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Effluent Quality Under Saturated Conditions for Wisconsin Mound Systems

by

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EFFLUENT QUALITY UNDER SATURATED CONDITIONS

FOR WISCONSIN MOUND SYSTEMS

James C. Converse* E. Jerry Tyler*

The Wisconsin mound on-site wastewater treatment and disposal system was developed in the 1970's for sites with slowly permeable soils, high water table soils or shallow soils over bedrock in which the in-ground trench or bed systems are not suitable. This technology has been incorporated into the Wisconsin Administrative Code (1983) and has been accepted by many states and counties in the United States and in several countries. Over the past decade mounds have been installed on sites outside the limits of the Wisconsin Administrative Code. As a result of the recent field experience Converse and Tyler (1990) have developed a siting, design and construction manual.

Mounds on slowly permeable soils with seasonally high water table, may saturate at the toe during wet seasons (Fig. 1). This saturation results in spongy areas or leakage to the ground surface at the toe of the mound. Leakage results only if the sand and top soil cover are saturated. If leakage is prevalent for extended periods, curtain drains may remove the water causing the leakage. The purpose of this paper is to report the quality of effluent from the toe of saturated mound fill and drain outflow.

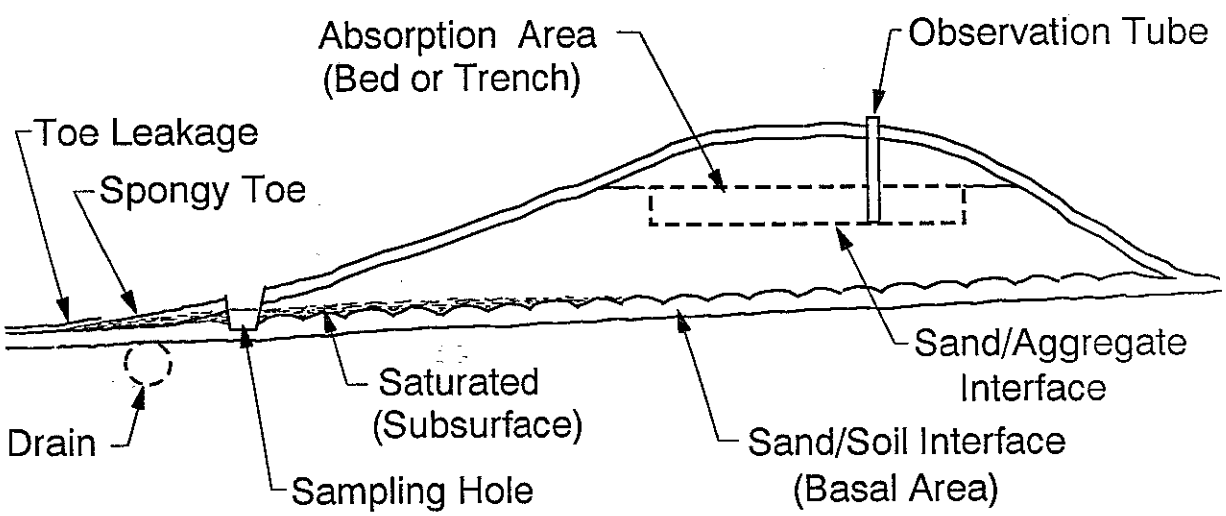

Fig. 1. A cross section of mound showing spongy area, toe leakage and sampling location for saturated toe and for mounds with drains installed.

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METHODS AND PROCEDURES

Mound Descriptions

Table 1 gives the characteristics of the fifteen mounds that were sampled for effluent quality at the saturated toe or from drains installed at the toe. Figure 2 shows a plan view and cross section of the mounds. Mounds 1-10 and 14 and 15 had no modifications. Mounds 11, 12 and 13 (Table 1) had drains installed at the toe to remove effluent. The drains consist of 4 in. perforated corrugated plastic pipe with a fabric covering.

In 1983 a mound (Fig. 3, Mound 12 in Table 1) was installed on a very slowly permeable soil consisting of a silt loam surface horizon with a massive clay loam subsoil. Leakage started shortly after construction and continued during a major portion of the year. Converse and Tyler (1987) reported on the mound and effluent quality at the toe of this mound prior to mound modification to overcome toe leakage. The toe of the mound was extended 10 ft and two drains were installed (Fig. 3). Mound sand enveloped the first drain. The second drain was installed in native top soil 2 ft downslope of the first drain.

In 1983 two parallel mounds (Fig. 4, Mound 12 in Table 1) were constructed with drains several feet from each longitudinal toe (Fig. 4). The drains were connected at one end and each daylighted to a ditch at the other end. The drains were located 3 ft from the mound toe and 18 inches deep. The purpose of the drains was to lower the high water table and remove excessive soil water. The soil consists of about 10 in. of silt loam over a mottled silty clay to clay subsurface horizon.

In 1990 a mound (Fig. 5, Mound 13 in Table 1) was installed with the mound toe adjacent to a driveway. Shortly after the system became operational the mound started leaking at several locations. The toe of the mound was adjacent to a gravel driveway which in all likelihood restricted horizontal flow of the effluent thus causing the toe leakage. The mound toe was allowed to dry and a drain was placed at the mound toe (Fig. 5). To avoid a large tree located near the longitudinal center of the mound, two drains were installed with one discharging to a ditch and the other one to a grass wooded area at the opposite end of the mound.

Sampling and Sample Analysis

Periodically, especially during wet weather, mound toes were observed for saturation, toe leakage and spongy toes. To check the moisture of materials within the mounds, a one inch diameter probe with a section of the side removed was inserted into the mound toe through the top soil cover, sand and into the native top soil and extracted. The core of soil removed was evaluated visually and by feel. Moisture level was described as dry, moist or saturated.

On most occasions if the sand fill at the toe was saturated, effluent samples were extracted from a hole excavated at the toe of the mound to just below the sand/soil interface (Fig. 1). Samples were collected in a sterile bottle with a hand vacuum pump. Samples were placed in a cooler and returned to the laboratory for analysis. If the mound toe was not saturated no samples were taken.

Table 1. Characteristics of the Twelve Mounds and Three Modified Mounds which were Sampled for Toe Saturation and Drainage.

Mound No.	Date Installed	No. Bedrooms	Slope	Dimensions*-(ft) B	A	I	D	E	High Water Table	Soil Profile Descriptions From CST Reports
			(%)	(ft)					(in.)	
1	1987	3	2	90	4.5	14	1.0	1.1	8-10	0- 8" Bl sil, 9-16" sil/cinder fill, 16-52" R c/sicl.
2	1979	3	4	47	8	25	1.25	1.5	12-14	O-12" fscl, 12-30" fsl/c bands.
3	1982	3	8	76	5	25	2.0	2.4	12-17	0-12" ts, 12-58" cl.
4	1980	3	2	47	8	10	1.0	1.1	19	0-8" ts/fill, 8-20" sic.
5	1984	3	3	100	5	21	1.3	1.5	6-16	0-16" Bn sicl fill, 16-28" sic.
6[a]	1985	6	3	190	4	11	2.0	2.1	5-12	0-9" si, 9-30 cl
7[a]	1985	6	3	190	4	11	2.0	2.0	5-12	0-9" si, 9-30 cl
8	1985	3	10	90	4.5	19	1.0	1.45	12-22	0-4" Bl sil, 4-19" cl/sil/gr
9	1981	3	8	75	5	25	1.0	1.4	-	0-10" ts, 10-60" sil/gr compacted
10[b]	1978	3	2	46	4	20	1.0	1.1	-	0-6" sicl, 6-26" cl
11	1983	3	2	125	4	13	1.5	1.6	10	0-8" sil, 8+" - cl massive. 1984 extended I by 10 ft and installed 2 drains with 2 ft separation.
12[c]	1982	0	0	61	5	13	1.5	1.6	12-13	0-10" sil, 10-24" sicl/cl/c.
				70	5	13	1.5	1.6	12-13	Installed 3 drains initially on edge and between mounds. Drains to ditch.
13	1989	3	2	104	3.6	10	1.0	1.2	24	0-10" sicl, 10-27"cl. Old driveway next to toe. Tree near midpoint at toe so put two drains beneath toe.
14/15[d]	1983	0	8	150	15	20	1.0	2.2	N.A.	N.A.

*Refer to Fig. 2.
[a]Mounds 6 and 7 are same except No. 7 is perpendicular to slope with break to reduce the D and E depths.
[b]Mound has two identical parallel trenches 20 ft on centers.
[c]Mound serves an apartment and bar.
[d]This system consists of 6 equal sized mounds serving a trailer court.

All samples were evaluated in the laboratory for total and fecal coliforms, ammonia, nitrates and chlorides. A few of the samples were evaluated for BOD, suspended solids and organic nitrogen. Fecal and total coliforms, BOD, suspended solids and nitrogen series were analyzed according to Standard Methods for the Examination of Water and Wastewater (APHA, 1985). Chlorides were determined using an automatic coulometric/amperametric chloride titrator.

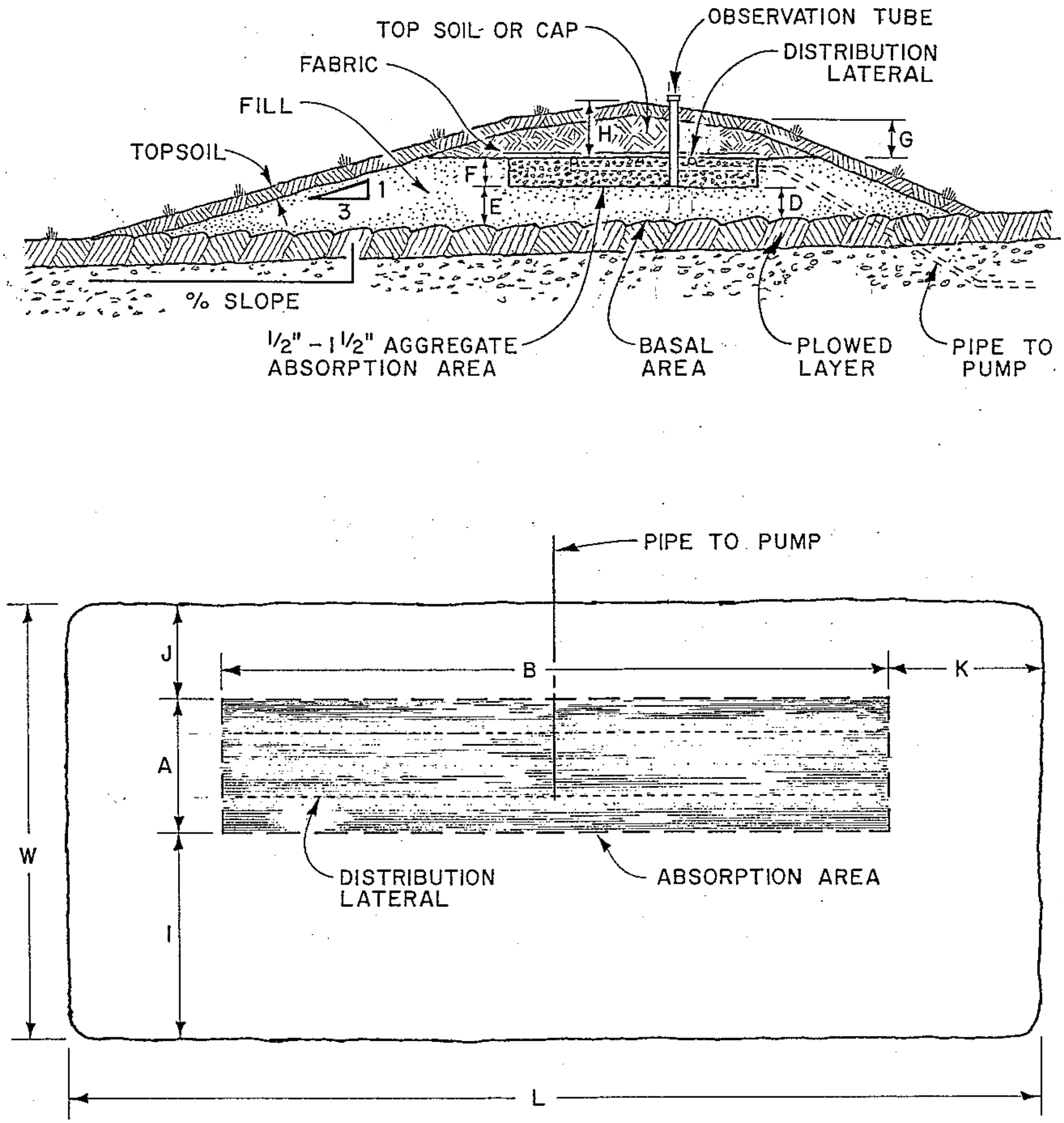

Fig. 2 Plan view and cross section of the mound showing dimensions corresponding to those in table 1.

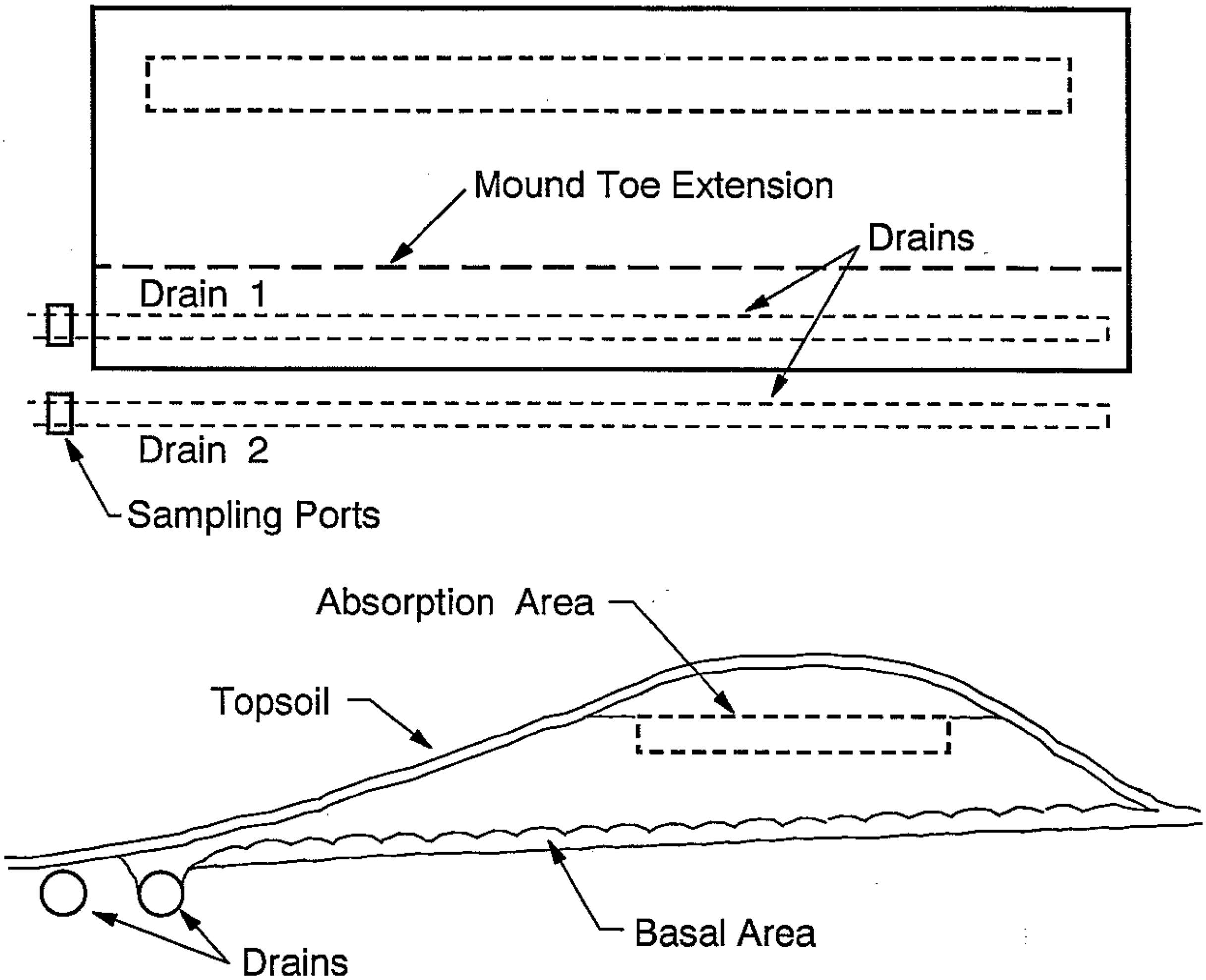

Fig. 3. Plan view and cross section of a mound showing two drains and mound toe extension.

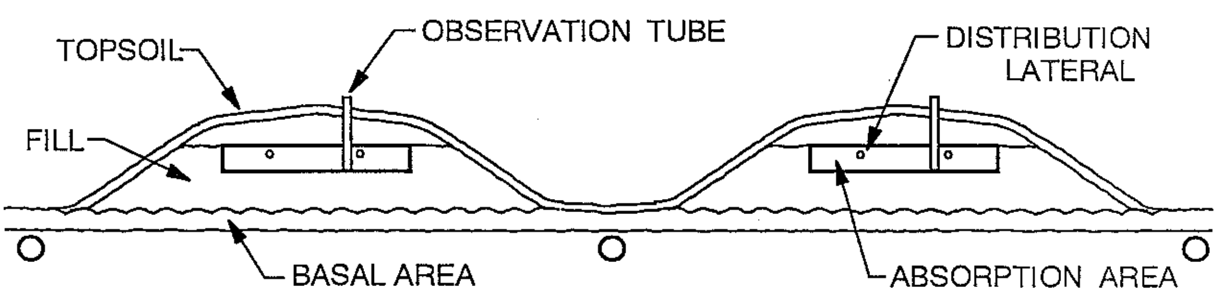

Fig. 4. Cross section of a two parallel mounds showing the drains adjacent and in between the mounds. The drains are connected at one end with a perforated pipe and are open to a ditch at the other end.

The effluent discharge rate from the drains was measured periodically at two of the three sites. The total volume discharging was collected over a measured time. Flow rates were taken at the time of sampling and are not a composite average. At the same time effluent discharging from the drains was collected in a sterile bottle, placed in a cooler and returned to the laboratory for analysis. Laboratory analysis consisted of measuring total and fecal coliforms, nitrogen series, chlorides and on some samples BOD and suspended solids.

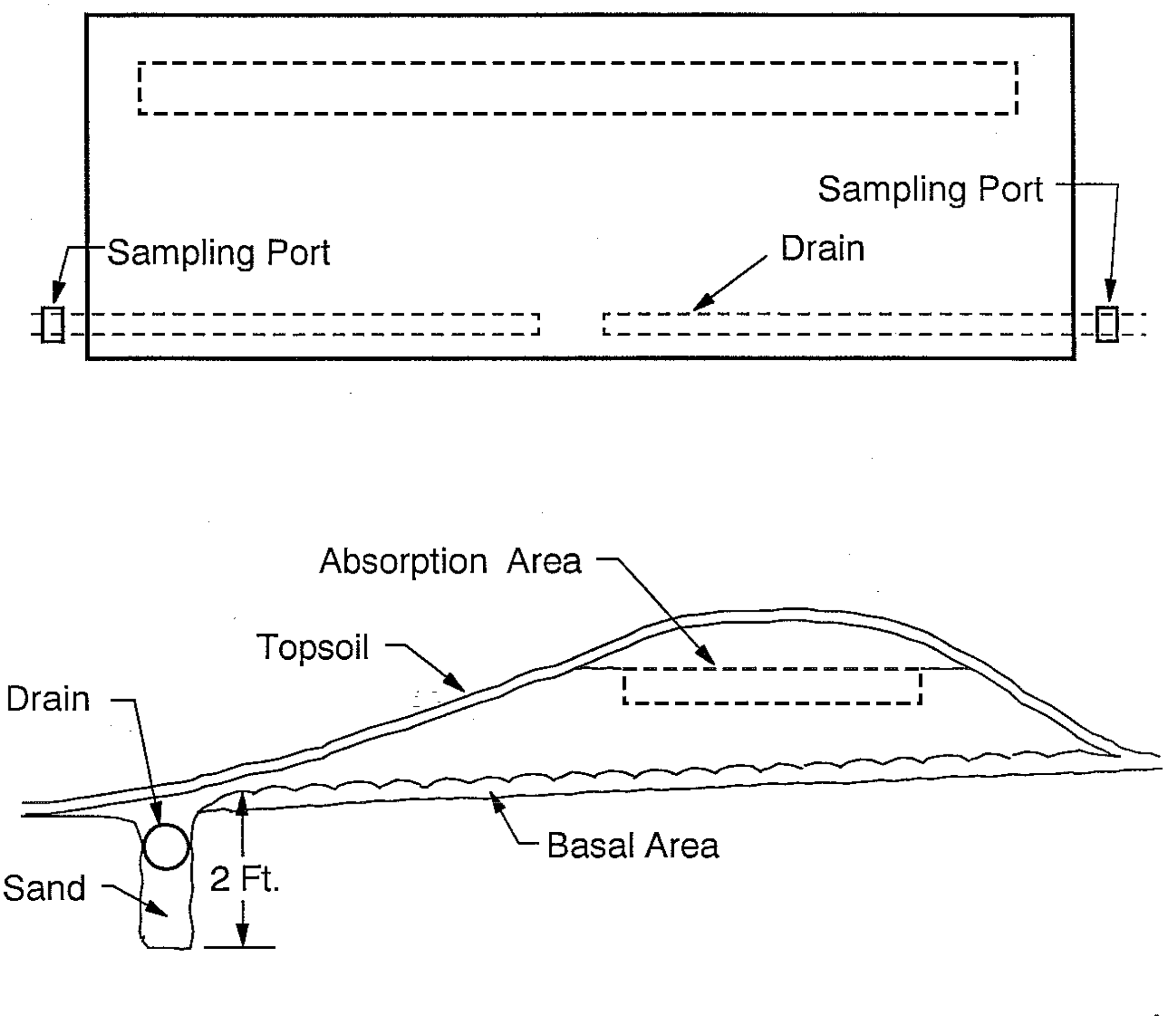

Fig. 5 Plan view and cross section of mound showing a drain beneath the mound.

RESULTS AND DISCUSSION

Table 2 gives the bacterial, nitrogen and chloride results for 10 mound systems (Mounds 1-10, Table 1) sampled intermittently from within the mound toe over the 12 years from 1979-91. Twenty eight samples were taken at the sand/soil interface of the mound toes. It is important to note that these are subsurface samples extracted in the saturated sand. No samples of ponded water on the ground surface was taken. Some mounds were sampled once and others sampled 4 different times. No mound was sampled over the entire 12 year period. Average fecal coliform count was 54 MPN/100 ml with a range of <1 to 700 MPN/100 ml. Of the 28 samples collected 19 samples (68%) had fecal counts of <10 MPN/100 ml.

The average ammonium concentration was <1 mg N/L with a range of 0 to 1 mg N/L. The average nitrate concentration was 4 mg N/L with a range of 0 to 20 mg N/L. Chloride concentrations averaged 71 mg/L with a range of 13 to 279 mg/L.

Table 2 Effluent Quality Under Saturated Conditions at the Mound Toe Over a 12 Year Period For Mounds 1-10 in Table 1 Serving Residences.

Parameter	Total Coli	Fecal Coli	Ammonia	Nitrate	Chlorides
	-------(MPN/100 ml)-------		------------(mg/l)---------------		
Ave *	24650	54**	0	4	71
Max	390000	700	1	20	279
Min	20	<1	0	0	13
Number	27	28	14	16	16

*No mound was sampled over the total 12 year period from 1979-91.
**Out of 28 samples 19 samples had fecal coliform counts <10 MPN/100 ml, four between 10 and 100 MPN/100 ml, three samples at 100 MPN/100 ml, one sample at 140 MPN/100 ml and one sample at 700 MPN/100 ml,.

Table 3 gives the effluent quantity and quality discharging from the drains installed at the toe and downslope of the toe extension (Fig. 3 and Mound 11 in Table 1). The average flow rate measured was 11 gph from the drain beneath the toe (drain 1) and 4 gph from the drain (drain 2) downslope of the toe. Average flow rates are based on periodic sampling and are not the average over time. In many cases when there was flow from drain 1 there was no flow in drain 2.

The average fecal coliform count for drain 1 was 6 MPN/100 ml with a range from <1 MPN/100 ml to 44 MPN/100 ml. Very few fecal coliforms were detected in the discharge from drain 2. The average total coliform count was greater from drain 2 than drain 1 but the high average was due to one very high value. The total nitrogen concentration in drain 1 averaged 12 mg N/L with 10 mg N/L as nitrate and the remaining as organic nitrogen with essentially no ammonium in the effluent. The average chloride concentration in drain 1 was 40 mg/L and 27 mg/L in drain 2. The water softener did not discharge to the septic tank. Drain 2 was separated from drain 1 with two feet of silt loam top soil. Thus it is likely that the discharge from drain 2 was primarily surface and ground water and not mound effluent.

Table 3 Effluent Quantity and Quality for Two Drains Installed at the Toe of a Mound on Very Slowly Permeable Soils (Mound 11 in Table 1, Fig. 3).

	Flow Rate	Total Coli	Fecal Coli	BOD	SS	TKN	NH4	NO3	Cl
	(gph)	-(MPN/100 ml)--		----------------(mg/l)--------------------					
Drain 1*									
Ave	11	3622	6	2	4	2	0	10	40
Max	100	57000	44	3	12	7	2	23	52
Min	0	1	<1**	1	1	1	0	1	12
Number	48	31	31	3	7	8	22	29	29
Drain 2*									
Ave	4	18919	3	-	-	1	0	4	27
Max	128	140000	<10	-	-	1	0	10	43
Min	0	1	<1**	-	-	1	0	1	2
Number	48	10	10	-	-	1	0	11	11

*Periodic sampling from 11-84 to 8-91 with 56 observations. For drain 1, located in the sand, there was no flow for 15 of the observations and there was non-recorded flow noted for 8 of the observations. For drain 2, located in the soil, there was no flow for 39 of the observations, trace flow for 6 of the observations and status unknown for 4 of the observations. These observations for both drains were are not included when determining the average flow rates.
**Fifteen samples had <1 MPN/100 ml; 27 samples out of 29 samples had <10 MPN/100 ml. for drain 1. Out of the 10 samples from drain 2, two samples had <10 MPN/100 ml and 8 samples had < 1 MPN/100 ml.

Table 4 shows the effluent quality from the three drains serving the double mound system (Fig. 4 and Mound 12 in Table 1). Very little data exists as the drains were dry on many sampling occasions. Sampling trips were done during the wet season. Of the 6 samples recorded all of them had fecal coliform

Table 4 Effluent Quality from Three Drains of a Double Mound (Mound 12 in Table 1, Fig. 4).

Date	Location	Total Coli	Fecal Coli	NH3	NO3	Cl
		---(MPN/100 ml)--		----(mg N/L)-----		(mg/L)
03-25-84	West*	11750	2	-	-	-
	Middle	6000	<4	-	-	-
	East	1550	<3	-	-	-
04-29-85	East	10	<3	-	15	712
04-08-86	East	500	<1	0	8	705
04-15-87	Middle	<10	<1	0	1	249

*If the other drain locations are not listed for a given date, there was no flow out of those drains.

counts of <5 MPN/100 ml. Nitrates were consistently low with a maximum concentration of 15 mg N/L. Chloride concentration was quite high ranging from 250 to over 700 mg/L.

A mound (Fig. 5 and Mound 13 in Table 1) was installed with the toe next to a gravel driveway. Shortly after construction, leakage occurred along the toe at several locations. Samples were taken from within the toe. A few months later a drain was placed in the toe of the mound with the outlet to a field on one end and a ditch on the other end. Effluent quality for five sampling periods, one in the toe prior to the drain installation and four from the drains, are given in Table 5. Sampling of the drains was done from a sampling port located at the end of the mound. After installation of the drain effluent flow was detected from the east drain two out of the four times observed. No flow was detected in the west drain. The fecal coliform count of the drain discharge was <5 MPN/100 ml.

Table 5 Effluent Quantity and Quality from a Mound with Two Drains (Mound 13 in Table 1, Fig. 5).

Date	Drain Location	Flow Rate (gph)	Total Coli -(MPN/100	Fecal Coli ml)-	NH3 ----(mg	NO3 N/L)----	Cl (mg/L)
05-31-90	East	-	200	4	2	20	23
	West	-	150	35	1	12	30
04-18-91	East	9.6	<5	5	1	22	14
	West	0	-	-	-	-	-
04-25-91	East	0	-	-	-	-	-
	West	0	-	-	-	-	-
07-24-91	East	0.4	125	3	0	13	24
	West	0	-	-	-	-	-
08-06-91	East	0	-	-	-	-	-
	West	0	-	-	-	-	-

In 1983 six identical mounds (Mound 14 and 15 in Table 1) were installed to serve a 62 unit trailer court. Periodically the mounds are alternated with three mounds receiving septic tank effluent at any one time. During normal spring evaluation in 1991, toe leakage from two of the three mounds in service was detected for the first time. In both mounds the leakage is located very near one end and confined to less than 10 ft along the length of the mound. Less than 30 ft of the toe had saturated conditions at the sand/soil interface at the May 20 sampling period.

Toe leakage was first observed May 5, 1991 on the SW mound. On May 15 a toe effluent sample was collected in the mound sand, as were all samples. It contained less that 10 MPN/100 ml (Table 6). On May 20 toe leakage from the CW mound was observed for the first time. Samples were taken in the mound sand for both mounds and found to contain 10 and 11 MPN/ 100 ml.

Ten days later and again three times after that each mound was sampled at the same location with fecal coliforms counts ranging from 5 to 3800 MPN/100 ml. Although this toe portion of the mound remains saturated, no leakage has been detected after the third sampling period. This change in concentration is similar to that reported by Converse and Tyler (1987) which proceeded the mound extension reported in Table 3. Nitrates in the saturated toe effluent during the first three sampling periods were 3-4 times lower in the CW mound than in the SW mound but increased during the latter sampling periods for both but more so for the CW mound. Also there was a general increase in chloride concentration for both mounds over the sampling period. These differences are difficult to explain as the septic tank effluent is applied alternately to three mounds from the same pump chamber.

Table 6 Effluent Quality from Two Mounds Serving a Trailer Court (Mound 14 and 15 in Table 1).

Date	Loc.	Total Coli	Fecal Coli	TKN	Nitrate	Chlorides
		-----(MPN/100 ml)--------		----------(mg/l)--------------		
CW Mound						
5-20-91	1*	850	11	2**	4	49
5-30-91	1	550	85	1	6	54
6-06-91	1	6000	60	3	3	44
6-12-91	1	16000	230	2	17	124
7-16-91	1	50	5	1	12	62
	2	12000	5	1	19	74
8-15-91	2	2000	90	4	24	129
SW Mound						
5-15-91	1	3500	<10	5	18	51
5-20-91	1	12000	10	1	19	50
	2	10	10	2	17	52
5-30-91	3	4500	880	1	15	54
6-06-91	3	12000	2400	2	22	56
6-12-91	4	12000	305	6	23	150
7-16-91	-	45000	5	1	24	65
8-15-91	-	6500	3800	2	22	111

*If the number is the same, the sample was taken from the same location, if not then it was taken within several feet of either side of location. 1.
**TKN is total Kjeldahl nitrogen which is the sum of the organic nitrogen and ammonia. In each case the ammonia was <1.0 mg/l.

If leakage does occur at the mound toe, which was very infrequent in the systems evaluated without drains (Mounds 1-10, Table 1) and very difficult to determine during the wet season, it is visually indistinguishable from precipitation with no sewage odor. However, toe leakage may contain some fecal indicators, nitrates and chlorides. In most all the cases evaluated the fecal count of the saturated effluent in the mound toe or discharge from the drains is below 10 MPN/100 ml except for some of the mound toe samples taken at the trailer court (Table 6).

According to water quality criteria for recreational use "the fecal coliform count may not exceed 200 per 100 ml as a geometric mean based on not less than 5 samples per month nor exceed 400 per 100 ml in more than 10% of all samples during any month" (Bureau of National Affairs, 1989). Thus based on the low fecal coliform counts and the number of times that leakage may occur for a given site, the risk that someone will come in contact with water that has fecal coliforms greater than the recreational standard is very low.. Thus it appears that mounds can be placed on sites with very shallow seasonally high water tables with minimal health and environmental impacts. The environmental and health impacts of some alternatives to the mound system on these sites may be much greater.

SUMMARY

Wisconsin mound performance has been evaluated for 15 mounds over the past 12 years for toe saturation and toe leakage including 3 mounds with toe drains. All mounds serve homes except for one that serves a bar and an apartment and two that serve the same trailer court. Mound toe saturation does occur periodically, especially in slowly permeable soils during seasonally high water table periods. Mound toe leakage is much less frequent than toe saturation. No toe leakage samples (on the ground surface) were collected in this study other than the drain outfall.

Fecal coliform counts were detected in the saturated sand in the mound toe at concentrations ranging from <1 to 3800 MPN/100 ml for the 12 mounds sampled with out drains. Of the 43 samples collected 16% (6 samples) had fecal coliform counts greater than 200 MPN/100 ml which is the limit set for recreational use. However, 5 of these samples came from two mounds where 15 samples were collected. For the other 10 mounds involving 28 samples only 3.5% (1 sample) had fecal coliform counts greater than 200 MPN/100 ml.

Fecal coliform counts in the drain outfalls ranged from <1 to 44 MPN/100 ml. Only three out of 51 samples (6%) contained fecal coliform counts greater that 10 MPN/100 ml. No samples contained fecal coliform counts greater 200 MPN/100 ml.

Nitrate concentrations in the mound toe effluent including the outfall from the drains ranged from 1 to 24 mg N/L with an average of 12 mg N/L. TKN (ammonia and organic nitrogen) concentrations were very low with most of the nitrogen in the nitrate form.

Mounds with toe leakage appears to present a very minimal chance of exceeding recreational use standards and may present less environmental impacts than some other alternatives such as holding tanks with land spreading or municipal treatment.

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