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professional papers on

the study of onsite and

small community

wastewater issues

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Editorial Review Board

From the Editor

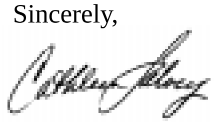
Among the offerings in this issue of *The Small Flows Journal* are two technical articles that focus on onsite systems, a subject of interest to most readers who live in or work with small communities. The first paper, *Effects of Length-Width Ratio and Stress on Rock-Plant Filter Operation*, examines rock-plant filter performance. According to the authors, rock-plant filters have low maintenance requirements and are a valuable alternative technology for sites with water-saturated soils with low permeability. The second paper, *Assessing the Impact of Household Cleaning Products on Wastewater Treatment Systems,* evaluates existing literature to determine whether down-the-drain disposal of household cleaning products upsets biological treatment processes in onsite wastewater systems.

Another interesting feature in this issue is information for readers from the National Small Flows Clearinghouse (NSFC), publisher of *The Small Flows Journal*. Internet users should refer to page 28 for information about the NSFC's new online discussion groups. Details about the NSFC's annual Earth Day special also are announced on this page. A new section, *Professional News*, follows the NSFC news section on page 29. Articles describing the research-related activities of two groups from different organizations are featured, and both articles outline the groups' efforts toward the development of performance-based standards for onsite systems. Both articles request feedback from the public and the research community.

This issue also marks another important change for the journal. Patricia Miller, Ph.D., who left the NSFC last year to begin work with the Virginia Department of Health, has continued to work as technical advisor for the journal on a volunteer basis. After this issue, she will begin a different role as a member of the journal's editorial review board. We thank Dr. Miller, who has worked with the journal since its inception, for being so generous with her time and for her valuable help and guidance.

This year, with the help of our editorial review board, we plan to evaluate the current role and format of the journal as it relates to the NSFC's mission to serve small communities. I would like to take this opportunity to invite readers who have thoughts, suggestions, encouragement, or criticism concerning the journal, to write to me at the National Small Flows Clearinghouse, West Virginia University, P.O. Box 6064, Morgantown, WV 26506-6064, or via e-mail to cfalvey@wvu.edu.

Sincerely,



Cathleen Falvey
Editor
The Small Flows Journal

Effects of Length-Width Ratio and Stress on Rock-Plant Filter Operation

by H. C. Bounds, Ph.D.
James Collins,
Zhiyun Liu,
Zhen Qin, and
T. A. Sasek, Ph.D.

ABSTRACT: *Three rock-plant filters sized to accommodate wastewater from a typical three-bedroom home were constructed with length-width (L-W) ratios of 4:1, 10:1, and 30:1. Each filter was preceded by two 1,900-liter (L) septic tanks in series, had a surface area of 25 m^2, and a design flow of 1,514 liters per day (L/day). Standard parameters of biochemical oxygen demand (BOD), total suspended and volatile solids (TSS, VS), as well as ammonium and sulfide effluent levels and biofilm accumulation on the gravel were determined over a 103-week (two-year) test period. No significant difference between the filters due to L-W ratio was observed, except for sulfide discharge amounts. Once plant and bacterial growth became established (approximately 6 to 8 weeks after initial start-up), each filter produced an effluent with BOD and TSS less than 30 mg/L. Various stress tests, such as "wash day," "equipment/power failure," and "10-day vacation," as well as unscheduled shutdowns, changing the plant species in the filters, and an extended period of intermittent flow all failed to reduce the efficacy of the rock-plant filters.*

Rock-plant filters (which are also sometimes referred to as submerged vegetated beds) include any system of wastewater treatment that uses a bed of gravel or rock in combination with various semiaquatic plants. The rocks provide a support medium for plant growth as well as surfaces for microbial activity (Cooper and Boon, 1987; Wolverton, 1987). The filter system is essentially a substitute for the traditional absorption field lines associated with septic tank systems (Wolverton et al., 1983; Wolverton et al., 1984).

Rock-plant filters have been shown by several studies to be an effective means of treating domestic wastewater (Burgan and Sievers, 1994; Huang et al., 1994), animal wastes (Maddox and Kingsley, 1989), and industrial wastes (Litchfield and Schates, 1989). The advantages of rock-plant filters over other methods of wastewater treatment include low maintenance requirements, few if any mechanical parts, and beds that can be lined and used in soils with low permeability.

The Louisiana Department of Environmental Quality's Nonpoint Source Management Plan (LDEQ, 1993) estimates that over 1.3 million people in Louisiana treat and dispose of their wastewater in individual septic tank systems even though soil surveys indicate that 87 percent of the soils in Louisiana are considered inadequate for conventional septic systems. For example, the 25 parishes (counties) that border or lie south of the Interstate 10-Interstate 12 corridor

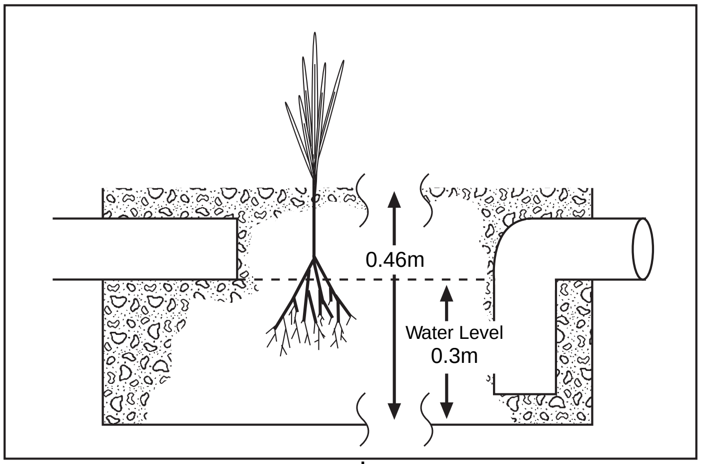


FIGURE 1 ▲
Generalized cross-section of the rock-plant filter bed (not to scale).

from Lake Charles to Slidell, Louisiana, comprise roughly 25 percent of the land area of the state and consist of mainly water-saturated soils with low permeability. Individual residences in these parishes not on public wastewater systems have the potential of contaminating the bayous, bays, and estuaries that feed into the Gulf of Mexico. Currently, the only approved option for new residential construction other than a septic tank is a mechanical aeration unit. The rock-plant filter, if incorporated into Louisiana's sanitary code, could be useful in such areas and would require only very low maintenance for several years.

An evaluation of the experimental rock-plant filter systems in use in Louisiana in 1992 showed that 30 percent (8 of 27) of the systems considered met the U.S. Environmental Protection Agency (EPA) standard for BOD effluent discharge of less than 30 mg/L, 37 percent produced effluents with a daily maximum of less than 45 mg/L, and 33 percent exceeded both limits (Bounds and Denison, 1992). There was no standardization of design for the systems in overall capacity, length-width (L-W) ratio, retention time, or type of gravel medium used.

After reviewing the report, the Louisiana Department of Health and Hospitals, Office of Public Health (LDHH/OPH) requested a study of the effect of L-W ratio on a design it would adopt for a typical three-bedroom residence. Another objective was to determine how well the filter system could recover from various types of stress such as might occur from "everyday" operation by the typical homeowner.

This report summarizes the data accumulated from three rock-plant filters, each with a design load of 1,500 L/day, during a 103-week test period from May, 1995 through April, 1997.

Methodology

Filter Bed Systems

Three rock-plant filters of equal surface area but with L-W ratios of 4:1, 10:1, and 30:1 were constructed on the Northeast Louisiana University campus. Each filter bed system was preceded by two metal 500-gallon (1,893-L) septic tanks in series, provided a surface area of approximately 25 m^2, and had a design flow of 1,514 L/day. Each filter bed was filled to a depth of 0.46 m with unwashed "oversize gravel" (19 to 64 mm in diameter). Effluent drains were placed to maintain a 0.3-m water level. Assuming a 40 percent void space, the hydraulic capacity of each filter was 3,028 L. This was the standard set forth by the LDHH/OPH for a typical three-bedroom home to provide for a 2.5-day retention time in the septic tanks and 2-day retention in the filter bed.

Overall dimensions for the three filter beds were as follows:

a) 2.5 m wide • 10.0 m long • 0.46 m deep (4:1 L-W ratio).
b) 1.58 m • 15.8 m • 0.46 m (10:1 L-W ratio).
c) 0.9 m • 27.4 m • 0.46 m (30:1 L-W ratio).

Because of the drop in elevation at the test site, the 30:1 filter bed was divided into three 9.14-m sections, with the second and third sections approximately 0.15 m lower than the first section. Drains placed at the end of each section maintained a 0.3-m water level throughout the filter. Figures 1 and 2 show a generalized cross-section of a filter bed with the layout and sampling points of the test facility. Photos 1 through 5 show the project site and the filter beds at different stages of the project.

Canna lilies (*Canna flaccida*) and elephant ears (*Colocasia esculenta*) were used in combination as the plant species in each bed during the first 48 weeks of operation (year 1) and were established from bulbs placed at the water line in the gravel beds in mid-April, 1995. The plants were spaced on 0.9-m centers down the middle of the 30:1 bed, but 0.9 m apart in staggered rows in the 10:1 and 4:1 filters. During weeks 49 and 50 of the test period in late April, 1996, the plant growth was changed to single species by removing all or part of the canna lily-elephant ear clumps and adding cattails (*Typhia latifola*) to the 30:1 filter, canna lilies only to the 4:1, and elephant ears only to the 10:1 filter.

Raw municipal sewage for the systems was pumped from a Monroe, Louisiana, sewage lift station approximately 60 m away. The sewage was pumped from the wet well by a 1/4 hp submersible pump and delivered to the septic tank systems via 38-mm PVC pipe. The flow rate of the influent sewage into the septic tanks was calculated by a timed-fill procedure, delivering 76 L/minute during the duration of the project.

Gravity flow from the septic tanks was distributed into the 30:1 bed through a standard 3-m section of 10-cm perforated PVC pipe with an extra row of holes drilled between the existing perforations. Influent was distributed to the 4:1 and 10:1 filters through two 1.5-m sections of perforated pipe connected to the septic tank line with a "tee" and short sections of PVC. The perforated sections were placed approximately 0.4 m from the sides of each filter (see figure 2).

The systems were charged in April, 1995, and sampling began on May 22, 1995.

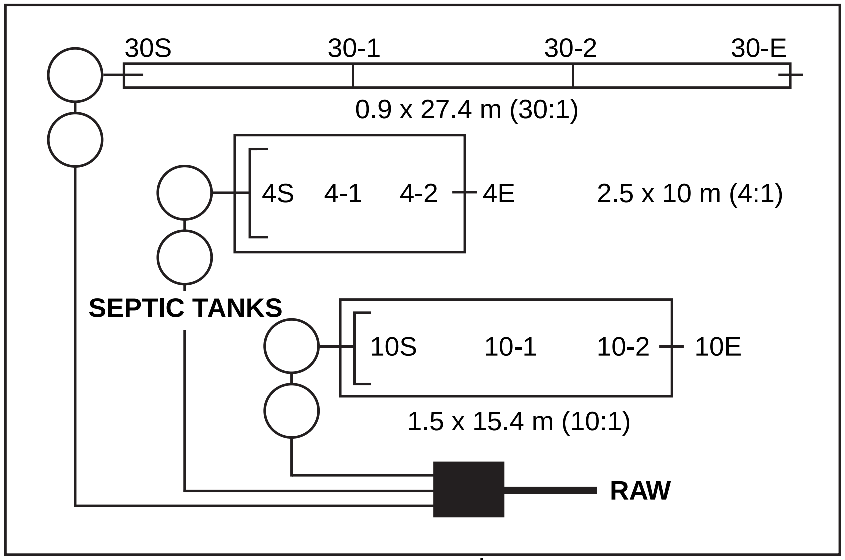


FIGURE 2 ▲
Plan view of experimental facility showing sampling ports for septic tank effluent (not to scale).

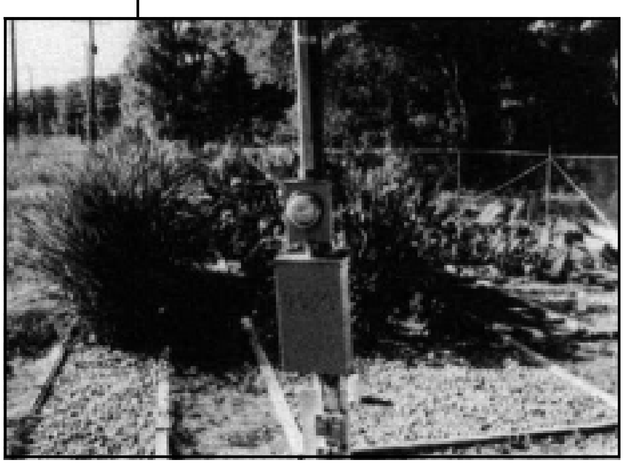
PHOTO 1 ▶
Original site in fall, 1994, before any excavation for rock-plant filters.

◀ **PHOTO 2**
Installing septic tanks (January, 1995).

PHOTO 3 ▲
Emergence of plants from completed beds (May, 1995).

PHOTO 4 ▲
Plant growth at the end of the first year (October, 1995).

PHOTO 5 ▶
Mature plant growth in the second year (fall, 1996). Beds have been converted to single species.



Dosing Schedule

The dosing schedule used in this project was a modification of American National Standard Institute (ANSI)/NSF International Standard 40 requirements for individual aerobic wastewater treatment plants (NSF International, 1990). The NSF 40 schedule calls for the hydraulic loading to be 35 percent daily flow in the morning, 25 percent at noon, and 40 percent in the evening. The flow into the municipal wet well did not fit this pattern. Apparently, most of the residents served by this lift station followed the "working parents" routine listed in NSF 40 as a stress test. The "working parents" routine (40 percent daily flow in the morning, 60 percent daily flow in the evening) was followed when the daily flow was 1,514 L/day. During some winter weeks of year 1, a reduced flow (757 L/day) was added at one dosing.

The filter beds were subjected to stress tests by altering the normal hydraulic loading to include "wash day," "equipment/power failure," and "10-day vacation" cycles as per NSF 40 guidelines. The "wash day" cycle modified the normal routine by adding three washer loads of detergent to each filter system during one 5-day period with a 24-hour period between each loading. The "equipment failure" test required 40 percent design flow added between 5 and 8 a.m., then no loading for 48 hours, followed by 60 percent design flow (including one load of washing). The "10-day vacation" cycle required 60 percent design flow between 6 a.m. and 2 p.m. on a Friday, followed by no influent until 5 to 8 p.m. on the second Sunday (60 percent design flow plus three loads of washing).

An unscheduled stress test occurred when the lift station was closed for 47 days for structural repairs. Dosing ceased on October 9, 1995, and resumed on November 25, 1995. After week 48 (when plant species were changed in the filter beds), intermittent flow of 1,514 L/day but dosing only three times per week was used during summer, 1996 to maintain plant growth. Daily dosing was resumed at week 68 and continued until the end of the project.

Sampling and Testing Methods

Primary composite samples were collected from raw sewage, septic tank effluents, and filter bed effluents daily using Sigma 800SL automatic samplers. Secondary samples were collected as grab samples usually once per week from sampling ports located at 1/3- and 2/3-bed length in each filter. Each daily sample was made by taking an amount proportionate to the morning and evening loading rate (40 percent from morning, 60 percent from evening).

The samples were held at 4°C between collection times and processed within one hour of the last sampling. The daily tests consisted of biochemical oxygen demand (BOD), total suspended solids (TSS), and volatile solids (VS), and were performed in accordance with *Standard Methods for the Examination of Water and Wastewater*, 18th ed. (Am. Public Health Assoc., 1992). For this report, BOD is reported as carbonaceous biochemical oxygen demand (CBOD) as described in *Standard Methods.*

Temperature determinations were made on site as samples were collected. Ammonium-N, nitrate-N, and hydrogen sulfide determinations were made on daily composite samples using Hach Chemical Company (Loveland, Colorado) reagents and test procedures. It is important to note that hydrogen sulfide measurements were made on the morning samples immediately upon return from the field when it was determined that chilling lowered the sulfide levels.

The oxidation-reduction potential (ORP) was determined on the filter bed fluid at 1/3- and 2/3-bed length and the effluent-end sampling ports of each bed with a Corning portable oxygen sensor. Samples were collected with a sewage sampler designed to hold 60-mL bottles but without the bottle. Measurements were made on site by inserting the sensor into the collected sample to a premarked depth and were read when the instrument reached equilibrium.

Biofilm accumulation on the gravel was estimated by collecting 400 g of gravel from the mid-level of the water area at 1/3- and 2/3-bed length, and effluent end of each filter. The gravel samples were collected with a shovel. Water was allowed to drain from the gravel, then individual rocks were removed with tongs and placed in a sealable plastic bag on the pan of a triple beam balance at the research site. Duplicate samples were taken from each location and the procedure repeated on three successive days.

At the lab, 200 mL of double-strength (2X) BOD buffer solution was added to each bag. A bag was placed in a sonicator-cleaner containing 1,000 mL of tap water and was sonicated for three minutes. The sonicate was decanted into a clean container and the bag was refilled with a second portion of 2X buffer solution. After sonicating for another three-minute cycle, the two aliquots were combined and the TSS of the material determined. Triplicate determinations were made on each sample. The results were reported as mg biofilm (dry weight) accumulated per kg gravel.

All data accumulated during the 103-week test were computed as per NSF standard 40 parameters of average value, standard deviation (s.d.) from the average, minimum-maximum, median, and interquartile range. Analysis of variance (ANOVA) was used to determine the significance of data.

Results

A summary of the CBOD values obtained over the course of the study is shown in table 1. The data are presented as year 1 and year 2 instead of an overall average since the plant species were changed from the combination of plants used in year 1 to single species per bed during year 2. While there were differences between year 1 and 2 CBODs, the data clearly indicate that no significant difference in CBOD was observed between the filter effluents due to L-W ratio.

TABLE 1

Summary of carbonaceous biological oxygen demand (CBOD).

	CBOD, mg/L			
	year 1 [a]		year 2 [b]	
sample	avg. (s.d.)*	range [c]	avg. (s.d.)*	range
raw	142 (26)	109–181	163 (58)	119–217
STE [d]	98 (28)	73–123	68 (23)	48–104
4E [e]	29 (16)	19–31	14 (6)	9–20
10E	27 (16)	17–29	12 (5)	8–19
30E	23 (15)	15–25	8 (4)	4–19

[a] Year 1 = weeks 1–48; plant species identical in each filter.
[b] Year 2 = weeks 68–103; plant species changed to canna lilies (4:1); elephant ears (10:1); cattails (30:1).
[c] Interquartile range = range about the median between the upper and lower 25% of all values.
[d] STE = septic tank effluent.
[e] 4E, 10E, 30E = effluent samples from 4:1, 10:1, and 30:1 filters.
* s.d. = standard deviation

TABLE 2

Effect of filter aging on the percentage of noncompliant effluent samples.

		percent samples CBOD >30 mg/L		
week #	sampling days	4:1	10:1	30:1
1–6	38	92	92	87
7–30	72	24	22	11
31–48 [a]				
@ 1,514 L/day	34	50	48	29
@ 757 L/day	20	0	0	0
49–67 [b]	-	-	-	-
68–103	115	2	0	0

[a] Weeks 31–48 includes winter months, 1995–1996.
[b] Intermittent dosing at 1,514 L/day, three times per week during summer, 1996.

The interquartile range is the range of values about the median between the upper and lower 25 percent of all values (NSF International, 1990). This calculation deletes extreme lows and highs for each sample and provides a more “normal” range of values. Extreme low CBOD values for raw sewage always occurred after heavy rainfall. Apparently, surface water runoff was infiltrating the municipal sewer. High CBODs could be obtained routinely only by amending the municipal sewage with 4 to 5 L of reconstituted powdered milk added to the wet well prior to pumping into the systems.

Amending the sewage during some weeks and not in others accounts for the large standard deviation for raw sewage and septic tank effluents (STE) as seen in table 1. For example, even though the milk was diluted in the wet well approximately 1:250, the average weekly CBOD of amended sewage was 184 mg/L. Non-amended sewage CBOD (weeks 77 to 78, 89 to 90, and 102 to 103) averaged only 71 mg/L (data not shown).

Ambient temperature extremes during the 103-week test resulted in weekly averages of 27 to 28ºC for the STE during the summer months and 10 to 14ºC during winter operation (data not shown). The filter bed effluents (4E, 10E, 30E) had weekly averages ranging from highs of 28 to 31ºC to a low of 6ºC during one winter period. Table 2 shows that cold temperature in weeks 31 to 48 did increase the percent of noncompliant samples; i.e., samples that exceed the EPA standard of less than 30 mg/L BOD. Reducing the hydraulic loading (increasing retention time) to 757 L/day allowed each filter bed to produce acceptable effluents. However, temperature extremes did not reduce filter efficiency during weeks 68 to 103, and no adjustments to the loading rate were made in year 2.

Table 2 also illustrates that while temperature had little or no effect on the overall operation of the filter systems, aging of the filter beds did result in increased filter efficiency. In the first six weeks of operation, 87 to 92 percent of all effluent samples, regardless of L-W ratio, exceeded the 30 mg/L standard. CBOD dropped to 11 to 24 percent during the next 24 weeks and was reduced to only two percent noncompliant effluent samples collected from the 4:1 filter in weeks 68 through 103.

Stress tests, as defined by NSF Standard 40 (NSF International, 1990), had little or no effect on the rock-plant filters in this study. Table 3 shows that none of the stress tests resulted in weekly CBOD values greater than 30 mg/L. The "10-day vacation" and the "unscheduled repairs" stress tests did produce some increase in the effluent CBODs from the previous week. The "vacation" test was conducted during the hottest part of late August and early September, 1995. Evapotranspiration lowered the water level in the filters 4 to 6 cm. Cooler weather and rainfall during the 47-day shutdown maintained the normal water level in each filter bed. Disturbing the beds by removing and replacing all or part of the plants had no effect on filter operation, even after 19 weeks of intermittent dosing.

The percent of CBOD removal within each filter bed was essentially the same during the first year of operation regardless of the L-W ratio (see table 4). Grab samples collected from specified sampling ports in the beds showed that each filter removed 54 to 60 percent of the raw sewage CBOD within the first third of its length, 70 to 74 percent at 2/3-bed length, and 80 to 84 percent at the effluent end of the bed. Occasional sampling during year 2 exhibited the same trend, except the overall effluent efficiency increased to 91 to 95 percent removal, irrespective of L-W ratio or plant species used (year 2 data not shown).

Removal of TSS and VS by the septic tank-filter bed systems closely followed that of CBOD removal. Table 5 demonstrates this quite well. The septic tanks routinely removed 50 to 70 percent of the TSS load and the filter beds removed 70 to 80 percent of what was left. Again, no

TABLE 3 ▼
Effect of stress tests on rock-plant filters.

	weekly CBOD, mg/L		
stress	4:1	10:1	30:1
"wash day" [a]			
week before	27	28	22
week after	8	7	5
"power failure" [b]			
week before	58	31	20
week after	16	17	12
"10-day vacation" [c]			
week before	17	16	16
week after	28	25	17
unscheduled repairs [d]			
week before	8	8	7
week after	19	16	6
change plants; Intermittent flow [e]			
weeks 47-48	27	26	25
weeks 68-69	7	6	5

[a] Normal cycle modified by adding three washer loads of detergent to each filter system during one, 5-day period with a 24 hour period between each loading.
[b] 40% of design flow added between 5–8 a.m., then no loading for 48 hours, followed by 60% of design flow including one load of washing.
[c] Vacation cycle requires 60% design flow between 6 a.m. – 2 p.m. on a Friday, followed by no influent until 5–8 p.m. on the second Sunday (60% desing flow plus three washings).
[d] Lift station closed for repairs from 10/16/95 to 11/20/95.
[e] Intermittent flow of 1,514 L/day.

TABLE 4 ▼
CBOD removal within rock-plant filters.

	average % removal [a]		
sampling site	4:1	10:1	30:1
1/3-bed length	54	54	60
2/3-bed length	70	71	74
effluent end	80	81	84

[a] Removal of CBOD from raw sewage; average of 20 samples.

TABLE 5 ▼

Summary of analytical results for total suspended solids (TSS).

	TSS, mg/L			
	year 1		year 2	
sample	avg. (s.d.)*	range	avg. (s.d.)*	range
raw	90 (51)	60–100	50 (20)	31–67
STE	27 (10)	15–30	24 (11)	18–31
4E	6 (3)	4–8	6 (3)	4–9
10E	7 (3)	5–9	5 (3)	4–9
30E	8 (5)	5–9	13 (5)	6–25

* s.d. = standard deviation

TABLE 6 ▼

Oxidation reduction potentials within the filter beds.

average ORP, millivolts			
sample site	4:1	10:1	30:1
1/3-bed length	-206	-206	-194
2/3-bed length	-201	-201	-149
effluent end	-195	-194	**-94***

significant at $P_{>0.01}$

TABLE 7 ▼

Effluent sulfide levels.

average sulfide, mg/L				
sample	year 1	(% reduction)	year 2	(% reduction)
raw	0.15		0.38	
STE	2.0		2.12	
4E	0.95	(52.5)	0.66	(68.8)
10E	0.80	(60.0)	0.61	(71.2)
30E	0.30	**(85.5)***	0.09	**(95.8)***

* significant at $P_{>0.01}$

TABLE 8 ▼

Effluent ammonium concentration.

NH4+-N, mg/L				
sample	year 1	(% reduction)	year 2	(% reduction)
raw	20.3		16.7	
STE	23.6		20.8	
4E	18.0	(23.7)	15.5	(25.5)
10E	19.3	(18.2)	14.9	(28.4)
30E	17.3	(26.7)	**6.7***	**(67.8)**

* significant at $P_{>0.01}$

significant difference was observed among the filters due to L-W ratio. The pattern for VS was similar to TSS (the VS data are not shown), but VS accounted for approximately one-third of the total TSS load.

Attempts to measure dissolved oxygen in the fluid in the sample port at the effluent end of each filter (rather than from collected samples) were abandoned early in the study. Sulfide in the effluent would contaminate the membrane of the oxygen probe. The sulfide, however, did not affect ORP determinations made on site with a portable meter. Table 6 shows that while there was no difference between the filter beds in regard to CBOD, TSS, or VS removal, there was a highly significant difference between the filters in ORP at the effluent ends. Normally, the 30:1 bed had a less anaerobic (less negative) ORP than the other two filters. This was characteristic of the bed in both years 1 and 2 even though the plant species were changed. The 4:1 and 10:1 filters had the same ORP throughout their respective bed lengths.

Hydrogen sulfide removal by the filter flora correlates quite well with the ORP data (see table 7). The 4:1 and 10:1 filters did reduce the sulfide level of STE by 52 to 60 percent in year 1 and 68 to 71 percent during year 2, but the 30:1 flora consistently released only 5 to 15 percent of the STE sulfide (85 to 95 percent removal). The increase in percent reduction during year 2 probably is due to filter aging rather than plant species since all three filters showed an increase.

On the other hand, ammonium concentrations in the effluents responded more to plant species than to bed aging as seen in table 8. During year 1 (when filters had identical plant flora), each filter removed only 18 to 26 percent of the NH4+-N released by the septic tanks. The 4:1 and 10:1 filter flora uptake during year 2 was only 25 to 28 percent. The cattails used in the 30:1 filter utilized this form of nitrogen to a greater extent, resulting in a 67 to 68 percent reduction.

The amount of biofilm accumulated on gravel surfaces was determined after the 48th and 103rd week of filter operation. Gravel samples collected from between clumps of plants were used to exclude as much visible root material as possible. Table 9 shows the results of the two biofilm determinations. There appears to be no consistent pattern other than a general increase in the amount of biofilm on the gravel in the second year.

No explanation can be given for the large increase in biofilm at the 1/3-bed length location of the 10:1 filter in year 2. Throughout the study, no attempt was made to restrict researchers from walking on the gravel beds. This may have accounted for some settling of the bed and gravel at this location.

TABLE 9

Biofilm accumulation with rock-plant filters

	biofilm, mg/kg gravel					
	4:1		10:1		30:1	
sample site	**year 1**	**year 2**	**year 1**	**year 2**	**year 1**	**year 2**
1/3-bed length	640	513	593	1,593	441	657
2/3-bed length	612	978	534	713	544	670
effluent end	759	615	457	778	703	950
bed average	**670**	**702**	**528**	**1,028**	**563**	**759**

Discussion

The three rock-plant filters used in this study proved to be efficient, easily maintainable alternatives for individual residence wastewater treatment. Once the plant and microbial populations became established, the filters consistently produced effluents below the EPA limit of less than 30 mg/L for BOD/TSS.

It is recognized that the hydraulic loading used for these filters was well below the maximum for the gravel medium. It was not our intent to determine the best design for rock-plant filters but simply to test variations of a design recommended to us by the LDHH/OPH. In our hands, the length-width ratio proved to be not as critical as previously reported (Wolverton, 1986) in regard to BOD, TSS, or VS reduction. In fact, the most striking similarity between the rock filters was that each reduced the BOD load 54 to 60 percent within the first third of the bed and 70 to 74 percent after passage through two-thirds of the filter length.

Rock-plant filters respond well to stress. A “48-hour power failure,” a “10-day vacation” period, and three washer loads of detergent (“wash day”) are recognized by NSF International as stress parameters for evaluating mechanical aeration units. Rock-plant filters are not mechanical aerators, but they should recover from such stress equally as well as any aeration unit. Our systems were constantly under stress (by NSF definition) since the “working parents” dosing schedule was used.

One proposed use for rock-plant filters, especially in Louisiana, would be for vacation homes or hunting/fishing camps in which the occupants are away for extended periods of time. In this study, extended periods of no dosing, intermittent dosing, and disruption of the filter medium failed to cause an increase in effluent BODs above the EPA limit. Rock-plant filters appear to be well-suited for such conditions.

The one significant difference between the three filters was the ORP at the effluent end. The 30:1 filter was always less anaerobic than the other two units, if not aerobic. This was observed repeatedly during both years of operation regardless of the plant species used. The result was a lower sulfide concentration in the 30:1 effluent than either the 4:1 or the 10:1.

On the other hand, selection of plant species for the filter bed can have an effect on ammonium released in the effluent water. Cattails used during the second year in the 30:1 filter proved to be much more effective in utilizing the ammonium in the wastewater than did either the canna lilies or the elephant ears. The cattails grew so well, in fact, that the homeowner would probably need to remove excess growth routinely from the bed to prevent clogging by roots. The removal should have no adverse effect on the system.

In conclusion, rock-plant filters can be used for residential wastewater treatment in any length-width ratio that fits the homeowner's grounds provided the septic tank-filter system has the hydraulic capacity for at least 4.5- to 5-day retention of the wastewater.

Acknowledgments

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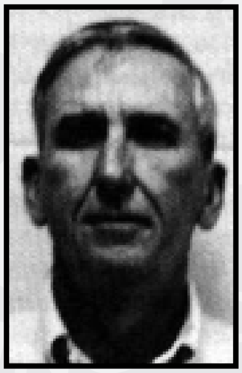

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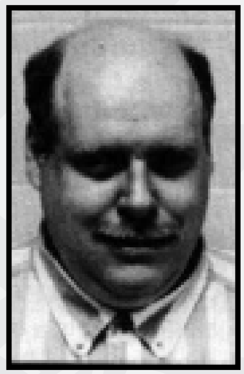

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Assessing the Impact of Household Cleaning Products on Wastewater Treatment Systems

by Daniel E. Edwards, Ph.D. and Alvaro J. DeCarvalho

ABSTRACT: *The concern has been expressed that disposal of unused household cleaning products can disrupt microbial wastewater treatment processes. This paper reviews the techniques used to evaluate the toxicity of cleaning products to residential wastewater treatment processes and examines examples of available data concerning common products under the most probable worst-case scenario—single-residence septic tanks. Microbial toxicity tests most commonly examine consumption of oxygen by microorganisms, production of anaerobic gases, or removal of a reference compound. If the concentration of the test substance is maintained below the "no-observed effect concentration" (NOEC) in these conservative tests, it is presumed that no toxicity will occur in the wastewater treatment process. The four case studies reviewed support the conclusion that disposal of whole-package quantities of typical household cleaning products results in little or no observed effect on septic tank function.*

Healthy microorganisms are critical to the efficiency of biological wastewater treatment processes. Optimization of environmental conditions for wastewater treatment microorganisms results in a robust living system and promotes efficient waste removal. Biologically adverse environmental conditions can result in the inhibition of microorganisms, possibly causing interference or failure of wastewater treatment processes.

Adverse conditions in wastewater treatment systems can result from exposure to toxic concentrations of chemicals in influent wastewater or chronic exposure to low concentrations of certain substances. In either case, the wastewater treatment efficiency of systems can be compromised for a period of time. In severe cases of biological system disruption, the wastewater treatment units may need to be restarted with new inoculum, or the microorganisms may require a significant period of recovery to rebuild a healthy population.

The majority of failures in publicly owned treatment works (POTWs) are caused by mechanical failures, hydraulic deficiencies, lack of maintenance, and interference by undesired microorganisms. When disruptions are caused by toxicity, the origin is usually large slug-doses of chemicals from industrial sources (Hänel, 1988). However, concern has been raised that microbial toxicity of household cleaning product ingredients may cause upsets in POTWs and household septic tanks, especially when whole containers of product are disposed of down the drain.

The purpose of this literature review is to evaluate the impact of down-the-drain disposal of cleaning products on wastewater treatment processes. Patterns of cleaning product disposal will be discussed, particularly in terms of dilution, to identify the wastewater treatment process most likely to be impacted by cleaning product disposal. Finally, case studies using worst-case assumptions will be reviewed to determine whether disposal of cleaning products has been found to upset biological wastewater treatment processes.

Wastewater Treatment Systems

As of 1992, 75.5 percent of the U.S. population was connected to POTWs (U.S. Bureau of the Census, 1993). The remaining population uses onsite treatment, predominantly in the form of septic tanks. The majority of onsite wastewater treatment systems are septic tank systems (EPA, 1987). In contrast to POTWs, most septic tank systems serve single-family residences, although some are designed for multiple dwellings and commercial businesses.

Septic tank systems gained widespread use in the U.S. during the 1940s and 1950s in both rural and suburban settings. Their design and construction is regulated according to individual state specifications (see table 1). Twenty-eight states require the minimum usable septic tank volume to be in the range of 750 to 900 gallons (2,839 to 3,407 L), 18 states require a minimum of 1,000 gallons (3,785 L), three states are regulated on a county or district basis, and one state (Louisiana) allows a minimum 500-gallon (1,893-L) septic tank for one-bedroom dwellings. In Louisiana, the typical septic tank would be expected to be larger because the primary design criterion for septic tank volume is 2.5 times the estimated daily flow.

Concentrations of Product Ingredients in Wastewater

Consumer products are not composed of single chemicals. Household cleaning products are generally formulations of active ingredients, a carrier (such as water), and additives that improve mixing and application or otherwise enhance

TABLE 1 ▼

Summary of state regulations on minimum septic tank capacities. [a]

state	minimum volume [b] gallons	additional volume gallons/bedroom
Alabama	750	250
Alaska	1,000	250
Arizona	960	300
Arkansas	750	250
California [c]	—	—
Colorado	750	250
Connecticut	1,000	250
Delaware	1,000	250
Florida	900	Add 1.5 X estimated additional daily flow
Georgia [c]	—	—
Hawaii	750	250
Idaho	900	250
Illinois	750	250
Indiana	750	250
Iowa	750	250
Kansas	750	250
Kentucky	750	250
Louisiana [d]	500	2.5 X estimated total daily flow
Maine	750	250
Maryland	750	250
Massachusetts	1,000	1.5 X estimated total daily flow
Michigan [c]	—	—
Minnesota	750	250
Mississippi	750	250
Missouri	1,000	250
Montana	750	250
Nebraska	1,000	250
Nevada	1,000	250
New Hampshire	1,000	250
New Jersey	1,000	250
New Mexico	750	250
New York	1,000	250
North Carolina	900	250
North Dakota	1,000	200-300
Ohio	1,000	250-300
Oklahoma	1,000	250
Oregon	1,000	250
Pennsylvania	900	Add 3.5 X estimated additional daily flow
Rhode Island	1,000	250
South Carolina	890	250
South Dakota	1,000	250
Tennessee	750	250
Texas	750	250
Utah	750	250
Vermont	1,000	1.5 X estimated total daily flow
Virginia	750	200-300
Washington	750	250
West Virginia	750	250
Wisconsin	750	225
Wyoming	1,000	250

[a] State regulations compiled by the National Small Flows Clearinghouse (1994).
[b] Minimum volumes may be based on 1, 1–2, 1–3, or 1–4 bedroom dwellings before additional volume is triggered, depending on the state.
[c] Regulations are based on a county-by-county or district-by-district basis.
[d] Minimum volume of 500 gallons (1,893 L) in Louisiana is for a 1-bedroom dwelling only. The primary design factor is 2.5 times the estimated daily flow.

product performance. Following disposal, each component of these mixtures meets its individual fate in the environment. Because certain household cleaning products are designed to have antimicrobial properties, the active ingredients providing these properties could logically represent the greatest potential of reaching concentrations that could inhibit biological wastewater treatment processes in residential systems.

The microbial toxicity of cleaning product ingredients should be evaluated in the context of typical and worst-case exposure concentrations under normal use and disposal practices. Some cleaning products, such as hand dishwashing detergents, will enter the disposal system on a daily basis in small quantities. Others will follow disposal of washwaters on a weekly basis. Pouring an entire package of a cleaning product down the drain represents the worst-case scenario.

In the case of POTWs, overall fluctuations in concentrations as a result of routine household use and disposal would be expected to be dampened by the presence of many POTW users. Because of the dampening effect that occurs in POTWs, the disposal of a single container of household cleaning product under a worst-case scenario would not impact the operation of the treatment works.

A simple mathematical method to predict the wastewater concentrations of consumer product ingredients in POTWs was developed by Holman (1981). This method uses general assumptions about per capita product and water use to provide an estimate of average product ingredient concentration in wastewater. This estimate is considered to be conservative because it assumes that all of the product is disposed of down the drain, and none is consumed during use or disposed of through other routes. The concentration of a product ingredient in municipal wastewater can be estimated by the following equation:

$$C_{mw} = \frac{X \cdot P}{Y \cdot Q} \qquad (1)$$

where:

C_{mw} = concentration of product ingredient in municipal wastewater (mg/L).

X = quantity of product marketed (mg/day).

P = ingredient fraction in product (percent by weight/100).

Y = population of market area (number of people).

Q = per capita wastewater flow rate (L/day).

The quantities X and P are available to the manufacturers of the products, and Y is available through census data. The quantity Q is variable according to geographic region and water use patterns. For estimation purposes, the per capita flow of 400 L/day is generally used for U.S. estimates (Cowen et al., 1992). More precise flow data may be obtained for specific wastewater treatment plants by consulting their records.

The general product ingredient category of surfactants may be used as an example to illustrate the application of equation 1. Surfactants are key ingredients in almost all cleaning product applications, including laundry detergents, dishwashing detergents, drying and antispotting products, and hard surface cleaners. More than one billion kilograms (9.8 million tons) of total nonsoap surfactants were sold in the U.S. for use in household cleaning product formulations in 1992 (U.S. International Trade Commission, 1994). No other single group of cleaning product ingredients would be expected to exceed the concentration of surfactants in average household wastewater.

Assuming the 1992 U.S. population of 260 million people produces wastewater at a rate of 400 L/day per capita, the average concentration of total surfactants calculated by equation 1 is 26 mg surfactant per liter of wastewater. This is a conservative calculation because some surfactants may biodegrade in sewers, and some are used in products that are not typically disposed of down the drain, such as automotive or agricultural cleaning products. The result of this calculation is consistent with the high-end of the ranges of surfactant concentration in residential community wastewater reported in reviews by Swisher (1987) and Srinivasarao et al. (1992).

In cases of onsite wastewater treatment, such as septic tanks, the lack of dilution from other households precludes dampening of high concentrations during periods of peak usage or disposal events. The dampening in this case is only a result of the wastewater coming from other uses in the household. Maximum ingredient concentrations resulting from disposal of unused product into septic tanks can be more directly calculated.

For example, if a liquid cleaning product contains 10 percent (weight/volume) of an ingredient, disposal of one gallon (3.785 L) into a 1,000-gallon (3,785-L) septic tank would lead to a maximum concentration of the ingredient of 100 mg/L in the aqueous phase, assuming the septic tank is completely mixed. Subsequent household water use would dilute and flush out this material, creating lower concentrations. This type of disposal into a septic tank can reasonably be expected to represent the worst-case scenario in terms of concentrations of cleaning product ingredients in a wastewater treatment system.

Patterns of Product Disposal

In order to understand the frequency of this worst-case scenario, the question remains: how often are cleaning products disposed of unused? In order to answer this question, The Soap and Detergent Association (SDA) commissioned a market research group (NPD Group, Inc.) to survey 20,000 randomly selected U.S. households. The following points from the summary of findings of the study are relevant to this report:

Of the 13,697 returned surveys (a 68.5 percent response),

- eight percent reported disposing of at least one unused cleaning product within the past three months,
- twenty-three percent reported using septic systems, and
- there was no difference in disposal patterns between those who used septic systems and those who used sewer systems.

Among the eight percent who reported disposing of unused products,

- the average number of products disposed of over the three-month period was 2.43,
- most of the product (67 percent) was disposed of by leaving it in the container and placing it in the trash, and
- ten percent was poured down the drain (no other single disposal pathway accounted for more than one percent of disposal).

The survey did not attempt to estimate the percent of the product remaining in the discarded container, but it does point out that down-the-drain disposal is performed infrequently. This is particularly true for higher volume products, which tend to get used up rather than dumped out (NPD Group, Inc., 1995). Because cleaning products are occasionally poured down the drain, manufacturers routinely address the impact of cleaning products on wastewater treatment systems.

Measuring Product Toxicity

The objective of wastewater treatment microbial toxicity tests is to determine the concentration at which a compound impairs the ability of the microorganisms to treat wastewater. If this concentration is greater than the expected exposure concentrations, then the compound is not expected to have a negative impact on the activity of wastewater treatment microorganisms. In general, there are three major categories of testing approaches: effects on respiration (or gas production from microorganisms), effects on removal of other compounds, and effects on performance during wastewater treatment simulations. These effects can be examined in both aerobic and anaerobic systems.

Oxygen Consumption

The major test currently addressing aerobic wastewater treatment microorganism toxicity in U.S. or European regulatory guidelines is Organization for Economic Cooperation and Development procedure number 209 (OECD 209): Activated Sludge, Respiration Inhibition Test (OECD, 1993a). This test is designed as a simple screening tool to assess the impact of a chemical on the overall respiration rate of activated sludge.

A solution containing an excess of nutrients is added to a beaker with microbial inoculum (seed) and various volumes of test substance stock solution. The microbial inoculum is activated sludge from a municipal facility treating primarily domestic wastewater. Controls without test substance are used in the test design to measure the background activity of the sludge. An inhibitor of respiration (3,5-dichlorophenol) is included as a negative control to assess sludge sensitivity to chemical inhibition. The 50 percent inhibition concentration of the standard inhibitor must be within a specified range in order for the test to be considered valid.

Each mixture of sludge, nutrient solution, test solution, and dilution water is aerated for a set period of time (usually three hours), following which the rate of dissolved oxygen (DO) consumption is measured. The "inhibitory effect" is defined by comparison to duplicate controls using the following equation:

$$1 - \frac{2R_s}{R_{c1} + R_{c2}} \cdot 100 \qquad (2)$$

where:

R_s = oxygen consumption rate (mg/ O_2/L/hour) at tested concentration of test substance,

R_{c1} = oxygen consumption rate (mg/ O_2/L/hour), control 1, and

R_{c2} = oxygen consumption rate (mg/ O_2/L/hour), control 2.

The percent inhibition is plotted as a function of the test substance concentration. The 50 percent inhibition concentration is determined from the resulting graph.

OECD 209 provides a measure of the overall impact of a chemical on a high-strength inoculum such as would be encountered in activated sludge-mixed liquor. This high concentration of sludge could buffer toxicity by adsorption of the test compound onto sludge solids. The high overall respiration rate of a variety of species consuming the abundant carbon also could mask some toxicity to individual species. The inhibition that is masked in this test could potentially become important in biodegradation tests using more dilute inoculum.

A test somewhat similar to the OECD test has been presented by Marks (1973). This test is a variation of the classic biological oxygen demand (BOD) test and is known as the BOD microbial toxicity test or BOD_m. In the BOD_m test a relatively dilute seed is prepared from domestic activated sludge. The seed is defined as 5 mL of a sludge culture that is fed daily with domestic sewage and whose "oxygen consumption rate is in the range of 1 to 3 mg/L/hour."

The seed is combined with a series of volumes of a test substance stock solution (or mixed waste stream of interest) in standard BOD bottles with a single concentration of a reference compound (glucose). The remaining volume in the BOD bottles is filled with dilution water and aerated to saturate the water with oxygen. The concentration of glucose is designed to be sufficient for the microorganisms to deplete one-half of the dissolved oxygen (DO) present in the mixture if no inhibition is encountered.

Each BOD bottle is incubated at 20ºC for three days without further aeration. The

DO is then measured in each bottle and plotted as a function of test substance concentration. The lowest concentration of test substance that causes a reduction in the oxygen consumption rate compared to a control is defined as the "threshold inhibition level." Concentrations of the test substance below the threshold are considered to be acceptable for wastewater treatment systems. The length of incubation can be shortened to less than three days if a higher concentration of sludge is used.

Numerous variations on methods measuring the impacts of chemicals on oxygen consumption have been published as biodegradation tests (Swisher, 1987). Many oxygen consumption tests use respirometers. A respirometer is a device that continuously monitors oxygen consumption and/or carbon dioxide generation in a test vessel. Respirometers can be used to measure real-time effects of substances on biological respiration in a continuously aerated system (Eckenfelder, 1980). Unfortunately, respirometric tests use apparatus that is relatively expensive and requires significant skill on the part of the analyst. However, recent technical advances in respirometer design and computerization are leading to wider use of these instruments (Mahendraker and Viraraghavan, 1995).

Anaerobic Gas Production

Anaerobic biological treatment is a major wastewater treatment process used throughout the world, primarily in the form of sludge digesters and household septic tanks. Because appreciable quantities of oxygen are not present in anaerobic systems, respiration tests based on dissolved oxygen are not applicable. In the place of oxygen consumption, gas production is the most common measurement of anaerobic activity.

The validity of gas production as an indicator of anaerobic activity is contingent on the presence of an active methane-producing (methanogenic) consortium of bacteria. The test system must be completely protected from exposure to oxygen, which is toxic to methanogens. Oxygen contamination in the test system can also lead to negative gas pressure as a result of absorption of oxygen into the test liquid. Examples of procedures used to evaluate anaerobic gas production are provided later in case studies reported by Yang et al. (1979) and Vaishnav and McCabe (1996).

Reference Compound Removal

An alternative to respiration measurements is measuring the effect of a chemical on the removal of a reference compound. The matrix containing the test chemical and a microbial seed (usually activated sludge or an anaerobic inoculum such as septage) is analyzed for the reference compound after a defined exposure period. This technique is regarded to be a conservative estimate of microbial inhibition because it measures a specific activity and not necessarily lethality.

A general test for inhibition of activated sludge using removal of ^{14}C-glucose has been described by Larson and Schaeffer (1982). In the aerobic version, sludge is obtained from a POTW receiving primarily domestic wastewater, aerated, and used within 2 hours of collection.

Aliquots of the sludge are placed in open beakers on a rotary shaking table with various concentrations of test substance stock solutions. After a five-minute equilibration period, an aliquot of ^{14}C-glucose solution is added to each mixture. Equilibration is continued for an additional 15 minutes, then terminated by the addition of hydrochloric acid. Samples of each mixture are filtered and assayed for ^{14}C activity by liquid scintillation counting (LSC), and the percent removal of the ^{14}C-glucose is calculated. The concentration of chemical inhibiting glucose removal by 50 percent (IC_{50}) is

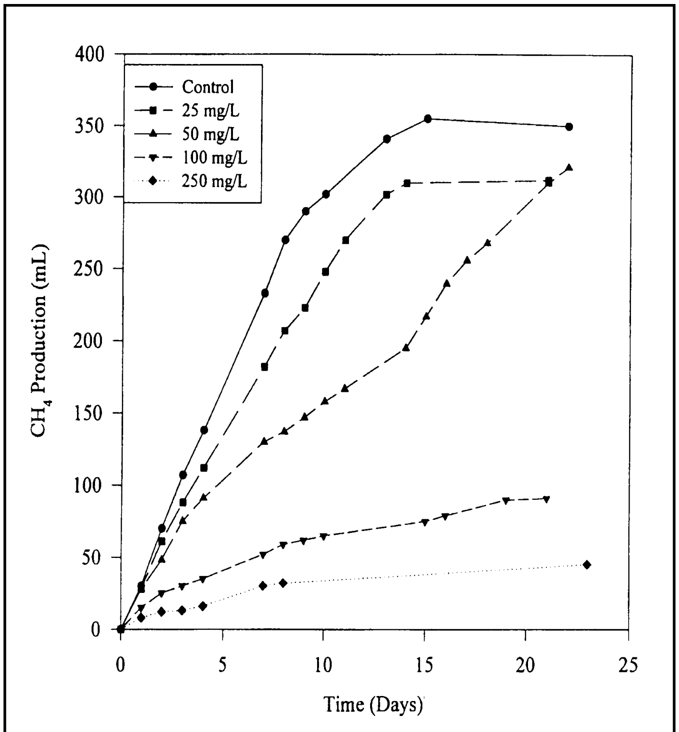

FIGURE 1 ▲
Response of unacclimated methanogens to an anionic surfactant (source: Yang et al., 1979).

calculated and normalized to the control response by using an empirical nonlinear regression model. The anaerobic version of this test is identical except that it uses septage as the test matrix, and the incubation is performed in an anaerobic chamber.

Wastewater Treatment Simulations

Laboratory-scale wastewater treatment simulations performed to determine the treatability of a test substance can also provide important information on the longer-term impact of chemicals in wastewater treatment. Simulation tests such as continuous activated sludge (CAS), porous pot (American Society for Testing and Materials [ASTM], draft method), and coupled units (OECD procedure number 303A) (OECD, 1993b) can provide insight into potential problems that can occur at wastewater treatment facilities. Simulation tests assessing the impact of cleaning product ingredients on septic tanks have been reported in literature (Pearson et al., 1991; Holman and Hopping, 1980; Truesdale and Mann, 1968).

Relevant Case Studies

It is generally recognized that normal use levels of household cleaning agents and disinfectants do not impair septic tank function (Gross, 1987; Truesdale and Mann, 1968). There have been few studies in the published research literature specifically examining the impact of disposing of larger quantities of household chemicals on wastewater treatment systems, although the procedures listed earlier in this article are commonly conducted by manufacturers to provide data for safety assurance on new or reformulated products.

Toxicity of Chemicals

In a report entitled *Recovery of Anaerobic Digestion after Exposure to Toxicants*, Yang et al. (1979) provide a detailed literature review on previously published data relating toxicity of various chemicals to anaerobic wastewater treatment microorganisms. The authors also performed their own experiments, examining the toxicity of more than 30 chemicals representing heavy metals, inorganics, various organic chemicals common to industry, and antibiotics.

This study was undertaken to test the previously widely held perception that methane fermentation cannot tolerate chronic or slug doses of toxicants. Two types of assays were used: an “anaerobic toxicity assay (ATA)” and an anaerobic filter assay. The ATA was designed as a short-term test to determine the impact of single doses of chemical into an unacclimated system. The anaerobic filter assay was used in a continuous flow mode that allowed long-term operation and acclimation by microorganisms. Gas production and COD removal were measured over time from each filter unit.

Under an ATA test using unacclimated sludge (figure 1), 25 mg/L of an anionic surfactant (tradename “WXN,” produced by American Cyanamid Corporation) reduced gas production to about 80 percent of the control. At 50 mg/L, the gas production rate gradually declined for the first 10 days then subsequently increased. At 100 mg/L, the initial gas production rate was about 20 percent of the control. Subsequently, it decreased and later showed acclimation after 20 days. Gas production ceased after 10 days at 12 percent of the control volume in the system with 250 mg/L of anionic surfactant.

Note that in this ATA system, the mixed liquor suspended solids (MLSS) were measured at 600 mg/L, significantly lower than typical anaerobic digesters where solids typically range from one to five percent (weight/volume), which is equivalent to 10,000 to 50,000 mg/L. Thus, the low MLSS level could have exhibited toxicity at lower chemical concentrations than would be seen in actual systems.

In the anaerobic filter system, continuous additions of 15 and 30 mg/L of the anionic surfactant did not produce sustained inhibition; however, 60 mg/L for 28 days produced a gradual decrease in gas production until the surfactant additions were stopped (figure 2). Gas production remained about 50 to 60 percent of the earlier maximum levels until beginning to improve approximately 30 days after the last surfactant addition. The study was terminated before complete recovery was evident.

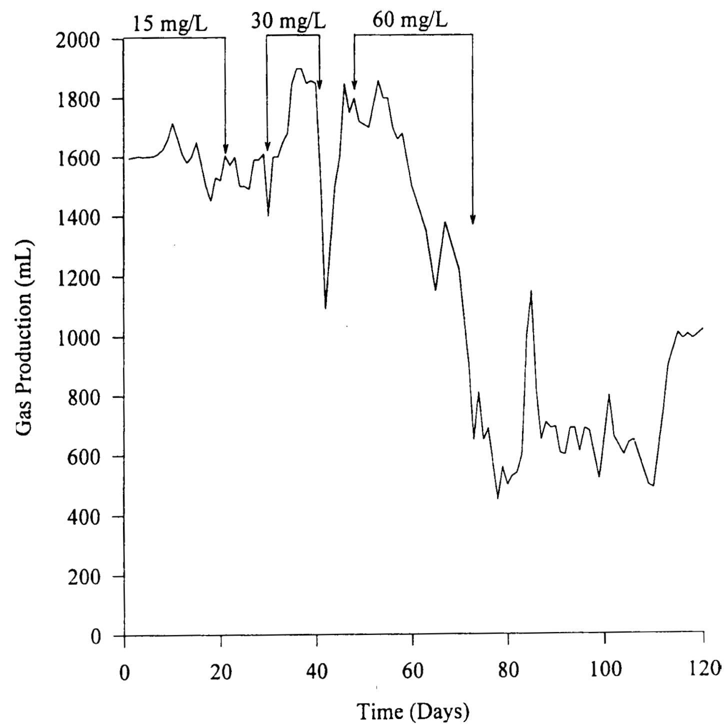

FIGURE 2 ▲
Response of anaerobic filter to an anionic surfactant (source: Yang et al., 1979).

Cleaning Product Safety

Inhibition of anaerobic gas production from cellulose degradation was used by Vaishnav and McCabe (1996) to assess safety of cleaning products to anaerobic microorganisms. In this procedure, various concentrations of the test compound were added to incubation vessels (250-mL flasks) containing constant amounts of anaerobic digester sludge, cellulose, and a synthetic sewage feed mixture.

The vessel was sealed, and the headspace was connected by tubing to a second vessel containing water. Water displacement into a third vessel was measured and used as an indicator of anaerobic respiration. The concentration of test substance inhibiting anaerobic respiration by 50 percent over a 96-hour exposure period (EC_{50}) was calculated, along with the no-observed effect concentration (NOEC). Sodium chloride was used as a reference compound.

Using the NOEC value derived from these test procedures and worst-case scenario of disposing of an entire container-full of a granular all-fabric bleach and a general purpose cleaner (trade names withheld at manufacturer's request) directly into a 750-gallon (2,839-L) septic tank, Vaishnav and McCabe calculated whether the product concentration in the septic tank would exceed the NOEC.

As table 2 describes, the worst-case predicted septic tank concentrations for

TABLE 2 ▼
Impact of two cleaning products on gas production by anaerobic sludge. [a]

products	NOEC	worst-case concentration
granular all-fabric bleach [b]	625 mg/L	356 mg/L
general purpose cleaner [c]	10,000 mg/L	750 mg/L

[a] source: Vaishnav and McCabe, 1996.
[b] assumes 64-oz. container (1.89 L).
[c] assumes 1-gallon container (3.785 L).

TABLE 3 ▼
Results of a field study on the impact of cleaning products on septic tank coliforms. [a]

		Septic Tank C 400 gallons (1,514 L)		Septic Tank D 375 gallons (1,420 L)	
product	dose	recovery time (hours)	coliforms (colonies/100 mL)	recovery time (hours)	coliforms (colonies 100 mL)
liquid bleach	2 gallons (7.57 L)	0	68E5	0	48E5
		4	0	4	0
		8	0	8	0
		11	19E0	11	6E1
		22	32E2	22	43E2
		26	86E2	26	92E2
		31	29E3	31	18E3
		43	99E4	43	19E5
		48	26E5	48	31E5
		52	42E5	52	42E5
Lysol®	2 gallons	0	6.7E5	0	3.8E5
		4	0	5	<10,000
		12	1E2	24	<10,000
		26	1.6E3		290.8E5
		32	2.9E3		483.2E5
		39	2.1E4		
		50	2.3E5		
		56	3.8E5		

[a] source: Gross, 1987.

either product did not exceed the NOEC. Therefore, it is unlikely that disposing of an entire container of either product will cause harm to septic tank microbes.

Impact to Septic Tanks

In a report presenting data on the impact of the disposal of household cleaning products on septic tanks, Gross (1987) examined chlorine bleach and Lysol® (a disinfectant). Gross suspected these common household products had the potential to harm septic tank operation because of their antimicrobial properties.

The first step in this study was to establish the concentration of each product required to "kill all of the bacteria." One-liter samples of septic tank effluent were subjected to interaction with various concentrations of the chemicals. They were allowed to interact for about one hour and then analyzed for total coliforms following standard procedures. The concentrations required to eliminate coliforms in effluent samples were 1.85 mL/L for chlorine bleach and 5 mL/L for Lysol.

Four septic tanks were used in a field study to assess the impact of these coliform-inhibiting levels of the products on septic tank operation. The volumes of these tanks were 400 gallons (1,514 L) for septic tank C and 375 gallons (1,420 L) for septic tank D. Prior to the field test, the tanks were pumped out and then operated for two weeks to allow return to normal operation.

The cleaning products were injected into the tanks by flushing them down a toilet. Samples of liquid were taken from the septic tanks periodically and tested for coliforms until the coliform population was found to reach predosing levels. When the concentrations of bleach and Lysol, equivalent to those determined in the first part of the experiment, were flushed into tanks C and D, coliform populations were temporarily reduced but returned to approximate predosing levels within 60 hours (table 3). The pH, BOD_5, and total suspended solids of septic tank effluents were not impacted by the chemical treatments.

Glucose Removal Method

Bookland et al. (1992) tested four materials using the glucose removal method in septage collected from a functioning septic tank. These four chemicals were chosen as representative of ingredients in cleaning products that could exhibit antibacterial properties: linear alkylbenzene sulfonate (LAS, an anionic surfactant), ethanol (an organic solvent), sodium hypochlorite (a bleach), and di-octyl di-methyl ammonium chloride (DODMAC, a cationic surfactant). The results of this study are reported in table 4 as HA_{50} (heterotrophic activity reduced by 50 percent as measured by reduction in glucose uptake) and as the NOEC (concentration having no effect on glucose uptake).

TABLE 4 ▼

Summary of septic tank safety data based on glucose removal. [a]

test material	HA_{50} (mg/L)	NOEC (mg/L)	NOEC equivalent amount of product in 750-gallon (2,839 L) septic tank (Pmax)
sodium hypochlorite	475	288	4.3 gallons (16.28 L) [b]
LAS	6,750	1,820	4.5 gallons (17 L) [c]
ethanol	80,000	10,000	150 gallons (568 L) [d]
DODMAC	>1,000	>1,000	2.5 gallons (9.46 L) [e]

a source: Bookland et al., 1992.
b assumes 5% sodium hypochlorite.
c assumes 30% LAS.
d assumes 5% ethanol.
e assumes 30% DODMAC.

These data were used to calculate the maximum ingredient concentration (ICmax) that can be disposed of into a septic system without causing an adverse effect in a 750-gallon (2,839-L) septic tank:

ICmax = NOEC (mg/L) • 3.785 L/gallon • 750 gallons per tank.

The maximum amount of product (Pmax) that can be safely disposed of is calculated by:

Pmax = ICmax/PICmax (mg/L),
where PICmax is the maximum product ingredient concentration.

For example, if ethanol is used in cleaning products at a maximum concentration of five percent NOEC (weight/weight), its NOEC would be converted to a Pmax as follows:

ICmax = 10,000 mg/L ethanol (NOEC) • 3.785 L/gallon • 750 gallons/tank = 28.4 kilograms (kg) ethanol/tank.

Pmax = 28,388 g/tank • 100 mL product/ 5 g ethanol • 1 L/1000 mL • 1 gallon/ 3.785 L = 150 gallons.

Therefore, up to 150 gallons (568 L) of product containing five percent ethanol can be added to a 750-gallon (2,839-L) septic tank without adversely affecting heterotrophic activity.

Similar calculations illustrate that up to 4.5 gallons (17 L) of product containing 30 percent anionic surfactant linear alkylbenzene sulfonate (LAS), 4.3 gallons (16.28 L) of bleach containing 5 percent sodium hypochlorite, and 2.5 gallons (9.46 L) of product containing 30 percent cationic surfactant DODMAC can be added to a 750-gallon (2,839-L) septic tank without adversely affecting heterotrophic activity (table 4).

Summary

These case studies support several statements related to down-the-drain disposal of cleaning products in septic systems:

- Septic tanks are robust in tolerating chemical exposures resulting from disposal of household cleaning products, even those designed as disinfectants.
- Rapid hydraulic turnover minimizes the exposure of microorganisms to high concentrations of chemicals resulting from one-time slug loads. This aids in the rapid recovery of microorganisms even if temporary adverse biological conditions are experienced in the tank.
- Quantities of cleaning products required to inhibit septic tank activity are larger than single packages, sometimes much larger. This is observed even when using conservative "no effect" indices of glucose uptake or toxicity to coliforms in septic effluent.

Conclusion

Because of the amount of dilution that occurs in POTWs, disposing of single household quantities of cleaning products that are normally mixed with water will not impact their concentration in POTW influent. In these community-level wastewater treatment systems, products can be regarded as safe for disposal if found to be nontoxic to waste treatment microorganisms at the average predicted concentration (plus a reasonable safety factor). Approximately 25 percent of the households in the U.S., however, use single residence onsite wastewater treatment, most commonly configured as septic tank/absorption field systems. For these systems, dilution is limited to the volume of the septic tank and subsequent household water use.

It is generally accepted that normal-use concentrations of unused cleaning products do not create problems in septic tanks, but it is possible to temporarily elevate product concentrations in a septic tank by pouring an entire package down the drain. A recent survey shows that disposing of unused household cleaning products down the drain is an infrequent practice. The worst-case scenario of product disposal in wastewater treatment is the disposal of a completely unused package of product in a minimum size septic tank. If a product does not impact waste treatment under this scenario, it may be assumed to be safe for other common use and disposal scenarios.

Available data indicate that disposal of household quantities of cleaning products, such as bleach and detergents, do not cause long-term septic tank upset. Screening tests indicate that disposal of whole packages of these products results in maximum concentrations in septic tanks that are within the no-effect concentrations for gas production and glucose uptake.

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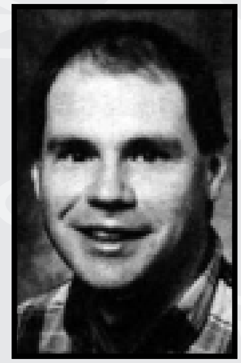

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NSFC News / Resources

NSFC Offers Discussion Groups on the Web

The National Small Flows Clearinghouse (NSFC) is pleased to announce its new online discussion groups—the most recent addition to the services the NSFC offers to Internet users.

Some of the topics currently posted for discussion in the NSFC group include septic tanks and grease, odors and house vents, soils evaluation versus percolation tests, and antibacterial cleansers. There are numerous others, and anyone is welcome to begin a new discussion concerning small community wastewater issues.

Internet users also can participate in a National Onsite Demonstration Project (NODP) discussion group. The NODP group allows users to connect across the country with people who are interested in the NODP or are involved in demonstration projects of their own. Current topics include older onsite demos, permaculture, and low-pressure sewer systems. Again, everyone interested is invited to join in or add new topics.

As well as being able to post and respond to questions, discussion group users can make use of a special "chat" feature that allows two or more users to communicate in a real-time, instant-message format.

Those interested in participating in these discussion groups can access NSFC's Web site at http://www.nsfc.wvu.edu.

Information about other NSFC services also can be found at the site, as well as links to other discussion groups offered by the National Environmental Training Center for Small Communities (NETCSC) and the National Drinking Water Clearinghouse (NDWC).

Special Spring Offer—All NSFC Products Half Price June 22–23

In celebration of Earth Day, the National Small Flows Clearinghouse (NSFC) is offering 50 percent off the regular price of all products for orders placed by phone, fax, or e-mail June 22 and 23, 1998. Phone orders must be placed between 8 a.m. and 5 p.m. Eastern Time. Orders placed by fax or e-mail will be accepted until midnight, Tuesday, June 23.

The NSFC maintains an inventory of more than 250 educational products about wastewater treatment technologies and issues for small communities. Categories of NSFC products include

- case studies,
- computer searches and software,
- design manuals/modules,
- finance and management,
- NSFC newsletters,
- operation and maintenance,
- public education,
- regulations,
- research,
- technology packages,
- fact sheets, and
- videotapes.

The NSFC's *1997 Products Guide* (Item #WWCAT) provides descriptions and prices for each of the products and is free upon request. To request a free catalog or to place your order, contact NSFC by calling (800) 624-8301 or (304) 293-4191, 8 a.m. to 5 p.m. Eastern Time. Orders may also be faxed to (304) 293-3161 or sent via e-mail to *nsfc_orders@estd.wvu.edu.*

The NSFC products guide also can be downloaded via the NSFC's Web site at *http://www.nsfc.wvu.edu.*

Earth Day 1998

Professional News

Group Seeks Comment on Proposed Performance Standards

A group of researchers and ASAE members (formerly the American Society of Agricultural Engineers) have developed a series of seven proposed performance-based standards for onsite wastewater systems, which are summarized in the table below. The proposed voluntary national standards could be used to either augment or replace prescriptive onsite system codes currently used by many towns, counties, and states, and they can be applied either to the performance of specific pretreatment units or to receiving environments.

The proposal, titled “Performance Standards for On-Site Wastewater Treatment Systems,” by Michael T. Hoover, Dennis Sievers, and David Gustafson, was first presented in March in Orlando, Florida, at ASAE’s Eighth National Symposium on Individual and Small Community Sewage Systems and is included in the symposium proceedings available from ASAE (see the ordering information on page 30).

The ASAE SW-262 Committee (Countryside Engineering Committee) is formally leading the effort to develop these standards and is seeking public comment and review of the standards until July 1, 1998. Afterwards, the ASAE SW-262 Standards Subcommittee led by David Gustafson of the University of Minnesota will compile the written comments and develop a formal draft. The subcommittee will establish an expert panel to work with other industry groups interested in developing performance-based standards, such as the National Onsite Wastewater Recycling Association (NOWRA), the American Society for Testing and Materials (ASTM), NSF International, and the National Small Flows Clearinghouse.

Performance-based standards have been advocated by many in the onsite profession as a more flexible water quality- and

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	constituent concentrations						
standard	**BOD**	**TSS**	**PO_4-P**	**NH_4-N**	**NO_3-N**	**total nitrogen**	**fecal coliform colony densities**
	mg/L					% removed [a]	no./100mL
TS1 - primary treatment							
TS1u - unfiltered	300	300	15	80	NA	NA	10,000,000
TS1f - filtered	200	80	15	80	NA	NA	10,000,000
TS2 - secondary treatment	30	30	15	10	NA	NA	50,000
TS3 - tertiary treatment	10	10	15	10	NA	NA	10,000
TS4 - nutrient reduction							
TS4n - nitrogen reduction	10	10	15	5	NA	50%	10,000
TS4p - phosphorus reduction	10	10	2	10	NA	25%	10,000
TS4np - nitrogen & phosphorus reduction	10	10	2	5	NA	50%	10,000
TS5 - bodily contact disinfection	10	10	15	10	NA	25%	200
TS6 - wastewater reuse	5	5	15	5	NA	50%	14
TS7 - near drinking water	5	5	1	5	10	75%	<1 [b]

[a] minimum % reduction of total nitrogen (as nitrate-nitrogen plus ammonium-nitrogen) concentration in the raw untreated wastewater

[b] total coliform colony densities <50/100 mL

source: Hoover, M. T., D. Sievers, and D. Gustafson. 1998. Perfomance standards for on-site wastewater treatment systems. In On-site wastewater treatment: Proceedings of the eighth national symposium on individual and small community sewage systems. St Joseph, Mich: ASAE.

risk-based alternative to the current variety of prescriptive codes used in most jurisdictions. The authors also argue that the lack of performance standards and code uniformity has inhibited the influx of venture capital into onsite system research and development, limiting manufacturers' capabilities to provide new, cost-effective onsite technologies.

A complete discussion of the proposed standards is published in ASAE publication number P0398, On-Site Wastewater Treatment: Proceedings of the Eighth National Symposium on Individual and Small Community Sewage Systems. *To purchase a copy, contact ASAE at (616) 428-6324, fax (616) 429-3852, or write to ASAE, Dept. 1677, 2950 Niles Road, St. Joseph, MI 49085-9659. The price is $49.00 for ASAE members and $59.00 for nonmembers plus $4.25 for postage and handling.*

To comment on the proposed standards, please write directly to David Gustafson, Agricultural Engineering Specialist, University of Minnesota, 1390 Eckles Ave., St. Paul, MN 55108, or via e-mail at gusta002@tc.umn.edu.

Call for Proposals

Innovative Onsite Wastewater
Demonstration Project For Very Poorly Drained Soils

CLERMONT COUNTY GENERAL HEALTH DISTRICT

The Clermont County General Health District is seeking proposals for field demonstration of innovative technology for household onsite wastewater systems in Clermont Silt Loam, a soil that is severely limited by wetness. Clermont County is located in the Illinoian Till Plain of southwest Ohio. Clermont Silt Loam is a widely distributed soil that does not perform well as a treatment medium. Some of the factors that contribute to its unsuitability are a seasonal high water table, slow internal drainage, limited response to subsurface drains, poor surface drainage, and a humid climate with an average of 42 inches of rainfall per year.

Proposals will be evaluated on the following criteria:

a) reliability and cost of components with estimated service life,
b) time required for installation,
c) ability to monitor and achieve performance criteria,
d) ease of maintenance and service, and
e) safety and site aesthetics.

This call is part of a USEPA 319 Project titled "Reduction of Nonpoint Source Pollution from Onsite Sewage Systems in Clermont County, Ohio." The project sponsor, the Clermont County General Health District, will select two types of innovative, nonproven systems that demonstrate potential for providing onsite wastewater renovation on the county's most severe wet soils. One of each type of system will be installed in 1999. A second system of each type, with possible modifications, will be installed in the year 2000. The systems will be evaluated for at least five years.

Information packages should be requested from Ralph Benson by phone at (513) 732-7603 or fax at (513) 732-7936.

Proposals must be received before July 1, 1998.

Committee Discusses Drainfield Questions, Identifies Topics for Further Research

As part of a continuing effort to develop scientifically-based performance standards for the onsite industry and to provide direction for future research, The National Onsite Wastewater Recycling Association (NOWRA)'s Technical Practice Committee is examining, in detail, various onsite system components and unit processes. The committee met in October, 1997, at NOWRA's annual meeting in Texas to discuss "drainfield dynamics."

"The goal of the meeting was to consider two questions, which may seem simple at first: how do drainfields work and how long do they last?" explains Bob Mayer, P.E., committee chair. "We hoped this topic would generate considerable discussion, and we weren't disappointed."

After hearing presentations from individuals familiar with different aspects of the onsite profession, the group discussed the following items with the goal of reaching some consensus:

- The committee agreed that total suspended solids (TSS) impact drainfield operation and that enhanced solids removal is available via various pretreatment devices (such as effluent filters); however, more needs to be known about exactly how much TSS removal is really practical and necessary for any given soil type or flow volume.

- The committee agreed that although it is known that effluent with high levels of biological oxygen demand (BOD), such as commercial wastewaters containing fats, oils, and greases, can limit the life of drainfields, many states either ignore or don't pay enough attention to high-strength waste characteristics in their regulations or practices.

- The committee questioned whether treating effluent to drinking water quality guarantees a permanent onsite installation, or whether saving money by treating only to moderate levels can still ensure long-term service from a system.

- The committee agreed that hydraulic overloading leads to system failures; however, predicting soil capacity with the variety of wastewater characteristics that exist is still not a defined science.

- The committee also agreed that nitrogen and pathogens are parameters that should be addressed in any analyses of drainfield performance because of their potential to impact public health and the environment. The group questioned, however, whether the national standard for nitrate (the 10 mg/L drinking water standard) is a realistic number, and where the samples should be taken for monitoring nutrients.

- The committee agreed that oxygen, temperature, and soil depth affect drainfield dynamics and that soil depth is not only a function of oxygen and temperature, but also of the living organisms present in shallow soils that are beneficial to system operation.

- The committee questioned the exact meaning of long-term acceptance rate (LTAR). Is LTAR a loading rate determined for the total size of the system that will help extend the life of the drainfield, or is it the rate at which effluent will pass through a mature anaerobic mat? No agreement was reached on this point.

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In addition, the group agreed on the following list of ten general subjects or questions that warrant further examination before definitive design criteria and ensuing performance standards for drainfields are developed.

1. Should there be one loading rate for all soils? Should all anaerobic drainfields have the same domestic strength application rate as defined by gallons per day per square foot and pounds of BOD per square foot per day? Are there two or more loading rates? Should load be determined from a design curve that assumes the less permeable the soil the lighter the load? Or should all drainfields be designed to be aerobic?

2. What is the role of microbes, worms, and other biota in shallow soils? It is known that the bioactive shallow soil is beneficial to treatment and disposal processes, but exactly how does it apply to drainfields?

3. Is pressure dosing superior to gravity distribution because of the increased amount of oxygen in contact with the wastewater in the systems using pressure dosing?

4. What is the role of synthetic fibers, such as lint and laundry fibers, in a system? How much of this material will clog piping or form mats in absorption trenches?

5. How do water softeners affect systems? Should the backwash from water softeners be disposed of in systems? If the backwash is not recombined with the softened water in systems, will a chemical imbalance result in the effluent that could be detrimental to the system?

6. Should sand-lined trenches be used in drainfields? Is the additional sand beneficial, harmful, or of little use to drainfield performance?

7. What is the effect of sodium on systems? How much sodium is too much for a given soil type?

8. How do we predict the life of a system?

9. Is effluent ponding in the drainfield good or bad? (This question also relates to item 3.) Is oxygen at the soil interface of the drainfield necessary for achieving a permanent system? Do anaerobic processes in ponded systems doom them to finite lifespans?

10. Is drainfield shape critical to its operation? Although it is known that drainfield length, width, and depth help define the type of processes that result when effluent is applied, questions concerning drainfield shape should be left open until agreement is reached concerning exactly what the relevant processes are.

While some of these issues may seem simple or obvious to experienced onsite system designers, some generally-accepted answers may be based mostly on anecdotal evidence. There is a need for scientifically proven design standards based on scientifically collected data and studies with reproducible results. The committee is questioning whether drain-field science has definitive answers to all of these questions and is encouraging input from the research community on these topics.

If you have input or questions concerning the Technical Practices Committee or NOWRA's performance-based standards initiative, contact Bob Mayer at (800) 345-3132, ext. 103, or by e-mail at topvacat@aol.com.

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Manuscripts that are prepared on a personal computer or Macintosh should be submitted in WordPerfect 5.1, Microsoft Word, or ASCII format. Files should include (in this order) abstract, text, footnotes, references, and tables. Figures prepared on a computer should be submitted on diskette as separate files (*.tiff or *.eps) with accompanying "camera-ready" copy. Photographs should be sharp, glossy, black and white prints, when possible, and identified on the back. Submit electronic files on 3.5 inch diskettes, an original of the manuscript, and three printed copies to the editor.

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