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SMALL SCALE WASTE MANAGEMENT PROJECT

Soil Dispersal of Highly Pretreated Effluent – Considerations for Incorporation into Code

by

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Soil Dispersal of Highly Pretreated Effluent -- Considerations for Incorporation into Code

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The primary role of the septic tank for treating domestic wastes is to remove settleable and floatable solids with the soil providing the treatment and dispersal into the environment. Soil loading rates and separation distances for septic tank effluent have been established for various soil and site conditions with typical loading rates in the range of 0.2-0.8 gpd/ft^2 and separation distances ranging from <1 to >4 ft. Higher wastewater loading rates to the soil and smaller separation distances from the infiltrative surface to groundwater or bedrock are possible if more advanced pretreatment units than a septic tank are used. These advanced pretreatment units, such as sand filters, recirculating sand filters, peat filters or aerobic treatment units (ATU), reduce BOD, TSS and bacteria allowing higher loading rates and lower separation distances than if septic tank effluent is applied directly.

The objectives of this paper are: 1) to summarize several research studies relating to a) treatment performance of three types of pretreatment units and b) soil dispersal of highly pretreated effluent, and 2) to discuss how the results may be interpreted for incorporation into code.

RESEARCH RESULTS

Converse and Converse (1998) evaluated 20 single-pass buried sand filters (Unit A), 21 suspended-growth-media aerobic units with vertical fabric filters (Unit B), and 10 suspended-growth-media aerobic units incorporating a septic tank, aeration chamber, and clarification chamber with fine mesh screen covering a plate filter (Unit C). Effluent samples were collected from the pump chambers. Standard laboratory procedures were used. Table 1 is a summary of the fecal coliform and BOD median values for Units A-C. The fecal coliform gives an indication of pathogen attenuation and public health concerns. BOD indicates the degree of organic matter degradation by the pretreatment unit. It does not serve as a public health indicator but as an indicator of potential clogging mat development. It is fairly well assumed that a clogging mat will not develop in soil absorption units receiving high quality effluent (low BOD and TSS). Values for other parameters, such as nitrogen, alkalinity, chloride, COD and TOC, are also available (Converse and Converse, 1998).

Converse and Tyler (1998) evaluated treatment performance of 39 modified mounds and at-grade units receiving highly pretreated effluent from aerobic units and sand filters. Seventy eight soil cores were taken directly beneath orifices at the infiltrative surface and at 6 in. intervals to a depth of 42 in. below the infiltrative surface. The soil cores were analyzed for fecal coliforms reported as MPN/g dry soil. Table 2 shows median, average, 90% less than and standard deviation of fecal coliform counts beneath the soil dispersal unit sorted into columns based on fecal coliform concentration entering the soil at the time of sampling. The influent concentrations range from Log 0-3 (1-1000), Log 3-4 (1000-10,000), Log 4-5 (10,000-100,0000) and Log 5-6 (100,000-1,000,000) col./100 mL.

A small field-cell study was conducted with effluent from an aeration unit applied to three 2-ft diameter cells loaded 6 times daily with loading rates of 1, 3 and 6 gpd/ft^2 (Converse and Tyler, 1998). Table 3 shows influent wastewater characteristics and the fecal coliform counts within the soil dispersal cells.

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[1] Member and Director, respectively, of the Small Scale Waste Management Project (SSWMP). Research supported by the College of Agricultural and Life Sciences.

TABLE 1. Fecal coliform counts and BOD_5 concentration for single-pass sand filter and aerobic units effluents serving residences (Converse and Converse, 1998).

Parameter	Sub Parameter	Unit A*	Unit B	Unit C
Fecal Coliform (col./100 mL)	Median (50%)	3	530	24,000
	Average	280	10,000	150,000
	90% Less Than	642	18,000	295,000
	Standard Deviation	950	41,000	350,000
	Minimum	<1	1	<1
	Maximum	7200	4.5×10^5	1.6×10^6
	Number of samples	79	185	66
BOD	Median (50%)	4.0	4.4	27
	Average	6.0	10.8	36
	90% Less Than	14.0	26.0	70
	Std. Deviation	5.4	16.0	25
	Minimum	0.9	0.5	0.5
	Maximum	23.0	76.0	103
	Number of samples	71	151	50

* Number of systems evaluated for Unit A, B and C were 20, 21 and 10, respectively. Unit A was a single-pass sand filter and Units B and C were suspended-growth-media aerobic units.

INTERPRETATION OF RESULTS

Table 1 provides field data relative to the quality of effluent being discharged to the soil treatment and dispersal unit. An important criteria in evaluating performance is variability of output from within and between units. Examination of the data for the three systems studied shows median (50%) fecal coliform counts of 3, 530 and 24,000 col./100 mL with averages of 280, 10,000 and 150,000 col./100 mL. The 90% less than values were 642, 18,000 and 295,000 col./100 mL for units A, B and C, respectively (Table 1). Based on the relative magnitudes between medians and averages, standard deviations, minimum and maximums, Unit A provides a more consistent, lower fecal coliform concentration effluent to the soil than does either Unit B or C, and Unit B provides a lower more consistent effluent than Unit C.

Table 2 provides insight as to how well the soil attenuates the fecal coliforms. It should be noted that the analysis was performed on soil samples rather than extracted soil water. The units for fecal coliforms are MPN/g dry soil and not the typical col./100 mL used for water samples. There is no direct correlation between the two methods, and the numbers are not interchangeable. At this time the significance of the MPN/g dry soil is unknown. However, if the number is <1 MPN/g dry soil, it means that fecal coliforms were not detected in the soil sample. Obviously, lower numbers indicate less potential for disease transmission than higher numbers.

Table 2 shows soil profile fecal counts sorted by the wastewater fecal coliform concentrations applied to the soil. The data is also grouped as median (50% of the time), average, and 90% less than (detects 10% of the time). If effluent with Log 0-3 (<1-1000) col./100 mL is applied to the soil at a reasonable loading rate, then one can expect that 50% of the time fecal coliforms will not be detected (<1 MPN/g dry soil) 6 in. below the point of application (Table 2, median, column 1, 6-12"). If a detection level of 50% of the time is not acceptable, then the separation distance increases to 24 in. (Table 2, 90% less, column 1, 24-30 in.) for no detects (<1 MPN/g dry soil) or a separation distance of 12 in. with the possibility of a detect (1 MPN/g dry soil) 10% of the time (Table 2, 90% less than, 12-18 in.).

TABLE 2. Median, average, 90% less than and standard deviation for fecal coliforms within soil dispersal units based on the fecal coliform concentration of the aerobically treated effluent entering the dispersal unit at the time of sampling (Converse and Tyler, 1998).

	Influent Fecal Coliforms (cols./100 mL) ---Log*---				Influent Fecal Coliforms (cols./100 mL) ---Log*---			
	0 - 3	**3 - 4**	**4 - 5**	**5 - <6**	**0 - 3**	**3 - 4**	**4 - 5**	**5 - <6**
Depth (in)	---**Median** (MPN/g dry soil)---				---**Average** (MPN/g dry soil)---			
0 - 1	1	14	40	329	8	16	48	364
1 - 6	1	5	9	112	15	8	34	270
6 - 12	<1	<1	1	39	2	11	22	90
12 - 18	<1	<1	<1	15	1	3	5	116
18 - 24	<1	<1	1	38	1	1	10	137
24 - 30	<1	<1	<1	9	1	1	3	123
30 - 36	<1	<1	<1	5	1	1	6	52
36 - 42	<1	<1	<1	1	1	1	3	2
Control†	<1	<1	<1	<1	16	5	2	8
No. Sites‡	19	7	9	4	16	5	2	8

	Influent Fecal Coliforms (cols./100 mL) ---Log*---				Influent Fecal Coliforms (cols./100 mL) ---Log*---			
	0 - 3	**3 - 4**	**4 - 5**	**5 - <6**	**0 - 3**	**3 - 4**	**4 - 5**	**5 - <6**
Depth (in)	----**90% Less Than** (MPN/g dry soil)----				---**Standard Deviation** (MPN/g dry soil)---			
0 - 1	2	17	83	700	24	8	42	366
1 - 6	5	18	98	773	78	7	45	350
6 - 12	2	9	46	254	9	29	52	116
12 - 18	1	5	4	354	1	5	16	197
18 - 24	1	2	3	383	4	5	36	183
24 - 30	<1	2	3	300	0	6	8	247
30 - 36	<1	<1	3	111	1	8	21	112
36 - 42	<1	2	2	2	1	11	8	1
Control	12	14	5	23	66	8	5	13

* Log 0 = 1, Log 2 = 100, Log 3 = 1000, Log 4 = 10,000, Log 5 = 100,000 col./100 mL.
† Controls were taken from 0 - 6 in.
‡ Number of cores is normally double the number of sites. However, there are instances where there may have been only one profile taken or profile not taken to 42 in. because of an obstruction.

TABLE 3. Fecal coliform concentrations in soil profile beneath the 3 cells receiving aerobically treated effluent (Converse and Tyler, 1998).

	Average			Minimum			Maximum		
	Loading Rates (gpd/ft²)								
	1.0	3.0	6.0	1.0	3.0	6.0	1.0	3.0	6.0
Depth (cm)	Fecal Coliforms (MPN/g dry soil)								
0 - 2	17	6	55	2	2	23	37	10	82
2 - 15	10	2	7	2	1	2	16	2	12
15 - 30	1	2	6	1	<1	<1	2	6	16
30 - 45	3	1	16	2	<1	2	4	2	35
45 - 60	5	3	25	2	2	2	6	5	53
60 - 75	1	30	121	<1	3	9	2	84	322
75 - 90	5	18	17*	5	3	14	7	32	19
90 - 105	<1	19	19*	<1	1	18	<1	51	19

Influent (col./100 mL)		
Sample Size = 7	Median .= 4900	Average = 6066
	Standard Deviation = 4575	Range = 560-15,000

* Average of 2 data points, all others are average of 3 data points. Some of these numbers are different than in Table 10 by Converse and Tyler, 1998. However, the trends and conclusions remain the same.

Separation Distance

Table 4 is information from Tables 1 and 2 for prediction of the separation distance for various pretreatment effluent qualities to meet an acceptable standard. For example, if the acceptable standard within the soil profile is 1 MPN/g dry soil or less for 90% or more of the time then the separation distances could be 12, 12 and >42 inches for sand filters (A), aeration units (B) and aeration units © respectively, row 5, based on the fact that the pretreatment unit will produce an effluent within the stated range or less at least 50% of the time (median values) and 12, >42 and >42 inches for sand filters (A), aeration units (B) and aeration units © respectively, row 11, based on the fact that the pretreatment unit will produce an effluent within the stated range or less at least 90% of the time. Conversely, and probably more important, pretreatment needs can be determined for the accepted combination of soil bacteria and percent of the time the goal is reached for the depth of suitable soil found at a site. So if there is 6 inches of suitable soil found at a site and the accepted goal is <1 MPN/g dry soil for 90% or more of the time then a sand filter or aerobic unit (B) meeting an effluent standard of less than 1000 col/100 mL for 50% or more of the time, row 1, or a sand filter meeting an effluent standard of less than 1000 col/100 mL for 90% or more of the time, row 7, would meet the goal. Therefore, with an established bacterial goal and probability of reaching that goal in the soil, as might be given by regulation, the site evaluator and designer can select the required level of pretreatment based on depth of suitable soil and the goal.

The data used for Tables 2 and 4 was collected beneath modified mounds and at-grade units from a wide range of soils in Wisconsin and has not been statistically analyzed. The bacterial acceptance levels (<1, 1, 2-5 MPN/g dry soil, Table 4) must be used with caution as they may not be significantly different. To effectively establish depths for treatment, data segregated by soil conditions and environmental conditions would be needed. The data shows logical trends and there is definitely fecal coliform concentration differences between sand filter and aerobic unit effluent. There may also be a fecal coliform count difference between aerobic units but more data from more types of units is required before that determination can be made.

TABLE 4. Separation distances in relation to pretreatment, acceptable levels of bacteria and % of time.

Row	% of time	Bacterial Acceptance (MPN/g dry soil)	Sand filter Unit A	Aerobic Unit B	Aerobic Unit C
	Soil Profile		Median - 50% (col./100 mL)		
			0-1000	0-1000	10,000-100,000
			Separation Distance (in.)		
1		<1	6	6	12
2	50*	1	6	6	6
3		2-5	<6	<6	<6
4		<1	24	24	>42
5	90	1	12	12	>42
6		2-5	<6	<6	12
			90% Less Than (col./100 mL)		
			0-1000	10,000-100,000	>100,000
			Separation Distance (in.)		
7		<1	6	12	>42
8	50	1	6	6	36
9		2-5	-	-	30
10		<1	24	>42	>42
11	90	1	12	>42	>42
12		2-5	<6	12	36

*50 refers to median (50% of the time) and 90 refers to 90% less than.

Hydraulic Loading Rates and Linear Loading Rates

Hydraulic Loading Rates: Since the advanced pretreatment units remove most of the organic matter compared to the septic tank, a clogging mat will typically not form within the soil dispersal unit unless solids are spilled over. Therefore, the hydraulic loading rate can be increased for most soil/site situations resulting in a reduced soil absorption area. However, if the pretreatment unit should fail and allow untreated effluent to enter the soil unit, or if it should spill a significant amount of solids, then the risk of a clogging mat increases dramatically because of the reduced size. A number of states allow reductions from 20-33% (Kaaterskill Engineering, 1997) when highly pretreated effluent is applied. Converse and Tyler (1998) reported that of the 39 sites evaluated for fecal reduction, 22 systems used only 50% of the design area and 17 used 100% of the design area with sizing based on septic tank effluent.

At higher hydraulic loading rates, the soil may not be able to adequately polish the effluent resulting in contaminants leaking out the bottom of the treatment/polishing zone. Table 3 shows the fecal coliform profile of three cells loaded at 1, 3 and 6 gpd/ft^2 to a well drained, strong structured silt loam soil. The fecal coliform concentrations are higher for the 3 and 6 gpd/ft^2 than for the 1 gpd/ft^2 loading rate, showing that the soil may not be capable of adequately treating the effluent to the desired level. Thus, consideration must be given not to downsize the soil absorption unit to the point where the loading rate exceeds the soil's ability to adequately treat the effluent.

Linear Loading Rate: When reducing the soil absorption bottom area, care must be taken as to how it is reduced. When working with highly pretreated effluent, typically it is not a problem of getting the effluent into the soil but a problem diffusing the effluent away from the system. Figure 1 illustrates the concept of linear loading rate which is defined as the amount of effluent applied per linear foot along the contour (gpd/linear ft). The figure on the left is the area (L×W) required for septic tank effluent. The middle and right figures represent the area (L×W)/2 required for highly pretreated effluent if the soil loading rate is twice that for septic tank effluent. The linear loading rate of the middle and left figure is the same, but the linear loading rate for the right figure is twice that of the other two, and the soil/site may not be able to handle the higher linear loading rate. Thus when reducing the area, the site must be evaluated to make sure that the

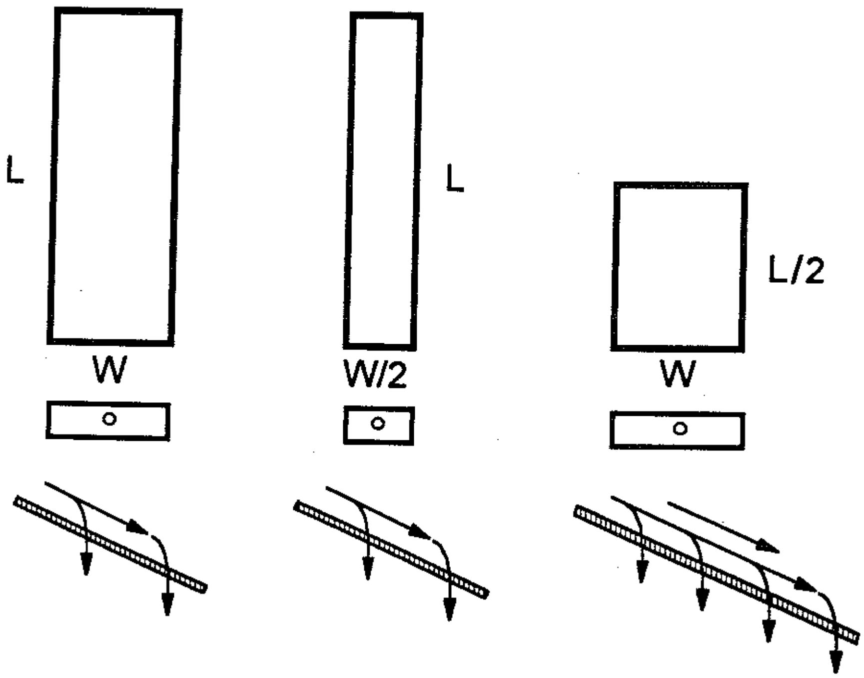

Fig 1. These three diagrams illustrate how configuration affects the linear loading rate. The left diagram represents the full size system. The middle one represents a half size system (bottom area) resulting in twice the soil loading rate and the same linear loading rate. The right one also represents a half size system (bottom area) resulting in twice the soil loading rate and also twice the linear loading rate.

effluent can adequately move away from the system, especially on sites with slowly permeable soil, with a shallow restrictive layer, or seasonal saturation. If it cannot, ponding will result with possible surface break out or backing up into home.

Effluent Distribution and Dosing Volumes

Since a clogging mat does not normally develop when highly pretreated effluent is applied, the localized soil loading rates for gravity flow will be extremely high and the soil may not be able to treat the effluent adequately. Pressure distribution will provide a more uniform application of the effluent, providing better treatment/polishing by the soil, especially in highly permeable soils. With pressure distribution, area/orifice should be relatively low (range of 6 ft^2) with low dose volumes (5 times distribution lateral volume) so as to minimize local overloading and yet provide reasonably uniform distribution. Orifice diameters of 1/8-3/16 in. should be utilized. In cold weather, all lines must drain after dosing to prevent freezing.

IMPLEMENTATION INTO CODE

Based on the research and discussion reported above, the State of Wisconsin implemented the following policy for replacement Private Onsite Waste Treatment Systems (POWTS) effective August, 1998. This policy applies to existing residential sites experiencing failing on-site systems. It is not available to new sites. The following is a summary of the design and soil/site conditions. As a point of reference, the current separation distance for septic tank effluent is 3 ft from the infiltrative surface to seasonal saturation or bedrock. The policy also contains administrative policies not included here (Baldwin and Burks, 1998).

1. The pretreatment unit must be a single-pass sand filter or an aerobic treatment unit (ATU).
2. For soils receiving effluent from ATUs, the separation distance is at least 24" from the point of application to seasonal saturation or bedrock.

3. For soils receiving effluent from a single-pass sand filter, the separation distance is at least 12" from the point of application to seasonal saturation or bedrock.

   Note: For items 2 and 3, if the soil is a loamy coarse sand, an additional 12" of separation is required if there is less than 35% coarse fragments or coarse sand. If there is > 35% coarse fragments or coarse sand, then the infiltrative surface is to be located on top of 24" (for ATU effluent) and 12" (sand filter effluent) of engineered soil (ASTM C-33).

4. Of the suitable soil, 12 or 24", at least 6" of the vertical separation between the infiltrative surface and limiting condition shall consist of *in-situ* soil with the rest consisting of engineered soil (ASTM C-33 specification).
5. The infiltrative surface area can be downsized (Table 5).
6. The treatment/dispersal area is to be designed using a linear loading rate that takes into account the shallow vertical separation distances and/or slowly permeable soils that may be present.
7. Pressure distribution must be used if the POWTS replaces a failing treatment/dispersal area or holding tank. For soil units being renovated using the highly pretreated effluent, the current distribution system may be used provided that the above separation distances are met.
8. If gravelless chambers are used, the infiltrative surface area is to be equal to or greater than the open bottom area of the chambers.
9. The local unit of government governing on-site treatment must agree to participate in the plan. Training of inspectors and installers is a prerequisite. Plans must be reviewed and approved by the State. Other requirements outlined in the Memorandum (Baldwin and Burks, 1998) apply.

TABLE 5. Soil loading rates for replacement systems in Wisconsin receiving aerobically treated effluent at the present time.

Soil Texture*	Soil Structure	--------Soil Loading Rate------- Septic Tank	Aerobic	Size Reduction
		------------(gpd/ft^2)-----------		(%)
Coarse Sand		0.8	1.6	50
Loamy Coarse Sand		0.8	1.2	37.5
Sand		0.8	1.2	37.5
Loamy Sand		0.8	1.2	37.5
Sandy Loam	Moderate to Strong	0.6	0.9	33
Loam	Moderate to Strong	0.6	0.7	17
Silty Clay Loam	Moderate to Strong	0.4	0.5	20

* More soil textures/structure classes may be added to the list in the future.

SUMMARY

Field data collected from monitoring 20 single-pass sand filters (Unit A), 21 aerobic units (Unit B), and 10 aerobic units (Unit C) were evaluated with field data collected from beneath 39 modified mounds and at-grade units receiving highly preteated effluent from aerobic units and sand filters to estimate separation distances from the infiltrative surface and seasonal saturation and bedrock. The criteria were fecal coliform concentrations in the effluent and the fecal coliform die-off in the soil profile. The State of Wisconsin has established separation distances of 12 and 24 in. between the infiltrative surface and seasonal saturation and bedrock for effluent from single-pass sand filter effluent and aerobic treatment units, respectively. Downsizing of the soil absorption area is also allowed on some soils.

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