SSWMP PUBLICATION #2.10

AN EVALUATION OF TWO EXPERIMENTAL HOUSEHOLD WASTEWATER TREATMENT AND DISPOSAL SYSTEMS IN SOUTHEASTERN WISCONSIN[1]

W. A. Ziebell, R. J. Otis and J. Bouma[2]

ABSTRACT

Two sites in Racine County having experimental wastewater treatment and disposal systems have been studied. Both systems involve a method of aerobic treatment of liquid waste with chlorination and effluent discharge to an absorption field. Curtain drains are used to improve drainage conditions in the absorption fields having slowly permeable silty loam soil.

---

[1] Report from the Small Scale Waste Management Project, Univ. of Wis., Madison; funded by the State of Wisconsin, 1973.

[2] Specialist, Sanitary Engineer, Professor of Soil Science, University of Wisconsin, Madison.

INTRODUCTION

In the interest of improving methods of on-site wastewater disposal, the Division of Health, in the Wisconsin Department of Health and Social Services, permits installation of alternative systems to the conventional septic tank-soil absorption field. A homeowner receiving approval for such a system, must allow inspection and sampling of the system for evaluation purposes. The Division of Health requested inspection and sampling of such systems by the Small Scale Waste Management Project so efforts to develop alternative systems would not be duplicated.

Two sites with an alternative system have been studied in southeastern Wisconsin. Here, severe problems exist due to very slowly permeable silty loam soil (Blount silt loam). Approvals for the conventional disposal system are not given because of the percolation rate (about 120 minutes/inch) in this soil. Thus, development in unsewered areas is limited.

Conventional systems often fail within a short period of time in such soils. This is due to severe reduction of the infiltration rate of septic tank effluent at the absorption field surface; resulting from the build up of organic material which creates clogged zones (crusts) on the infiltrative surface.

Several approaches have been considered for preventing such failure. One method proposed is treatment of wastewater to a much higher degree than provided by the septic tank, thereby, reducing the amount of potential clogging material (nutrients and suspended solids) which reaches the field. Manufacturers, of treatment units designed to produce high quality effluents, claim only 1/3 as much absorption field area is required when such effluents are applied as compared to septic tank effluent.

A second method is to build the absorption field large enough to accept a given quantity of wastewater (regardless of its quality) under clogged conditions. However, this approach is often prohibited by area requirements and costs.

A third method is to promote decomposition of the clogging material in the field by insuring aerobic conditions under which this decomposition occurs most efficiently. This can be accomplished by intermittently applying effluent (dosing) over the entire field at a rate which permits unponded (hence aerobic) conditions between doses. In addition, curtain drains have been proposed to improve the drainage conditions in the absorption field. The curtain drain's original purpose was to intercept water moving laterally through the relatively permeable topsoil and to collect periodically ponded or stagnant water upslope from the absorption field. The drain would then discharge such water (generally to a ditch or stream) at a distance from the absorption field; preventing an increase in liquid load on the seepage area. However, occasionally the drains are installed to intercept wastewater which has percolated laterally through the soil from the seepage area. In such cases the amount of soil between the seepage area and the curtain drain must provide sufficient purification of the wastewater or contamination of surface waters from the curtain drain discharge would result.

MATERIALS AND METHODS

The experimental waste treatment and disposal system, at two sites, was designed and installed by J. Burgless and M. Nelson of the North Cape Septic Tank and Tile Co., North Cape, Wi. The system at Site A (the Harris residence, Racine County) was studied primarily for evaluation of the treatment process, while the study at Site B (the Hazlett residence, Racine County) concentrated on evaluation of the curtain drain.

Samples taken at various points in the systems were obtained on two occasions from each site. Separate samples (generally grab samples) were obtained for BOD, COD and solids; nitrogen; and bacteriological analyses. All samples were placed on ice immediately after sampling and returned to Madison for analysis. Analytical methods were bases on Standard Methods (1971). The first set of samples from Site A were not chemically treated to remove residual chlorine, however, this has been considered in the interpretation of the results. Measurements of temperature, pH, dissolved oxygen, and residual chlorine (using a Hach colorimetric kit) were made in the field.

RESULTS AND DISCUSSION

Site A

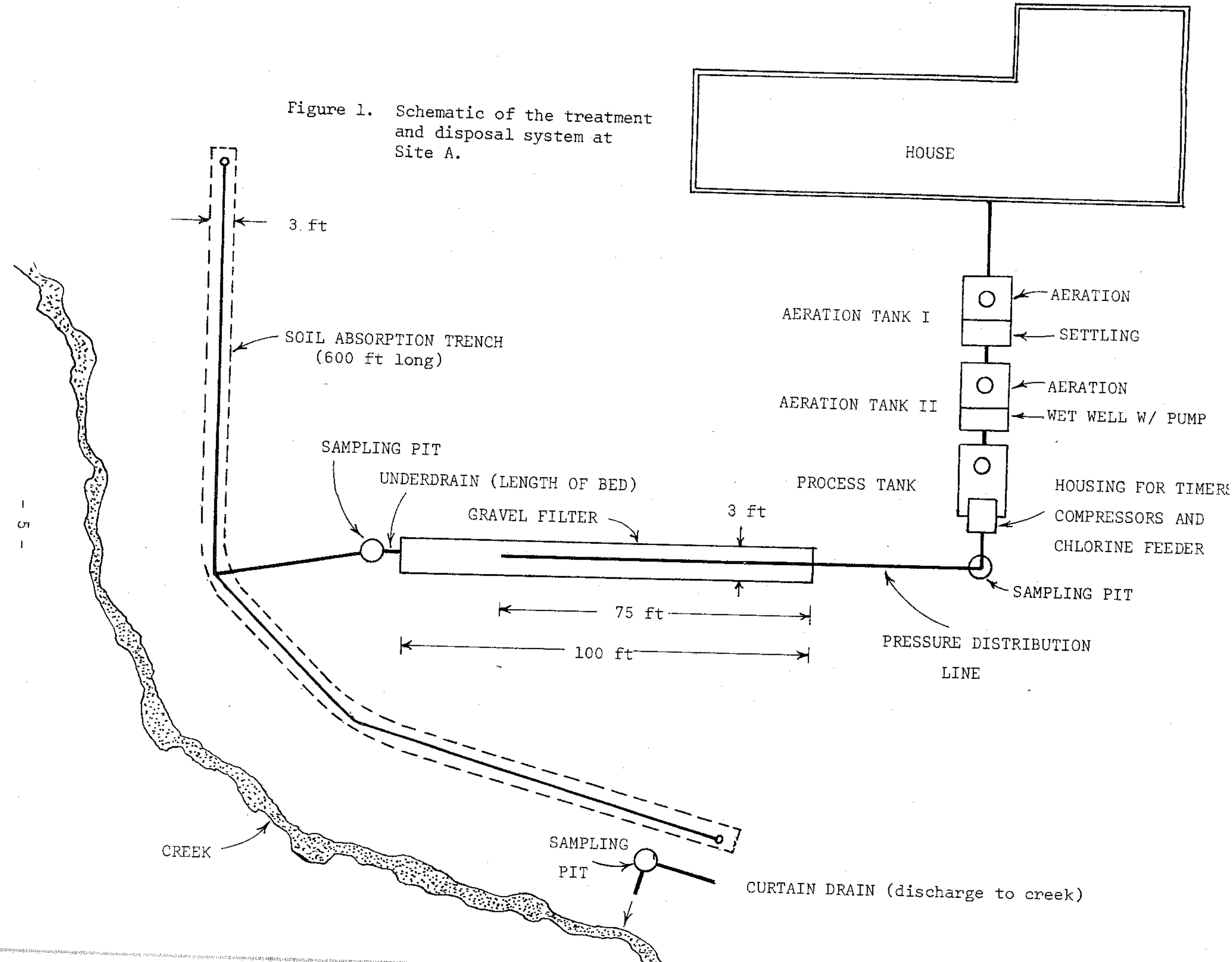
A description of the treatment process, an evaluation of its efficiency, and a discussion of the soil, absorption field and curtain drain at Site A is given below. Pertinent data are presented in Tables 1, 2 and 3, and Fig. 1 and 2.

The treatment process:

The estimated wastewater flow to this system is 550 gal/day. Aeration Tank I (the first treatment unit as indicated in Fig. 1) is a 1,000 gal (4' by 8') concrete tank, divided into two chambers by a concrete block baffle. The first chamber provides a detention time of about 28 hours and is aerated continuously by spargers. The wastewater flows under the baffle through three (4" by 8") openings to a 350 gallon settling chamber. The bottom of this chamber is flat and positive sludge return is not provided. The openings in the underflow baffle were reported by the designer to serve as the means of returning sludge.

From Aeration Tank I flow is by gravity to Aeration Tank II (another 1,000 gallon concrete tank). It is also divided into two chambers, the first having a three-inch baffled overflow outlet. This chamber, having a detention time of approximately 32.5 hours, is also aerated continuously but at a lower rate than in Tank I. The second chamber, when filled to 250 gallons, is emptied by pumping into a Process Tank. The pump is set off the bottom to prevent sludge pump out. The sludge is not returned to the aeration chamber,

Figure 1. Schematic of the treatment and disposal system at Site A.



but is allowed to accumulate and is removed, when necessary.

Wastewater is pumped to the Process Tank (a third 1,000 gallon tank) until 750 gallons have accumulated. The submersible pump in Aeration Tank II is then automatically "locked off" and aeration begins in the Process Tank. The wastewater is aerated for 7-1/2 hours at which time approximately one pint of a 15% chlorine solution (in NaOH) is pumped in by a chemical feeder. Aeration then continues for another half hour. Immediately after this eight hour aeration-disfection period, the 750 gallons is pumped out preventing sludge accumulation. The tank is then ready for the next cycle.

Wastewater from the Process Tank is discharged, under pressure, over a subsurface gravel bed (Fig. 1). An underdrain collects the effluent, which flows to a soil absorption trench (3' by 600'). A curtain drain installed for demonstration purposes, extends for only a short distance (5' - 10') parallel to the absorption trench and discharges to a creek.

Mechanical equipment includes 2 air compressors, 2 submersible pumps, 1 chemical feed pump, and 2 time clocks. The cost of equipment and installation is "reported" to be approximately $2,500. Operational costs were estimated at $4.00/month for electricity and $7.00/month for chlorine. Regular maintenance of the mechanical system is provided by the manufacturer and includes re-filling of the chlorine solution feed tank.

Treatment process evaluation:

The evaluation of this treatment process is based on inspection of the units (described above) and on analytical data from samples taken of the aeration chambers of the three tanks and effluent of the Process Tank and gravel filter.

Aeration in the three tanks of this system provides mixing and sufficient dissolved oxygen (0.8 to 2.5 mg/l) to insure aerobic decomposition of waste. However, Tanks I and II, which are intended to be extended aeration units (with detentions of greater than 28 hours) do not have efficient sludge return mechanisms; the development and maintenance of sludge (containing a high and active bacterial population) being a key factor for biodegradation of wastewater nutrients in such units. Typical total syspended solids concentrations (reflecting the amount of biologically active material present) for extended aeration units would be of the order of 2,000 mg/l, only 22 to 152 mg/l was found in this system (Table 1). Fecal coliform (FC) to fecal streptococcus (FS) ratios in Tanks I and II (8.0 and 8.5, respectively) are similar to those observed by Geldreich (1966) in fresh domestic sewage and human fecal material.

The Process Tank operates as a batch process, but again without sludge development. Furthermore, the concentrated chlorine solution added to this tank (estimated at 20 ppm after dilution in the tank) destroys the majority of the bacteria (along with the indicator bacteria). Less than 100 total bacteria/ml (and <0.05 indicator bacteria/ml) were detected in the Process Tank when chlorine was being supplied to the system.

Table 1 Analytical results from the experimental treatment system at Site A

Sample date	pH	Temp	D.O.	Cl	BOD	COD	Solids				Nitrogen			Bacterial counts/ml			
							TS	TVS	TSS	VSS	Total	NH_3	$NO_2 + NO_3$	FS	FC	TC	TB X 10^5
Tank 1 8/3/72	7.6	23	0.8		230	520	1194	318	152	132	62.2	31.2	0.6	6,000	48,000	120,000	670
Tank 2 8/3/72	7.5	22	2.2	<0.01	84	300	2448	294	70	70	40.1	33.5	0.1	2,000	17,000	20,000	500
Process Tank 8/3/72	7.2	21	2.5	>3	54	300	2398	406	55	44	26.4	22.1	2.3	<0.05	<0.05	<0.03	43*
10/2/73	7.5			<0.01	12	34	910	340	22	18	46.5	44.7	0.7	300	340	640	130
Process Tank Effluent 8/3/72	8.3	21		>3	64	360	3990	584	86	57	31.6	23.3	2.4	<0.05	<0.05	<0.03	4*
Gravel Filter Effluent 8/3/72	7.5	19		≥3	24	270	3828	628	51	37	32.8	25.5	2.5	<0.05	<0.10	<0.03	24*
Curtain Drain 8/3/72	7.3	19		<0.01	35	240	3126	418	18	17	25.5	17.3	6.8	5	<0.04	52	8.3
10/2/73	6.9	18			44	85	980	410	60	44	40.6	2.2	38	11	1.3	26	14

Key:
Temp = temperature, °C
D.O. = dissolved oxygen, mg/l O_2
Cl = total residual chlorine, mg/l Cl_2
BOD = biochemical oxygen demand, mg/l O_2
COD = chemical oxygen demand, mg/l O_2
TS = total solids, mg/l
TVS = total volatile solids, mg/l
TSS= total suspended solids, mg/l
VSS = total volatile solids, mg/l
Nitrogen = mg/l N

Bacterial counts, #/ml
FS = fecal streptococci
FC = fecal coliforms
TC = total coliforms
TB = total bacteria

* TB/ml not TB X 10^5

The chlorine also affects treatment in the 18 inch deep gravel filter. Nitrification would be expected in the filter, however, the effluent contained 25.5 mg/l N as ammonia and only 2.5 mg/l N as nitrate.

Significant BOD removal is indicated (from 230 mg/l O_2 in Tank I to 24 mg/l O_2 in the gravel filter effluent), while the COD remains high (270 mg/l O_2 in gravel effluent). The chlorine undoubtedly affected seed organisms in the BOD test. More realistic values were estimated by dividing the COD values by the average COD/BOD ratio from Tanks I and II (unaffected by chlorine). Table 2 gives the results of this adjustment showing a BOD of 92 for the gravel filter effluent.

Sedimentation appears to be the primary treatment functioning in this system as indicated by the suspended solids reduction (from 152 mg/l in Tank I to 86 mg/l in Process Tank effluent).

An evaluation based upon a low number of samples is difficult. However, the following general statements can be made. In principal, the system can not be considered an aerobic process because it lacks characteristic utilization of biologically active sludge. Consequently, the treatment provided in removing BOD and suspended solids is similar to the septic tank (Robeck et al. 1964). The system is apparently capable of providing high degrees of disinfection when chlorine is provided, although, the chlorination is detrimental to the nutrient removal process. The complexity of the system is greater than other household aerobic systems available, adding to cost and chance of mechanical failure (Otis 1972).

Table 2 Adjusted BOD_5 for samples from Site A (8/3/72)

Sample	BOD_5 Measured	COD Measured	COD/BOD	Adjusted BOD_5 (2.93)
Aeration Tank I	231	520	2.25	178
Aeration Tank II	84	304	3.62	104
Process Tank	54	304	5.63	104
Process Tank Effluent	64	360	5.63	123
Gravel Filter Effluent	24	270	11.25	92

The soil absorption field and curtain drain:

The hydraulic conductivity data, graphically represented in Fig. 2, shows the capacity of the Blount silt loam soil to transmit water. These values were determined by methods developed at the University of Wisconsin (Bouma et al. 1972). The topsoil (the IIB1 horizon described in Tables 3 and 4) has a permeability of about 3 cm/day and the subsoil (IIB2tg), at the depth of the absorption trench, 2 cm/day. These values are low. Furthermore, the soil undoubtedly will not be able to accept even this amount of liquid, especially after crusting (clogging) or physical compacting of the infiltrative surface in the seepage trench occurs.

The curves in Fig. 2 can be used to predict the decrease in acceptance of liquid as a function of crusting. Crusting results in a moisture tension in the soil below the seepage area; the stronger the crust the higher the moisture tension with associated lower hydraulic conductivity. Although measurements of moisture tensions below the trench in this system have not been made, the data and soil descriptions indicate that this soil has very marginal capacity for accepting liquid wastes. Results of percolation tests at 20, 35, 50 and 60 cm depths in the soil were 240, 120, 120 and 120 minutes/inch, respectively; confirming marginal liquid acceptance.

Assuming a soil moisture tension of 20 millibars (for a crusted absorption field) the hydraulic conductivity drops from 2 cm/day to 1 cm/day (see Fig. 2). At the estimated daily flow (550 gal/day) and assuming uniform distribution, the loading rate to the field is about 1.2 cm/day, implying failure of this field is probable.

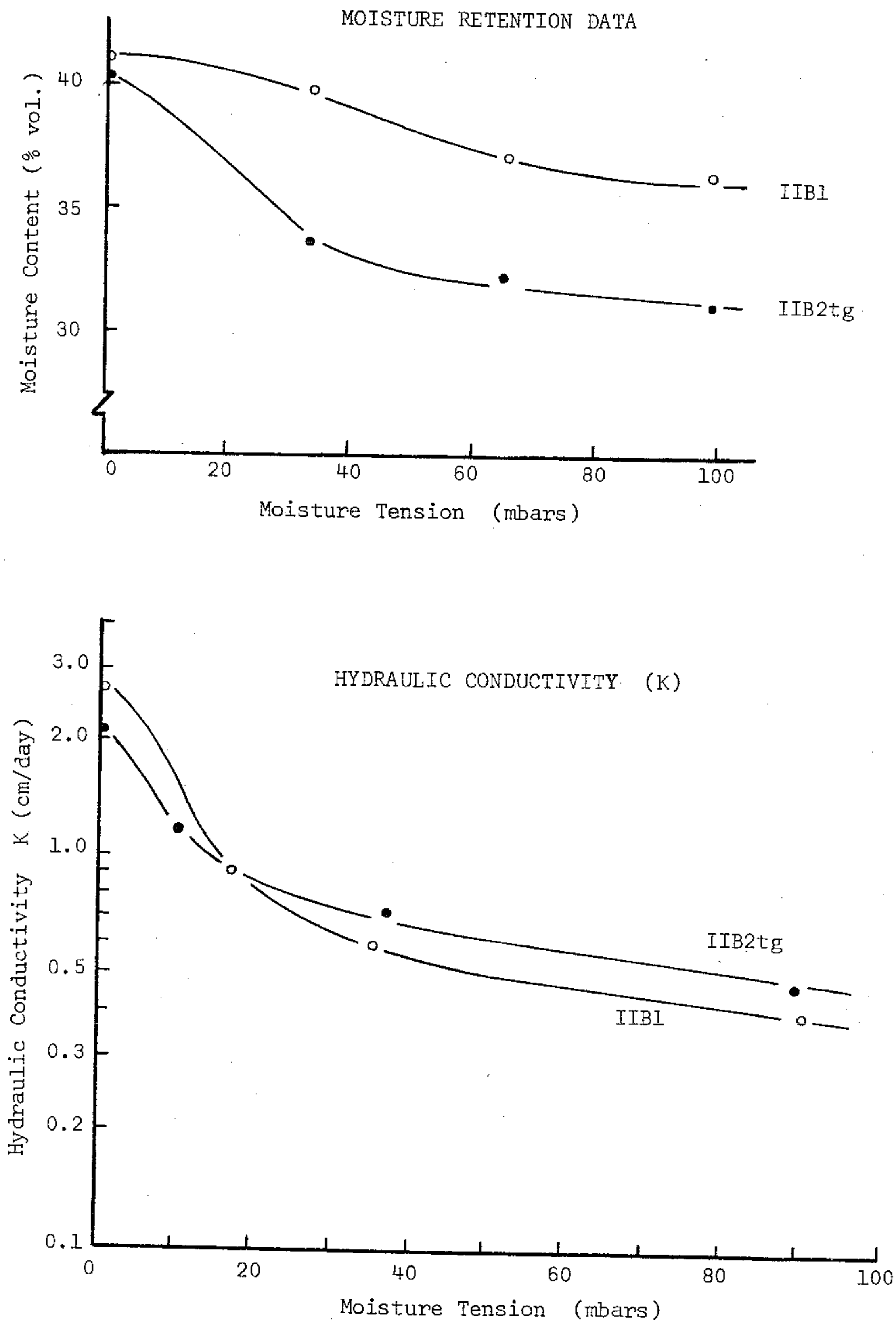


Figure 2. Moisture retention data and hydraulic conductivity for two horizons (IIB1 and IIB2tg) in a Blount silt loam.

Table 3 Profile description of the Blount silt loam

Soil Horizon	Depth (cm)	Description
A1	0-7	Brownish black (10YR 3/1) silt loam, medium granular structure, friable; few faint fine dull brown (7.5YR 4.4) iron mottles.
IIB1	7-25	Brown (7.5YR 4/4) clay, moderate medium subangular blocky structure; firm; common clear fine bright brown (7.5YR 5/6) iron mottles.
IIB2tg	25-50	Dull brown (7.5YR 5/3) silty clay loam, moderate medium angular blocky structure; firm; common clear medium brownish gray (7.5YR 6/1) coatings, mainly on ped faces.
IIB3tg	50-80	Dull yellowish brown (10YR 5/4) silty clay loam; moderate coarse prismatic structure parting into a moderate medium angular blocky structure; firm; common clear fine bright brown (7.5YR 5/6) iron mottles and common clear medium light gray (7.5YR 8/2) coatings concentrated on ped faces.
IIC	80+	Bright brown (7.5YR 5/6) silty clay loam; moderate medium platy structure parting into a medium angular blocky structure; firm; many clear medium bright brown (7.5YR 4/4) iron mottles inside peds and many clear light gray (7.5YR 8/1) coatings on ped faces.

Note:

This pedon can be classified as an Aeric Ochraqualf (Blount silt loam).

The soil shows many signs of impeded drainage. Iron mottles and reduced spots, occurring in the B and C horizons, indicate waterlogged conditions. The physical measurements made at the site confirmed these indications.

Table 4 Particle size analyses, particle density and bulk density of soil in horizons of Blount silt loam

	VCS	CS	MS	FS	VFS	CSi	MSi	F Si	Clay	Total	Texture	Bulk Density	Particle Density
A1	0.0	0.3	3.4	6.9	6.4	11	23	18	31	100	Silt loam		2.29
IIB1	0.0	0.2	1.2	2.4	3.2	4	14	16	57	100	Clay	1.39	2.39
IIB2tg	0.0	0.3	1.6	3.5	6.6	6	20	18	44	100	Silty clay loam	1.41	2.39
IIB3tg	0.1	0.4	1.8	3.8	5.9	6	21	18	43	100	Silty clay loam		2.33
IIC	0.1	0.4	1.6	3.3	6.6	6	23	17	42	100	Silty clay loam		2.46

However, during the study, surfacing of effluent was not apparent. Evapotranspiration and the curtain drain may have prevented failure.

Discharge from the curtain drain was observed on both sampling trips. High ammonia concentrations (17.3 mg/l) in the first sample (8/3/72) of curtain drain effluent, as well as, relatively high numbers of indicator bacteria (11 FS/ml, 1.3 FC/ml and 26 TC/ml) in the second samples (10/2/73) indicated an effluent of questionable quality. However, the FC/FS ratio is <0.1, which may reflect pollution from other sources or contaminants from the bacterial flora of the soil and plants (Geldreich 1966). Never-the-less, short-circuiting of liquid from the absorption trench is suggested.

Site B

The treatment system and soil type at this site are similar to those of Site A. Evaluation of the curtain drain in this system was of primary interest. A topview of the soil disposal system is presented in Fig. 3. The sump from which the curtain drain liquid was obtained is marked with the letters CD. The dimensions and depths of the seepage trenches and curtain drains are given on the figure.

Results of sampling are presented in Table 5. On both sampling trips liquid was discharged by the curtain drain. Soil borings (on 9/10/73) to a depth of five feet showed soil upslope from the curtain drain was extremely dry, estimated at 20% moisture content, corresponding to a tension of about 60 millibars. Under these conditions water movement from the surrounding soil to the curtain drain was physically impossible.

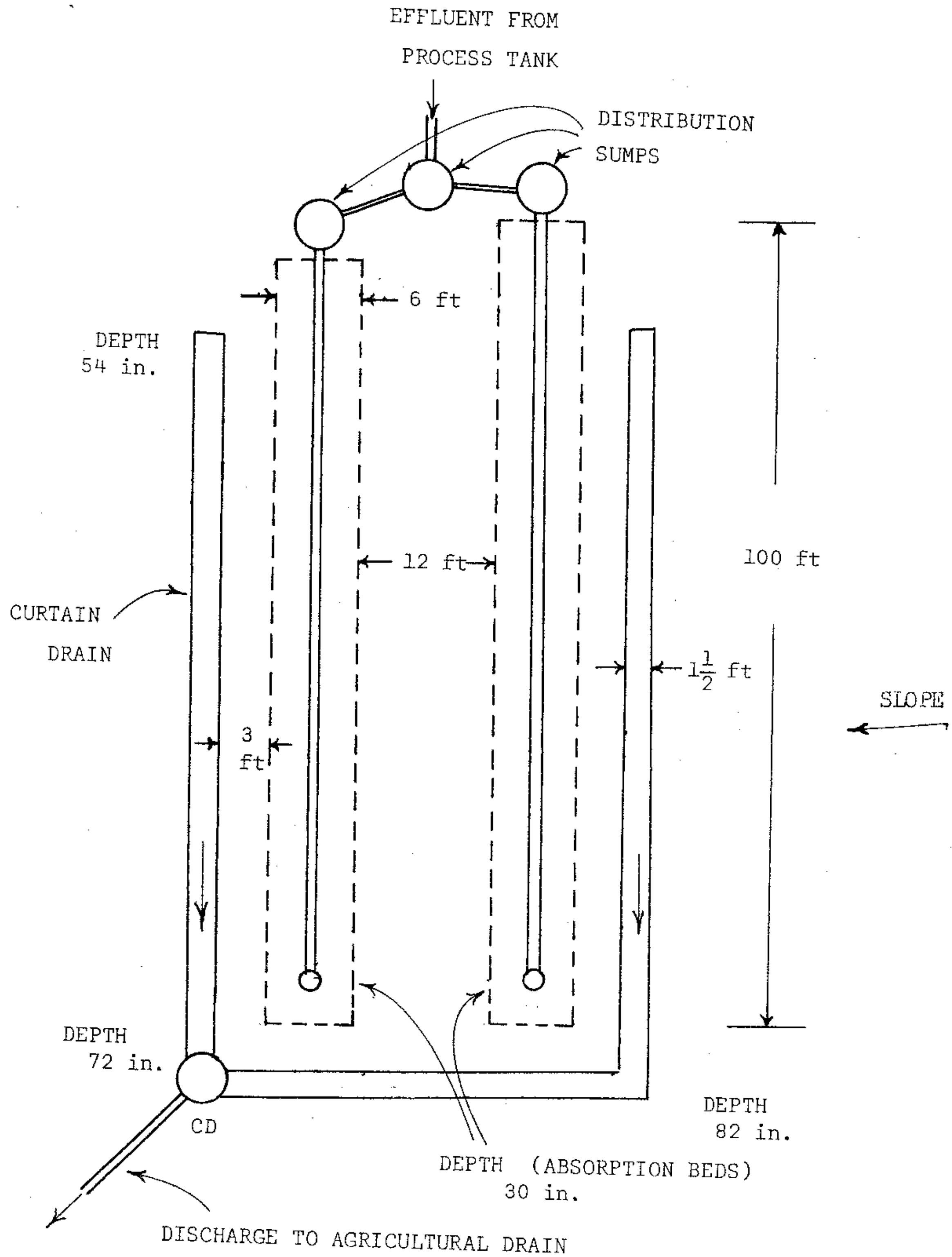


Figure 3. Top view of soil absorption field with curtain drains at Site B. Indicated depths are to tile in curtain drain and bottom of absorption beds from ground surface.

Table 5 Analytical results from the experimental treatment system at Site B

Sample date	pH	Temp	Cl	BOD	COD	Solids				Nitrogen			Bacterial counts/ml			
						TS	TVS	TSS	VSS	Total	NH_3	$NO_2 + NO_3$	FS	FC	TC	TB X 10^5
Process Tank																
9/10/73	7.5	23	<0.01	82	326	1720	248	272	256	37.2	32.9	0.2	16,000	14,000	25,000	100
Sump																
9/10/73	7.7	22	<0.01	43	272	1670	272	276	228	41.7	37.5	0.2	8,000	4,000	12,000	82
10/2/73	7.6	20	<0.01	70	139	980	312	44	36	36.6	36.4	0.2	7,300	850	11,000	15
Curtain Drain																
9/10/73	7.3	17	<0.01	37	208	1700	580	336	88	32.6	22.6	0.9	84	85	220	25
10/2/73	7.3	16		14	28	1010	350	52	40	11.8	<0.01	11.5	13	9.5	80	0.16

Key as in Table 1

Analytical results on samples from the curtain drain indicated potentially hazardous pollutants had reached the curtain drain from the absorption field. The curtain drain effluent contained 22.6 mg/l ammonia - N and high numbers of fecal indicator organisms (84 FS/ml, 85 FC/ml and 220 TC/ml). The FC/FS ratio of 1.0 is within the range (0.7 to 4.0) suggesting an effluent which may contain human fecal contaminants (Geldreich 1966). Similar results were obtained from samples taken on 10/2/73, however, nitrification occurred with 11.2 mg/l of nitrate in the curtain drain effluent and somewhat lower numbers of indicator bacteria then in the earlier sample. The FC/FS ratio remained in the 0.7 to 4.0 range.

It should be pointed out that outlets from the sumps not indicated on the designer's plans (in addition to those leading to the absorption field) were found. Rodamine dye was added to these outlets followed by flushing with large quantities of water to investigate the possibility of a direct connection (or bypass) to the curtain drain. Dye was *not* observed in curtain drain effluent two hours after addition.

In summary, this disposal system did not function adequately. The liquid discharged to an agricultural drain from the curtain drain contained unacceptable levels of fecal indicator bacteria. Also, short-circuiting of wastewater from the absorption field to the curtain drain is suggested by the data and may have caused system failure.

CONCLUSIONS

1. The mechanical treatment units evaluated cannot be considered typical aerobic units because proper mechanisms for maintaining biologically active sludge are not provided. Consequently, the quality of the effluents is similar to that of a septic tank.

2. Chlorination provides a high degree of disinfection, however, biodegradation (treatment) is restricted in the Process Tank and the gravel filter due to the affect of chlorine on the bacterial flora.

3. The system is elaborate, adding to cost and the possibility of mechanical failure. Proper maintenance, as providing chlorine feed solution, is not assured.

4. The curtain drain (at Site B), placed down slope of the absorption beds in the silt loam soil, discharged liquid which had not been sufficiently purified. Short circuiting of sewage (from the absorption bed to the curtain drain) between soil aggregates is strongly suggested, although, sewage bypassing the absorption field via pipes (found in the sumps) with unidentified points of discharge and not on offical plans may have contaminated the curtain drain liquid.

REFERENCES

Bouma, J., W.A. Ziebell, W.G. Walker, P.G. Olcott, E. McCoy and F.D. Hole. 1972. Soil Absorption of Septic Tank Effluent. Information Circular No. 20. University of Wisconsin-Extension. Geological and Natural History Survey. 235 p.

Geldreich, E.E. 1966. Sanitary Significance of Fecal Coliforms in the Environment. U.S. Department of Interior, Federal Water Pollution Control Administration. Publication WP-20-31.

Otis, R.J. 1972. Characteristics of Commercially Available Aerobic Household Wastewater Treatment Units. Appendix D, Small Scale Waste Management Project--Progress Report. University of Wisconsin, Madison.

Robeck, G.G., T.W. Bendixen, W.A. Schwartz and R.L. Woodward. 1964. Factors Influencing the Design and Operations of Soil Systems for Waste Treatment. JWPCF 36: 971.

Standard Methods for the Examination of Water and Wastewater. 1971. 13th edition. Prepared and published by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation.