercial facilities such as restaurant establishments. Flow data is essential to proper system operation and management and to interpretation of system performance.

3. Separate septic tank facilities should be used for pretreatment of the kitchen waste stream only. The effluent from these facilities should enter the main building sewer prior to its entry to the remaining septic tanks.

4. Septic tank treatment should consist of three or more tanks in series. The tanks should be pumped quarterly during the initial period of operation until the rate of sludge and scum accumulation is known at which time an appropriate pumping schedule can be established.

5. For restaurant subsurface wastewater absorption systems of bed geometry installed in soils of sand texture, maximum loading rates for STE of approximately 0.70 gpd/ft^2, 40 lb BOD_5/d/acre and 15 lb TSS/d/acre appear reasonable (all rates based upon bed bottom area). Lower loading rates are likely appropriate for bed systems installed in fine textured soils. Substantially higher loading rates may be feasible for systems of shallow narrow trench design, for systems with better than septic tank pretreatment, or for systems with long-term resting provisions. Further investigation is warranted to quantify the relationship between applied wastewater quantity and composition, soil morphology and system geometry and that of long-term infiltration and purification capacities.

6. Soil absorption systems of shallow, narrow trench design should generally be used in preference to squarish beds.

7. Further field and laboratory investigation of restaurant systems are necessary to enhance the data base established by this investigation. Consideration and investigation of other commercial establishment systems would also be valuable.

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