RULE DEVELOPMENT COMMITTEE ISSUE RESEARCH REPORT

DRAFT

SEPTIC TANK EFFLUENT VALUES

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Topic & Issues:

Septic Tank Effluent Values

- **What should single-sample threshold values for residential STE be, and how should they be applied?**

Summary:

This report summarizes the literature on the topic of residential septic tank effluent (STE) values. The DOH Rule Development Committee (RDC) has requested that DOH Wastewater Program staff and the Technical Review Committee define threshold values for single sample testing of STE to distinguish the line between typical residential STE and “high strength STE”. Values for the following parameters were requested: Carbonaceous Biochemical Oxygen Demand ($CBOD_5$), Total Suspended Solids (TSS), Fats, Oils and Greases (FOG), and pH.

Sizing onsite sewage systems necessitates consideration of more than just hydraulic loading rates. Wastewater strength and resulting mass loading also must be taken into consideration for system design. A major concern of having high STE strength is an increase in soil or media clogging in which long-term infiltration and treatment is reduced. Research has shown that the major factor influencing soil clogging is the organic loading rate to the infiltrative surface resulting from the combination of wastewater quality and hydraulic loading rate. This suggests that establishing organic loading rate threshold values in rule is as equally important for addressing high STE strength issues as identifying STE effluent values.

Although the RDC requested a single sample $CBOD_5$ standard, BOD_5 should be used for characterizing STE due to limited availability of STE $CBOD_5$ data, and a BOD_5/$CBOD_5$ conversion factor cannot accurately predict $CBOD_5$ values for STE. Since the term FOG has now been replaced by the term oil and grease (O&G), O&G should be used for characterizing STE as well. Suggested single-sample residential STE threshold values include: BOD_5 <220 mg/L, TSS <100 mg/L, O&G < 30 mg/L, and a pH range between 6.0 and 9.0.

These single sample threshold values cannot be applied without considering the larger context of overall operation of the on-site wastewater treatment system. In order to help regulators and service personnel assess the field performance of these systems, a Monitoring Guidance Document needs to be developed.

KEYWORDS: wastewater strength, organic loading, septic tank effluent, pH, CBOD5, BOD5, TSS, FOG

Introduction:

During the last meeting of the DOH Rule Development Committee (RDC) in 2003, the Committee requested the Department work with the Technical Review Committee to define residential sewage by using threshold values for septic tank effluent. The specific request includes:

- Identify single-sample values for residential septic tank effluent using the following parameters: $CBOD_5$, TSS, FOG, & pH
- These values would describe that line between "typical residential STE" and "high-strength STE"

Although a considerable body of research exists to define septic tank effluent characteristics, these are based generally on average values that are derived from collecting a large number of samples to reflect the variability of the tank's operating conditions over time. Variability over time can occur from changes in waste disposal patterns and practices, schedules, peak and off peak production, treatment process variations, and seasonal changes. The collection of frequent samples even over short periods of time to provide results representing average operating conditions, such as a 30-day average, is not practical for the purpose of monitoring septic tank performance on an on-going basis in the field.

Single-sample results for septic tank effluent, on the other hand, present a small "snap-shot" of septic tank performance at that moment the samples are taken in the field. They do not necessarily represent the effluent characteristics of a septic tank at any other time. There are many indicators that can be easily measured or observed in the field and used in conjunction with analytical wastewater sampling results to provide a more complete picture of system performance over time.

Subsequently, the outcome of the work to establish single-sample residential septic tank effluent values is to place the criteria for their use in a monitoring guidance document to assist service providers and local regulators in their field assessment of system performance.

A major concern of having high septic tank effluent strength is an increase in soil or media clogging to a degree where infiltration is reduced dramatically and anaerobic, saturated conditions develop. Concentrations of biochemical oxygen demand (BOD_5), total suspended solids (TSS), and fats, oils, and grease (FOG) typically determine septic tank effluent strength. Research studies and field experience have shown as BOD_5, TSS, FOG loading rates increase, the probability of biological clogging and hydraulic failure increase. Current problems observed with sizing on-site sewage systems based primarily on hydraulic loading rates are the wastewater strength and resulting mass loading are not taken into consideration for onsite sewage system design. The lack of consideration for the wastewater strength can result in very high mass loading being applied to the soil or media infiltrative surface.

The purpose of this review is to synthesize the literature available on the topic of septic tank effluent values so that the Technical Review Committee can make appropriate recommendations about how these values should be set and applied in Washington State. More than 50 publications, which include peer reviewed journal articles, conference proceedings, textbooks, master thesis, and government reports were collected and reviewed.

Body:

Background

High mass loadings of organic matter and suspended solids can overload the soil capacity to degrade these materials. Research has shown that soil clogging is generally accelerated under increasing hydraulic loading rates of a given septic tank effluent or under increasing concentrations of organic matter and suspended solids at a given hydraulic loading rate (Jones and Taylor, 1965; Laak, 1970; Hargett et al., 1982; Mitchell et al. 1982; Siegrist, 1987; Siegrist and Boyle, 1987, Duncan et al., 1994). However, it is still common practice not to consider wastewater strength and hydraulic loading rate interactions and simply apply septic tank effluent to soil or media infiltrative surfaces at the established hydraulic loading rates in rule. Severe soil clogging may result and effluent ponding may develop to the point where surfacing effluent or plumbing backups occur.

The current proposed Treatment Level E (maximum 30-day average of 200 mg/L $CBOD_5$, 80 mg/L TSS, and 20 mg/L FOG) in the draft onsite rules came from work by Hoover (1998), who presented treatment standards under the assumption that they will be applied as a measure of the level of pretreatment that occurs prior to the wastewater being applied to the soil. However, the intended use of these 30-day average threshold values, as provided in draft rule, is for the purpose of treatment component performance testing according to establishing protocols. The application of 30-day average values for the purpose of monitoring treatment component performance on an on-going basis in the field is not practical.

Currently, threshold values for residential septic tank effluent are only mentioned in guidance for intermittent sand filters and mound systems. The guidelines for these sand-based treatment systems suggest that the wastewater applied to the system must not be higher in strength than 220 mg/L BOD_5 and 145 mg/L TSS. This implies that high strength wastes with BOD and TSS greater than these values should not be applied to sand-based treatment systems without additional pretreatment. However, this guidance does not indicate whether septic tank effluent should be measured according to these threshold values by obtaining single or multiple sample results in the field, nor does guidance include threshold values for other important wastewater parameters for evaluating system performance in the field, such as FOG or pH.

Residential Septic Tank Waste Strength

Septic tank effluent will vary in quality according to the characteristics of the wastewater and condition of the tank. Effluent leaving a conventional septic tank (one not equipped with an effluent filter) typically has concentration of 150 to 250 mg/L for BOD_5, 40 to 140 mg/L for TSS and 20-50 mg/L for FOG (Crites and Tchobanoglous, 1998). Septic tank effluent from a tank with an effluent filter has different characteristics from unfiltered effluent. Typical effluent concentrations from septic tanks equipped with effluent filters range from 100 to 140 mg/L for BOD_5, 20 to 55 mg/L for TSS, and 10 to 20 mg/L for FOG (Crites and Tchobanoglous, 1998; Stuth, 2004).

Numerous studies have shown that septic tank effluent concentrations of organic material and solids of restaurants and similar commercial establishments are significantly higher than those of residential septic tank effluent (Siegrist et al. 1984; Stuth and Guichard, 1989; Stuth and Garrison, 1995; Matejcek et al. 2000). A Wisconsin study compared the concentrations of restaurant and domestic effluent quality (Siegrist et al. 1984). Ranges for domestic effluent concentration for BOD_5 (118 to 189 mg/L), TSS (41-50 mg/L) and O&G (16 to 45 mg/L) were reported as average for three small communities. Ranges for restaurant effluent concentrations for BOD_5 (101 to 800 mg/L), TSS (44 to 372 mg/L) and O&G (24-144 mg/L) were reported.

Typical septic tank BOD_5 removal efficiencies are 30 to 50 percent and removal efficiencies for TSS are 60 to 80 percent (Boyer and Rock, 1992; University of Wisconsin, 1978; EPA, 2002). A well-functioning septic tank will reduce BOD_5 by 40 percent, TSS by 70 percent, and FOG by 77 percent (EPA, 2002; NSFC Pipeline, 2003; Bounds, 1997). Assuming that septic tanks will maintain these performance efficiencies when treating raw domestic wastewater that is classified as “strong” (400 mg/L BOD_5, 350 mg/L TSS, and 150 mg/L FOG; Meltcalf & Eddy, 1991), relatively high septic tank effluent values of 240 mg/L for BOD_5, 105 mg/L for TSS, and 34 mg/L for FOG can be expected. These values could be used as septic tank threshold values where corrective actions should be taken (such as measures to reduce the waste strength at the source or providing additional pretreatment) when a single sample result indicate these limits are exceeded. This approach in establishing septic tank effluent threshold values, however, does not consider potential mass loading impacts to the downstream treatment or soil dispersal component.

More recent residential waste strength information from national demonstration projects in the towns of the Burnett, Washington and La Pine, Oregon are presented in Table 1 & 2. Although the La Pine septic tank effluent concentrations are significantly higher than the Burnett septic tank effluent concentrations and values typically found in the literature, they are not considered abnormally high (Rich, 2004). The older homes in Burnett, which are more likely to have old style plumbing fixtures producing higher flows than in the La Pine homes, may partially account for the higher waste strength in La Pine. The average wastewater flow from the Burnett homes was 228 gpd, whereas the average wastewater flow from the La Pine homes was 146 gpd ((Adolfson Associates Inc., 1999; Rich, 2004). While the waste strength increases with water conservation, the mass loading rate to systems does not increase. For example, the average organic loading (BOD_5 concentration x gpd flow) is 0.29 lb BOD_5/day in Burnett and 0.30 lb BOD_5/day in La Pine, which are relatively insignificant differences. Other possible reasons for differences in waste strength may be demographic, socioeconomic or lifestyle dissimilarities in the communities. Any of these factors may result in different types of foods and household products used and placed into the waste streams. Increasing waste strengths in recent years can be due several factors such as increased use of low flow plumbing fixtures, the increased use of antibiotics and other prescription drugs that seem to affect the septic tank, the cumulative effect of increased use of antibacterial products and household cleaners (Stuth, 2004).

Table 1. Burnett, WA - Two-Compartment Septic Tank Performance (Adolfson Associates, Inc. 1999)

9 households	Average	Median	Min.	Max.	Std. Dev.	Units	# Samples
BOD_5	153	135	3	480	101	mg/L	66
TSS	41	36	7	145	24	mg/L	66
Oil & Grease	10	7	15	31	9	mg/L	33
PH	7.3	7.3	6.5	8.4	0.37	Std. Units	58

Table 2. La Pine, OR – Two Compartment Septic Tank Performance w/o O&G/BOD_5 outliner (Rich, 2003)

10 households	Average	Median	Min.	Max.	Std. Dev.	Units	# Samples
BOD_5	249	240	63	570	108	mg/L	131
TSS	57	48	0.5	210	31	mg/L	131
Oil & Grease	29	27	2.5	160	17	mg/L	127
PH	7.6	7.6	5.4	9.6	0.72	Std. Units	132

pH

pH is a measure of the hydrogen ion concentration in water. Low pH indicated increasing acidity, whereas a high pH indicates increasing alkalinity. The acidity or alkalinity of wastewater affects both treatment and the environment. The pH of domestic wastewater typically falls between 6.5 and 8.0 (Canter and Knox, 1985; Hunter and Heukelekian, 1965). The optimum pH for bacteria growth lies between 6.5 and 7.5 (Bitton, 1999), which is close to the normal range of 6.5 and 7.2 reported by Stuth (2003) for residential septic tank effluent.

To protect microorganisms, the pH of wastewater needs to remain between 6 and 9. Microbial activity is inhibited at pH above 9 and at pH below 6.0, fungi are favored over bacteria in the competition for food. Using EPA secondary treatment guidelines parameters, ANSI/NSF Standard 40 for residential wastewater treatment systems requires the pH of individual effluent samples to be between 6 and 9.

In order to ensure efficient anaerobic digestion in a septic tank, a balance between the acid-forming and hydrogen-forming bacteria and the methane-forming bacteria must be maintained (Metcalf and Eddy, 1991). Acidity is more inhibitory to methane-forming bacteria than to acid-forming and hydrogen-forming bacteria. Most methane-forming bacteria function at a pH range of 6.7-7.4, but optimally at a neutral pH of 7.0-7.2, and the process cannot function if the pH is close to 6.0 (Bitton, 1999). Production of organic acids by acid-forming and hydrogen-forming bacteria tends to lower the pH of the septic tank. Under normal conditions, this pH reduction is buffered by bicarbonate produced by methane-forming bacteria (Bitton, 1999). Thus, in a stable tank in which there is a balance between the various bacteria that are involved in digestion, the pH will remain close to neutral.

Under adverse environmental conditions, the buffering capacity of the septic tank can be upset, which may eventually stop methane production. During septic tank imbalance, which may be caused by excess organic loading, changes in hydraulic characteristics, a temperature change, or introduction of toxic substances, organic acids produced by acid-forming and hydrogen-forming bacteria typically increase at a faster rate than can be decomposed by the methane bacteria (Parkin and Owen, 1986; Long, 1995). Unless there is sufficient buffer capacity, the pH will drop to unacceptably low levels, and methane production will decrease and may eventually stop if the pH drop is of sufficient magnitude or duration (Bitton, 1999). The septic tank can go “sour” in this situation, and strong odors are released. The La Pine dataset (Table 2) demonstrates septic tank anaerobic digestion upsets periodically do occur by showing high corresponding septic tank effluent BOD_5 concentrations (>400 mg/L) to low pH (< 6.0) (Rich, 2004). An increase in pH to 9.0 may also result in cessation of methane production, but system recovery should be prompt and complete if pH levels are returned to optimum levels (Parkin and Owen, 1986).

Organic Mass Loading Rates

Organic loading rate is defined as the product of the hydraulic loading rate and the BOD_5 concentration (HLR X BOD_5). It is typically expressed on an area basis as pounds of BOD_5 per unit area, such as lb BOD/ft^2/day (Otis, 2001; EPA, 2002). Design organic loading rate values are derived from the design hydraulic loading rates by assuming a BOD_5 concentration, such as 150 mg/L for typical septic tank effluent (EPA, 2002). For septic tank effluent, EPA recommends a maximum design organic loading rate applied to soil of 1.0×10^{-3} lb BOD_5/ft^2/day, which is based on a maximum 0.8 gpd/ft^2 design hydraulic loading rate (EPA, 2002). Using the EPA recommended value of 150 mg/L for typical septic tank effluent and the proposed draft rule hydraulic loading rates, design soil organic loading rates range from 2.5×10^{-4} to 1.2×10^{-3} lb BOD_5/ft^2/day (Table 3). These derived values incorporate implicit factors of safety found in the design hydraulic loading rate. The system's true organic loading rate would be determined by using the actual hydraulic loading rate and the actual BOD_5 concentration, and can be calculated by using equation 1.

Equation1: OLR = (BOD_5) X (HLR) x (3.78 L/gal) x (1g/1000 mg) x (1 Ib/454g)
Where: OLR is organic load rate in Ib BOD_5/ft^2/day
HLR is hydraulic loading rate in gpd/ft^2
BOD_5 is concentration in mg/L

Table 3. Soil Organic Loading Rates (lbs. BOD_5/ ft^2/day)

From Various BOD_5 Concentrations of Residential Strength Septic Tank Effluent

Hydraulic Loading Rate[1] (gpd/ ft^2)	Soil Organic Loading Rate[2] BOD = 150 mg/L	Soil Organic Loading Rate BOD = 200 mg/L	Soil Organic Loading Rate BOD = 250 mg/L	Soil Organic Loading Rate BOD = 300 mg/L
0.2	.00025	.0003	.0004	.0005
0.4	.0005	.0006	.0008	.001
0.6	.00075	.001	.0012	.0015
0.8	.001	.0013	.0017	.002
1.0	.0012	.0017	.002	.0025

[1] Proposed WA State hydraulic loading rates for various soil types in rule
[2] EPA Recommended Soil Organic Loading Rates using BOD_5 = 150 mg/L

In a Wisconsin study, Siegrist et al. (1984) examined soil absorption systems (SAS) at 12 restaurants for efficiency of operation and for evidence of failure such as ponding within the SAS (Table 4). Several of these systems failed hydraulically within months of being put into operation despite the fact that no errors in system design or construction could be found. Of the 12 systems, 5 were performing badly and 3 of the 5 had surface effluent breakout. The mass organic loading rates applied to the SAS of all 12 restaurants ranged from 2.0×10^{-4} to 2.3×10^{-3} Ib BOD_5/ft^2/ day. Four of the 5 systems that performed poorly were found to have organic loading rates greater than 9.0×10^{-4} Ib BOD_5/ft^2/day. This organic loading rate is more than twice as high as that typically applied to SAS's for domestic septic tank effluent (Table 4). The average concentrations of BOD_5 were 2.7 times higher in restaurant septic tank effluent than in typical residential septic tank effluent and the TSS values were 2.8 times higher. The results of this study suggested that the maximum organic loading for septic tank effluent applied to a bed in sandy soil should be approximately 9.2×10^{-4} Ib BOD_5/ft^2/ day, and 3.4×10^{-4} Ib TSS/ft^2/ day. These results also showed that the wastewater constituent mass loadings are at least as important as hydraulic loading rates, and are critical in the design process. The authors suggested that lower rates would be anticipated for beds in finer textured soils, and the organic loading rates would be expected to be somewhat higher for long, narrow trenches in sandy soils.

Table 4. Summary of Soil Absorption System Loading and Performance (From Siegrist, 1984)

Type	Site No.	Hydraulic (gpg/ft^2)	BOD_5 ($lb/ft^2/day$)	TSS ($lb/ft^2/day$)	Oil/Grease ($lb/ft^2/day$)	System Type[a]	Infiltration Performance[b]
Restaurant	1	0.08	0.0004	0.0001	0.00007	IGGT	2
	2	---	----	----	----	IGGB	3
	3	0.11	0.0008	0.0003	0.00013	IGGB	3
	5	---	----	----	----	IGGB	2
	7	0.29	0.0017	0.0003	0.00015	IGPB	0-2
	9	0.43	0.0009	0.0002	0.00017	IGPB	1
Restaurant/	4	0.70	0.001	0.0004	0.0003	IGGB	1
Motel	6	0.90	----	----	-----	IGPB	0
Restaurant/ Golf Club	8	---	----	-----	-----	IGGB	0
	10	0.82	0.0023	0.0008	0.0003	IGPT	2
	11	0.24	0.0002	0.00008	0.00006	IGPB	3
Bar/Grill	12	0.28	0.0004	0.0002	0.00011	MB	2
Domestic	-	0.38	0.0004	0.0003	----	MB	3

[a] IGGT= Inground gravity trench (conventional), IGGB = Inground gravity bed (conventional), IGPB = Inground pressure bed, MD = Mound bed, IGPT = Inground pressure trench.
[b] Rating Scale: 0 = hydraulically failed; 1= mostly flooded but handling daily flow; 2 = intermittent ponding or partial system ponding; 3 = no ponding
[c] First bed failed, replacement system ponded after two months.
[d] Single family home STE (Harkins et al., 1979).

In a Florida study, Matejcek, et al. (2000) evaluated the behavior of various soils loaded with a range of concentrations of simulated 'high-strength' septic tank effluent. The major finding in this work was the identification of a threshold for organic loading at which drainfields will fail due to mass loading. No failures were recorded in lysimeters with low strength wastewater (111mg/L $CBOD_5$, 39 TSS mg/L, & 14 mg/L O&G), which received a daily mass loading of 1.5×10^{-3} $lb/ft^2/day$ or less. The study identified a combined $CBOD_5$ and TSS loading threshold between 1.5×10^{-3} $lb/ft^2/day$ and 2.4×10^{-3} $lb/ft^2/day$. The study recommended that mass loading rates should not exceed 1.5×10^{-3} $lb/ft^2/day$ for typical soils, and this threshold is a reasonable strength to base system design on unless additional research is conducted to further clarify the upper limit. A $CBOD_5$ loading threshold alone, however, would be somewhat lower than the combined $CBOD_5$ and TSS loading threshold recommended in this study.

Crites and Tchobanoglous (1998) reported typical design organic loading for single pass sand filters to be less than 1.0×10^{-3} lb $BOD_5/ft^2/day$ with a range of 5.0×10^{-4} to 2.0×10^{-3} lb $BOD_5/ft^2/day$. In a field evaluation of forty-seven intermittent sand filter systems, Converse (1999) found the median organic loading rate on the sand filter for all sites was 5.8×10^{-4} lb $BOD_5/ft^2/day$, while the average is slightly larger at 6.8×10^{-4} lb $BOD_5/ft^2/day$ (Table 5). The rate ranged from 1.9×10^{-4} to 1.7×10^{-3} lb $BOD_5/ft^2/day$, with 90% of all the samples being below 1.2×10^{-3} lb $BOD_5/ft^2/day$. A significant relationship was found between the organic loading rate on the sand filter, and the sand filter effluent BOD_5, which indicated that as the organic loading rate increased so did the BOD_5 concentration in the sand filter effluent.

In his evaluation of intermittent sand filters, Converse (1999) found two prematurely failing sand filter (ponded beds), which had average organic loading rates of 1.3×10^{-3} lb $BOD_5/ft^2/day$ and 1.4×10^{-3} lb $BOD_5/ft^2/day$. The average BOD_5 loading rates of these failed systems were higher than 90% of the samples taken during the study (Table 5). The author did not attribute these failures solely to high organic loading, but to a combination of design, installation, and operation issues that may have inhibited oxygen transfer to the filters. Similar organic loading studies by Stuth (1999), Thurston

County Public Health (1999), and Stuth and Lee (2001) have shown the majority of systems can operate with minimal clogging problems at organic loading rates around 5.0 $x10^{-4}$ lb BOD_5 /ft^2/day, whereas increase biological clogging and ponding occurs when organic loading rates greater than 1.2 x 10^{-3} lb BOD_5 /ft^2/day are applied on a continuous basis, particularly if problems with oxygen transfer to the system exist.

Table 5. Septic Tank Effluent BOD_5, TSS, pH Concentrations and Mass Loading Rates (Converse, 1999)

	Capita	Hydraulic Load Gpd/ft^2	BOD_5 Mg/L	BOD_5* lb/day-capita	BOD_5* lb/ft^2/day	TSS Mg/L	TSS* lb/day-capita	TSS* lb/ft^2/day	pH
Median	4	0.44	178	0.06	5.8×10^{-4}	69	0.02	2.3×10^{-4}	7.46
Average	3.6	0.44	192	0.08	6.8×10^{-4}	87	0.04	3.4×10^{-4}	7.70
Maximum	7	1.07	548	0.25	1.7×10^{-3}	626	0.32	2.7×10^{-3}	8.56
Minimum	1	0.10	32	0.02	1.9×10^{-4}	14	0.04	3.4×10^{-4}	6.60
Standard Deviation	1.4	0.18	91	0.05	3.9×10^{-4}	91	0.05	4.1×10^{-4}	7.82
90^{th} Percentile	5	0.62	300	0.14	1.2×10^{-3}	146	0.06	6.0×10^{-4}	8.02
10^{th} Percentile	2	0.23	89	0.03	2.8×10^{-4}	30	0.01	7.2×10^{-5}	7.02
Count	47	42	141	42	42	47	42	42	140

* Loading rates were computed using the average BOD_5, TSS and the average water usage on the day that samples were taken resulting in a loading rate of lb/day, which was divided by the area of the filter to get the sand filter loading rate in lb/ft^2/day.

$CBOD_5$

In residential wastewater, the source of the largest portion of BOD is carbonaceous or organic carbon matter. The carbonaceous biochemical oxygen demand ($CBOD_5$) is a measure of the amount of the oxygen used by microbial and chemical processes that breakdown organic carbon into carbon dioxide and water. Carbonaceous material is that consumable material, which does not contain nitrogen. $CBOD_5$ is simply a BOD_5 analysis with a nitrification inhibitor, usually using a pyridine compound, added to prevent any oxygen loss during the five-day test due to the nitrification process (Brake, 1998). The resulting oxygen depletion is solely the result of microorganisms respiring.

Because $CBOD_5$ is a measure of only the carbonaceous material, and BOD_5 is a measure of nitrogenous and carbonaceous material, a correlation for BOD_5 and $CBOD_5$ for a given sampling site would be expected (Brake, 1998). The Department of Health has used a conversion factor with a $CBOD_5$/BOD_5 ratio of 25/30 or 0.83, which is based on results from EPA municipal sewage treatment plant effluent data, for testing wastewater treatment systems under ANSI/NFS Standard 40. For example, using the conversion factor, the current BOD_5 septic tank effluent threshold value of 220 mg/L that is in guidance would have $CBOD_5$ value of approximately 180 mg/L. Because of source variably of wastewater, however, this conversion factor is not constant or of the same magnitude for every given sampling site. In addition, $CBOD_5$ analysis is generally not performed on septic tank effluent samples in the field, whereas $CBOD_5$ is the test preferred for sampling secondary effluent. Consequently, because of limited available septic tank effluent $CBOD_5$ data, and an individual BOD_5/$CBOD_5$ conversion factor cannot accurately predict septic tank $CBOD_5$ values at every site, BOD_5 should be used instead of the $CBOD_5$ for characterizing septic tank effluent.

TSS

Total suspended solids (TSS) consist primarily of organic particles with a specific gravity near or below unity that are not easily removed by sedimentation but can be filtered. TSS are measured by forcing wastewater through a 2 μm filter after removing any dense inert particulate solids. Material remaining on the filter after drying at 103 to 105^0C is the TSS (Standard Methods, 2001). Suspended solids are not only important for aesthetic reasons, but they also host microorganisms, block soil pores, and exert a demand for oxygen.

Normal residential septic tank effluent typically contains about 80 mg/L TSS, a substantial portion of which are slowly biodegradable or inert (Siegrist, 1978). Comparing the soluble versus particulate long-term BOD_5 of domestic septic tank effluent and graywater septic tank effluent, Siegrist (1987) found that approximately half of the TSS in the domestic septic tank effluent and one-third of the TSS in the graywater septic tank effluent were comprised of slowly biodegradable or inert materials.

Maximum TSS loads reported by Van Buuren et al. (1986) at which clogging is prevented are approximately 8.0×10^{-4}, 2×10^{-3}, and 2.7×10^{-3} lb/ft^2/day at surface layer grain sizes of 0.17, 0.40, and 0.68 mm, respectively. Since the effective particle size for intermittent sand filter is between 0.3-0.5 mm, by adopting 2.0×10^{-3} lb/ft^2/day as the maximum mass TSS load, and using the maximum hydraulic design-loading rate of 1.0 gpd/ft^2/day, the maximum TSS concentration for coarse sand would be 250 mg/L. However, as the effective particle size influences the potential for clogging, soil with smaller particle sizes will have greater likelihood of clogging at this TSS loading rate. Fortunately, the occurrence of excessive TSS mass loading does not appear to be as great a problem as the excessive BOD_5 mass loading because normal residential septic tank effluent TSS rarely is above 150 mg/L (Crites and Tchobanoglous, 1998; Bounds, 2001, EPA, 2002). Additionally, high residential septic tank effluent TSS concentrations normally can be reduced and controlled with the use of effluent filters to obtain consistent low concentrations.

FOG

FOG refers to fats, oils, and grease in wastewater, which is typically originating from food stuffs (animals fats or vegetable oils) or consisting of compounds of alcohol or glycerol with fatty acids (soaps and lotions) measured in mg/L. The term FOG, as previously used in the literature, has now been replaced simply by the term oil and grease (Crites and Tchobanoglous 1997). When oil and grease reaches a soil dispersal component it can physical clog the soil pores preventing both wastewater and oxygen from moving freely. High BOD present in grease also promotes excessive bacterial growth, which causes the formation of a thick anaerobic soil clog that has less ability to actually treat the wastewater. The result is premature failure of the soil dispersal component.

The normal range for oils and grease in residential septic tank effluent is between 10 and 20 mg/L (Stuth, 2003). An elevated oil and grease value can be the result of doing all the laundry on one day or the cooking habits (heavy use of cooking oils, salad dressings, garbage grinder, etc.) of the household. Family members that use bath oils, lotions, shampoos, etc, can also increase this value (Stuth, 2003).

The typical restaurant has oil and grease concentrations varying between 1,000 and 2,000 mg/l, but maximum septic tank effluent concentrations should be less than 30 mg/l to prevent problems with the downstream treatment or soil dispersal component (Stuth and Garrison, 1995; Crites and Tchnobanoglous, 1998; Stuth, 2003). Using the proposed draft rules maximum hydraulic loading rate of 1.0 gpd/ft^2, an oil and grease threshold value of 30 mg/L would result in a maximum oil and grease mass loading rate of 2.5×10^{-4} lbs/ft^2/day.

Septic Tank Effluent Threshold Values-Other States

To provide additional information on septic tank effluent threshold values, a review of septic tank treatment performance expectations from other states was conducted. Table 6 summarizes the findings of this review. Of the states reviewed, septic tank values are either expressed as monthly, 30-day averages or maximum values.

Without an understanding of the actual wastewater flow to a system, the application of any of these maximum values is limited. As presented in the review of organic loading rates, the major factor influencing soil clogging is the organic mass loading (i.e. per unit area loading of organic matter) to the infiltrative surface resulting from the combination of wastewater quality and hydraulic loading rate. High mass loading rates could occur from additions of a low volume of wastewater with high amounts of organic matter or a high volume of wastewater with lower amounts of organic matter.

Table 6. Summary of STE Values for Residential Wastewater from other States
(All values are in mg/L except for pH, which is in Standard Units)

State	BOD_5	TSS	FOG	pH
Arizona (max. 30 day avg.)[4]	150	75	-----	-----
Florida (max. values)	300[1]	200	----	6-8
Minnesota (max. values)	220	65	30	
Montana (max. values)	300	150	25	
New Mexico (max. monthly avg.)[2, 4]	150	60	----	-----
North Carolina (max. monthly avg.)	200	75	30	-----
North Carolina (max. values)	300	150	50	
Ohio (max. values)[3]	250	150	25	-----
Oregon (max. values)	300	150	25	-----
Virginia (max. values)	200	150	30	
Washington (max. 30 day avg.)[3]	200[1]	80	20	
Washington (max values in guidance)	220	145	----	
Wisconsin (max. monthly avg.)	220	150	30	-----
EPA (2002) (representative concentrations)	140-200	50-100	----	
Crites and Tchobanoglous (1998) (without effluent filter)	150-250	40-140	20-50	
With effluent filter[4]	100-140	20-55	10-20	

(1) $CBOD_5$
(2) Albuquerque, Bernalillo County
(3) Proposed Standards
(4) Values are for a septic tank with an effluent filter

Conclusions:

A comprehensive review of the literature to address identified key issues on the subject of septic tank effluent values was conducted. The following conclusions can be drawn from the information available in the literature:

1) Research has shown that the major factor influencing soil clogging is the organic mass loading (i.e. per unit area loading of organic matter) to the infiltrative surface resulting from the combination of wastewater quality and hydraulic loading rate. Increasing the septic tank effluent organic loading rate tends to accelerate the biological clog growth. The result can be an inadequate long-term infiltration and treatment capacity. Consequently, single sample results to determine the waste strength of residential septic tank effluent are of little use in the field unless the actual hydraulic loading rate to a system is known.

2) For the purposes of monitoring systems in the field, organic loading rates are shown to be a more useful measurement of system operation than septic tank effluent threshold values alone. This suggests that establishing organic loading rate threshold values in rule is as important for addressing high strength tank effluent strength issues as identifying single-sample septic tank effluent values. These values can be established from the maximum hydraulic loading rate of a soil type and the assumed BOD_5 concentration of 150 mg/L for typical septic tank effluent (see table 3).

3) To protect microorganisms during anaerobic digestion, the pH of the wastewater needs to remain between 6 and 9. ANSI/NSF Standard 40 for residential wastewater treatment systems requires the pH of individual effluent samples to be within this range. This is a reasonable pH range to use as single-sample values for residential septic tank effluent where the pH should remain at or between these values.

4) Since the FOG has been replaced by the term oil and grease (O&G), O&G should be used for characterizing STE instead FOG. The literature suggests that the septic tank effluent O&G concentration be less than 30 mg/L to avoid problems with the downstream components of the system. Accordingly, a residential septic tank effluent single-sample threshold value for oil and grease of 30 mg/L is appropriate.

5) $CBOD_5$ analysis is generally not performed on septic tank effluent samples in the field, whereas $CBOD_5$ is the test preferred for sampling secondary effluent. The BOD_5 parameter should be used instead of the $CBOD_5$ parameter for characterizing septic tank effluent, due to limited available septic tank effluent $CBOD_5$ data, and a $BOD_5/CBOD_5$ conversion factor cannot accurately predict $CBOD_5$ values for septic tank effluent at all sites.

6) Field studies have shown the majority of the sand-based treatment systems and soil dispersal components operate with minimal clogging problems when an organic loading rate of around 5.0×10^{-4} lb/BOD_5/ft^2/day is applied. EPA recommends a maximum design organic loading rate of 1.0×10^{-3} lb BOD_5/ft^2/day for septic tank effluent applied to soil. This loading rate has an implicit factor of safety found in the design hydraulic loading rate of 0.8 gpd/ft^2, and assumes a BOD_5 concentration of 150 mg/L. A number of field studies have found when the organic loading rate is greater than 1.2×10^{-3} lb BOD_5/ft^2/day on a continuous basis there is increased likelihood of biological clogging and ponding of the soil or sand media, particularly if problems with oxygen transfer exist in the system.

7) The current BOD_5 threshold value of 220 mg/L in guidance appears reasonable to use as a single-sample threshold waste strength for residential septic tank effluent. This is equivalent

to an organic loading rate 1.8 x 10^{-3} lb BOD_5/ft^2/day if the system was hydraulically loaded at the maximum design rate of 1.0 gpd/ft^2. This threshold value does not imply that applying a BOD_5 loading rate near 1.8 x 10^{-3} lb/ft^2/day on a continuous basis is appropriate, because a system's actual hydraulic loading rate should be less than the maximum design hydraulic loading rate of 1.0 gpd/ft^2.

8) The draft rule $CBOD_5$ 30-day average threshold value of 200 mg/L in Treatment Level E is not consistent with the current septic tank effluent threshold value in guidance and suggested rule single-sample value of 220 mg/L BOD_5 (≈180 mg/L $CBOD_5$). Using the maximum design hydraulic loading rate of 1.0 gpd/ft^2, and the proposed Level E $CBOD_5$ value of 200 mg/L would result in an organic loading rate of 1.7 x 10^{-3} lb $CBOD_5/ft^2$/day or approximately 2.0 x 10^{-3} lb BOD_5/ft^2/day, which is substantially higher than what the literature suggest soil disposal components and sand-based treatment systems should be organically loaded on a continuous basis. In order for the Treatment Level E to be useful for testing pre-treatment components, the $CBOD_5$ threshold value should be adjusted to a value that will not create potential organic overloading conditions when effluent is applied to soil or media infiltrative surfaces on a sustained basis. Based on the draft rule hydraulic loading rates, the literature supports using an average value of 150 mg/l BOD_5 (≈125 mg/L $CBOD_5$), which is typical septic tank effluent to based system design on. The use of this lower value, and the maximum 1.0 gpd/ft^2 design hydraulic loading rate results in a maximum organic loading rate of 1.2 x 10^{-3} lb BOD_5/ft^2/day or 1.0 x 10^{-3} lb $CBOD_5/ft^2$/day that could be applied to a system on a 30-day average.

9) Excessive TSS mass loading does not appear to be as great as a problem as excessive BOD_5 mass loading. Accordingly, the current sand-based treatment system guidance TSS threshold value of 145 mg/L could be reduced to a residential septic tank effluent single-sample value 100 mg/L or less. This is equivalent to a TSS loading rate of 8.0 x 10^{-4} lb/ft^2/day if the system was hydraulically loaded at the maximum design rate of 1.0 gpd/ft^2. This threshold value does not imply a TSS loading rate near 8.0 x 10^{-4} lb/ft^2/day on a continuous basis is appropriate, because a system's actual hydraulic loading rate should be less than the maximum design hydraulic loading rate of 1 gpd/ft^2.

10) The suggested single sample STE threshold values cannot be applied without considering the larger context of overall operation of the on-site wastewater treatment system. In order to help regulators and service personnel assess the field performance of these systems, a Monitoring Guidance Document needs to be developed.

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