On-Site Wastewater
Technical Advisory Group

May 16, 2019
Kittitas County Courthouse
County Commissioners Chambers
Ellensburg, WA

Meeting Summary

MEETING ATTENDEES

Core Group Members Present

Dave Lowe, Lowridge
David Jensen, P.E., Jensen Engineering
Eric Evans. Kitsap County LHJ
Eric Knopf, Indigo Design, Inc.
Robert Monetta, Windermere Real Estate-Methow Valley
Chris Plager, Benton Franklin District LHJ
Justin Hartmann, CPSS, Wahkiakum County LHJ

Group Core Not Present

Season Long, Cowlitz County LHJ
Dave Hilton, Okanogan County LHJ

DOH Staff Present

Leslie Turner, LHSP Staff

INTRODUCTION:

The meeting began at 10:00 AM on May 16, 2019.

SUMMARY OF TECHNICAL DISCUSSIONS

Treatment Levels, Vertical Separation, and Hydraulic Loading Rates

Based on the issue paper and discussion, the WA Technical Advisory Group (TAG) recommends that the vertical separation and treatment levels remain as in the current WAC 246-272A.

Treatment Level delineations are currently being reworked by the Rule Revision Technical Subcommittee.

The TAG would like to see further research regarding hydraulic loading rate increases. They advise increasing the hydraulic loading rate for all soil types by a factor of 0.2 when Treatment Level B is applied. Further research will be presented in an issue paper to follow.

WRAP UP:

The meeting ended at 2:00 pm, May 16, 2019.
The next meeting will be in Fall 2019.

Residential vs High Strength Waste

Leslie Turner
May 2019

The WA Technical Advisory Group (TAG) recommends adopting the following parameters for Residential Strength Waste:

Effluent:

CBOD5 228 mg/L

TSS 80 mg/L

O&G 20 mg/L

WAC 246-272A Onsite Sewage Systems (OSS) allows LHJs to permit wastewater from non-residential (not industrial) if it is treated to residential strength. The rule does not define maximum values for residential strength. Waste sampling results were collected from a number of reliable results which are presented in this paper. The numbers were averaged to obtain a recommendation for Carbonaceous Biological Oxygen Demand ($CBOD_5$), Total Suspended Solids (TSS), and Fats, Oils and Grease (FOG or O&G) values. Nearly all of the study results were reported in BOD_5. The current rule uses $CBOD_5$ in lieu of BOD_5. To reconcile the numbers, BOD_5 results were adjusted in the tables by applying the following conversion: $CBOD_5 = BOD_5 \times 0.83$. WAC 246-272A-0125 (5) (c) allows test results for BOD_5 to be submitted in lieu of test results for $CBOD_5$ using a 0.83 conversion factor.

There have been many studies and a variety of values for residential versus commercial wastewater strengths collected from various states and literature regarding wastewater. An analysis of these values will hopefully lead to drawing the fine line between residential and high strength waste values for the State of WA. In this paper, several studies with conclusive numbers are compiled and compared. A set of parameter values are recommended.

A biomat is a beneficial biological layer which develops at the soil interface of the drainfield and causes the effluent movement to slow down. It provides an ideal habitat for anaerobic microorganisms that digest effluent particles. The formation of the biomat is a progressive event. This living slimy layer also restricts the flow of the effluent and its infiltration rate into the unsaturated soil which is commonly referred to as the vadose zone. If equilibrium between the biomat and soil interface are not achieved the biomat layer becomes too thick restricting wastewater flow and failure may result.

High strength wastewater has more organic matter than residential strength wastewater. Biological Oxygen Demand (BOD_5) is a 5 day test measuring the amount of dissolved oxygen consumed by microorganisms as they feed on the organic matter in sewage. The higher this value is, the more organic matter exists which in turn can support more microorganisms. With a high organic composition, more organisms are needed for digesting the organic matter and therefore more oxygen is needed. Greater organic matter may lead to an excessive biomass which in turn can lead to clogging of components and the biomat, and ultimately shorten the life of the OSS. The higher the BOD_5, the higher the overall strength of the wastewater.

Total Suspended Solids (TSS) are also evaluated to determine wastewater strength. The suspended solids may be organic or inorganic particles. Inorganic particles are not broken down by the biological processes. The tests for TSS may be a solids and/or a turbidity analysis. High turbidity is an indicator of high TSS. High TSS can lead to clogging devices and clogging orifices and impact the biomat.

Fats, Oils and Grease (FOG or O&G) are evaluated to determine wastewater strength. These constituents do not break down easily. Fats and oils may be made up of animal fats, vegetable oils and other cooking shortening. Grease comes from body lotions, laundry detergent, shampoos, dead microorganisms, etc. They are lighter and less dense than water and float to the top of the septic tank and grease traps. The accumulation of FOG is typically called the "scum" layer in a septic tank. High amounts of FOG can accumulate in the pipes and the biomat and lead to clogging, interfering with aerobic treatment processes and cause a decrease in the treatment efficiency.

Beside the 5 day Biological Oxygen Demand test, there is a 5 day Carbonaceous Oxygen Demand ($CBOD_5$) test also used to analyze the microorganism mass. A nitrogen inhibitor is added to the $CBOD_5$ to lower the oxidation of carbonaceous matter. With lower oxidation, there are fewer bacteria so the $CBOD_5$ is less than BOD_5. The BOD_5 should be higher than the $CBOD_5$ by approximately 15 - 20 %. (Muirhead et al.)

FOG state at room temperature and toxicity levels (Lesikar, B., Stuth Sr., W., et al, 2008)

Constituent	State at Room Temperature[1]	Derived From	Comments[2]
Fats	Solid	Animal fat	Non-toxic to the system
Oils	Liquid	Vegetable and cooking oils	Non-toxic to the system
Grease	Liquid	Petroleum based products: soaps, hair conditioners, tanning oils, oil/grease on hands/ clothes, bath oils, etc.	Residual material on appliances; solid material attached to pans/ equipment; may potentially be toxic to microbes commonly present in the wastewater treatment system.

[1] Room temperature assumes 80°F.
[2] Warning: the use of a degreaser will move all of these components through the wastewater system.

Treatment of commercial waste containing FOG such as from a food service can lack enough oxygen to break down the FOG and the pH may not be high enough for the microorganisms' survival. This may lead to pipe and drainfield clogging.

In this paper, all BOD_5 values were converted to $CBOD_5$ by a factor of 0.83. Unless from the study, average values are the range of measured values divided by two. The recommended values are the sum of all of the averages below divided by the number of averages. In effluent values, all strengths were included, with or without effluent filters, and with or without food grinders were all added into the average total.

Section 1
Residential Strength Wastewater

Residential strength waste effluent (Stuth and Wecker)

$CBOD_5$ mg/L	**TSS** mg/L	**O&G** mg/L
108 – 144	47-62	10 – 20
Average 126	**Average** 55	**Average** 15

Stuth, William L, 2003

Typical residential waste strength values

Parameter	Range	Typical
BOD_5	110 to 250 mg/l	140 mg/l
TSS	20 to 155 mg/l	40 mg/l
FOG	10 to 20 mg/l	15 mg/l
DO	0 to 1.0 mg/l	0.5 mg/l
pH	6.5 to 7.2	7.0

Note: BOD5 110 to 250 mg/l = 91 $CBOD_5$ to 208 mg/l. Typical BOD_5 mg/L = 116 $CBOD_5$.

Effluent values of residential septic tank with and without an effluent filter, mg/L
Crites and Tchobanoglous

With garbage disposal and w/o effluent filter Mg/L		With garbage disposal and effluent filter Mg/L	
$CBOD_5$	**RANGE**	**$CBOD_5$**	**RANGE**
158	100 - 140	116	83 - 116
TSS	**RANGE**	**TSS**	
85	40- 140	30	20 - 55
O&G	**RANGE**	**O&G**	**RANGE**
30	20 - 50	20	10 - 20

Untreated domestic wastewater in mg/L Metcalf & Eddy, Inc. 1991

	$CBOD_5$	**TSS**	**O&G**
Weak	93	100	50
Medium	183	220	100
Strong	332	350	150

Untreated domestic wastewater in mg/L Metcalf & Eddy, Inc. 2003

	$CBOD_5$	**TSS**	**O&G**
Weak	91	120	50
Medium	158	210	90
Strong	291	400	100

Crites and Tchobanoglous 1998.

$CBOD_5$	TSS	O&G
	95	31

Gunn 2014

Raw sewage characteristics

$CBOD_5$	TSS	O&G
120 - 237	155 - 330	
Average 179	**Average** 320	

Gunn

Septic tank effluent

$CBOD_5$	TSS	O&G
98 - 157	36 - 85	
Average 177	**Average** 79	

CIDWT glossary

Residential Wastewater definition; from septic tank or treatment device	$CBOD_5$ Mg/L	TSS Mg/L	FOG Mg/L
Less than or equal to	141	60	25

2004 High Strength Waste Values by State (SORA)

State	$CBOD_5$ Mg/L	TSS Mg/L	FOG Mg/L
Montana	249	150	25
New Mexico, with effluent filter	150	60	
North Carolina monthly average	200	75	30
North Carolina Maximum values	300	150	50
Virginia	200	150	30
Ohio	250	150	25
Minnesota	220	65	30
Oregon	300	150	25
Utah	250	145	25
Wisconsin	220	150	30

State	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
Arkansas	>249	>300	>25
Colorado Influent Colorado Effluent	>249 >149	>200 >80	>50 >25
Connecticut Low Weak Medium Strong	<191 91 183 332	<150	<25
Idaho	129 - 232	155-330	70-105
Ohio	208	330	25
Minnesota Influent Minnesota Effluent	249 141	200 60	50 25
Oregon Effluent	249	150	25
Utah Effluent	183	145	25
Wisconsin Influent Monthly Average	183	150	30
WA TL E	125	80	20
WERF 2009 Influent WERF 2009 Effluent	450 268	334 68	50 19

Residential WW

Reference	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
EPA (2002) Average	129 – 238 248	155 – 330 320	70 – 105 88
Crites and Tchobanolglous 1998 w/out effl. Filter Average with effl. Filter Average	125 - 208 167 83 -116 141	40-140 110 20-55 48	20-50 45 10-20 15
Lesikar, Stuth, et al. (2008) **Raw** High Strength WW High Strength STE	 >249 >141	 >200 >60	 >50 >25
Burks & Minns (1994) **Raw** Typical	 83 – 332 208	 100-400 220	 50 – 150 100
Tchobanoglous (1991) **Raw** WW Weak Medium Strong	 91 183 332	 100 220 350	 50 100 150
Goldstein and Moberg Suggested $CBOD_5$ for restaurants (used as upper limit for residential)	 374		
Stuth, William, L. (2003) Typical Residential waste strength Range Average	 91 – 208 116	 20 – 155 98	 10 – 20 15

Water Environment Research Foundation (WERF) conducted a comprehensive field study through the Colorado School of Mines, measuring several parameters of residential influent and effluent. The collection of data was 2007 to 2008.

- The study looked at 3 regions in the US
  - Midwest/Northeast = Minnesota
  - South = Florida
  - West = Colorado
- 68 sites (with data)
- Systems were under 25 years old with concrete chambered septic tanks serving 2 to 6 occupants varying in age from small children to seniors.
- 24 hour composite samples were collected from the Influent and effluent
- The sites were monitored in the fall 2007, winter 2007, spring 2008, and s55ummer 2008.
- The Hydraulic Retention Time (HRT) is estimated based on daily flow and the reported tank size

WERF Averages:

Septic Tank Influent	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
Average	419	335	From 34 Sites 326

Septic Tank Effluent	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
Average	228	63	From 34 Sites 21

Please see attached charts

Section 2
Commercial, high strength wastewater

Facilities that typically generate high strength waste:

- **Restaurants**
- **Laundromats**
- **Catering / Banquet / food services**
- **Nursing Homes**
- **Supermarket / meat cutting**
- **Bakery / deli**
- **Schools**
- **Youth Camps**
- **Coffee / Espresso stands**
- **RV Parks / wet sewer**
- **RV dumps / boat pump-out**
- **Farm worker camps**

CIDWT glossary

High Strength Wastewater definition	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
Influent	>249	>200	<50
Effluent From a septic tank or other pretreatment component	>141	>60	>25

High Strength Wastewater Literature Review by Sara F. Hager

	$CBOD_5$ Mg/L	**TSS Mg/L**	**FOG Mg/L**
Range Average	83 – 3059 3100	142 – 4375 2330	50 – 14,958 7504
Median in the high to mid strength entering ST or grease trap	2075	1200	300

- Please see attached charts for Grant County Yearly Septic Reports for miscellaneous commercial facilities for 2013 through 2018

STE from various commercial establishments

Siegrist et al., 1985 **STE**	**$CBOD_5$** **Mg/L**	**TSS** **Mg/L**	**FOG** **Mg/L**
Restaurant A	483	187	101
Restaurant B	203	65	40
Restaurant C	730	372	144
Restaurant D	313	247	101
Restaurant E	575	125	65
Restaurant F	217	66	47
Motel	142	66	45
Country Club A	164	56	24
Country Club B	276	121	46
Country Club C	84	44	33

Bar/Grill	149	79	49

Chen, X et al. 2000

Restaurant Wastewater	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
Chinese	48 – 1187	13.2 – 246	120 – 172
Average	618	130	146
Western	406 – 1170	152 – 545	52.6 – 2100
Average	788	349	1076
American	336 – 1859	68 – 345	158 – 799
Average	1098	241	558
Student Canteen	452 – 1353	124 – 1320	415 – 1970
Average	903	784	1400
Bistro	374 – 584	359 – 567	140 – 410
Average	665	643	345

Hammerlund, D., Glotfelty, B.

Commercial Septic Tank Effluent Quality

	BOD5	COD	TSS	TKN	NO3	TP	FOG
MEAN	888	1206	132	69	<0.2	18.5	182
MEDIAN	626	1090	90	60	<0.2	---	67
MIN.	155	170	10	29	<0.2	16.9	13
MAX.	2951	2888	642	127	1.4	20	814
#of Samples	26	27	27	26	15	2	8

All Sample Results are in milligrams per liter (mg/l)

(Samples collected from 13 sites in Maryland)

The average $CBOD_5$ = 737 mg/L

PARKS RV **dump** sampling data

samples taken in 1998 at 33 parks

	(Influent) Parameter					
	pH	COD	BOD	TSS	NH_4	FOG
Average	**7.16**	**7815**	**5042**	**5215**	**786**	**682**
Maximum	8.5	32300	24,300	31, 330	1110	2910
Minimum	6.69	1620	520	152	542	11
Median	7.07	4180	2875	1570	822	330

	(Effluent) Parameter					
	pH	COD	BOD	TSS	NH_4	FOG
Average	**7.27**	**2961**	**2743**	**1560**	**526**	**306**
Maximum	7.70	8820	21330	24400	919	2190
Minimum	7.09	271	138	68	140	21
Median	7.20	3110	2140	374	580	84

from: 1999 PARKS Report: "RV Waste Treatment Facilities Assessment" - Moore & Gerst

Average Influent $CBOD_5$ = 20,169 mg/L

Average Effluent $CBOD_5$ = 17,704 mg/L

Conclusion and Recommendations

Parameter values for both influent and effluent residential vary greatly. Parameter values for both influent and effluent commercial facilities vary greatly.

The average of all values for residential effluent are:

Septic Tank Influent	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
Average	227	223	96
Recommended	230	225	95

Septic Tank Effluent	**$CBOD_5$ Mg/L**	**TSS Mg/L**	**FOG Mg/L**
Average	222	95	29
Recommended	220	95	25

Appendix A

Original Charts in BOD_5

Residential Septic Tank Effluent Values (mg/L)

	EPA[1]	DOH[2]	Stuth[3]	TLE[4]
BOD_5	160	100	140	125*
TSS	100	37	40	80
O&G	37	15	15**	20

[1]EPA Onsite Manual 2002 - 5 study averages

[2]DOH Waste Strength Technical Paper (with eff. filter)

[3]Residential Wastewater Profiles, Stuth 2003

[4]WAC 246-272A (treatment compliance standard)

*($CBOD_5$) **FOG

2018 High Strength Waste Values by State (SORA)

State		BOD_5 Mg/L	TSS Mg/L	FOG Mg/L
Arkansas		300	300	25
Colorado	**Influent**	300	200	50
	Effluent	180	80	25
Connecticut	Low	230	150	25
	Weak	110		
	Medium	220		
	Strong	400		

Idaho Average	155-280 218	155-330 243	70-105 88
Ohio	250	330	25
Minnesota **Influent** Effluent	300 170	200 60	50 25
Oregon Effluent	300	150	25
Utah Effluent	250	145	25
Wisconsin **Influen**t Monthly Average	220	150	30
WA TL E	$CBOD_5$ 125	80	20

Table 4-12. Average septic tank effluent concentrations of selected parameters from various commercial establishments[a]

Wastewater Type	BOD_5 (mg/L)	COD (mg/L)	TSS (mg/L)	TKN (mgN/L)	TP (mgP/L)	Oil/Grease (mg/L)	Temp (°C)	pH
Restaurant A	582	1196	187	82	24	101	8–22	5.6–6.4
Restaurant B	245	622	65	64	14	40	8–22	6.6–7.0
Restaurant C	880	1667	372	71	23	144	13–23	5.8–6.3
Restaurant D	377	772	247	30	15	101	16–21	5.7–6.8
Restaurant E	693	1321	125	78	28	65	4–26	5.5–6.9
Restaurant F	261	586	66	73	19	47	7–25	5.8–7.0
Motel	171	381	66	34	20	45	20–28	6.5–7.1
Country Club A	197	416	56	36	13	24	6–20	6.5–6.8
Country Club B	333	620	121	63	17	46	13–26	6.2–6.8
Country Club C	101	227	44	36	10	33	10–23	6.2–7.4
Bar/Grill	179	449	79	61	7	49	8–22	6.0–7.0

[a] Averages based on 2 to 9 grab samples depending on the parameter taken between March and September 1983.

Source: Siegrist et al., 1985.

Wastewater parameter	Lesikar, et. al Study AUG 2006
BOD_5 (mg/L)	1523
TSS (mg/L)	664
FOG (mg/L)	197
Flow	96 (L/day-seat)

average results, 28 restaurants, 12 samples each

Table 4—Characteristics (average range of values) of restaurant wastewater

Wastewater parameter	Chinese restaurant	Western restaurant	American fast food	Student canteen	Bistro
BOD_5 (mg/L)	58 to 1430	489 to 1410	405 to 2240	545 to 1630	451 to 704
SS (mg/L)	13.2 to 246	152 to 545	68 to 345	124 to 1320	359 to 567
FOG (mg/L)	120 to 172	52.6 to 2100	158 to 799	415 to 1970	140 to 410

Chen, X.; Chen, G.; Yue, P. L. (2000) *Separation of Pollutants from Restaurant Wastewater by Electrocoagulation.* Separation Purification Technology. Elsevier Science B.V.: Cambridge, Massachusetts.

Raw wastewater

PARKS RV **dump** sampling data

samples taken in 1998 at 33 parks

	(Influent) Parameter					
	pH	COD	BOD	TSS	NH_4	FOG
Average	**7.16**	**7815**	**5042**	**5215**	**786**	**682**
Maximum	8.5	32300	24,300	31, 330	1110	2910
Minimum	6.69	1620	520	152	542	11
Median	7.07	4180	2875	1570	822	330

	(Effluent) Parameter					
	pH	COD	BOD	TSS	NH_4	FOG
Average	**7.27**	**2961**	**2743**	**1560**	**526**	**306**
Maximum	7.70	8820	21330	24400	919	2190
Minimum	7.09	271	138	68	140	21
Median	7.20	3110	2140	374	580	84

from: 1999 PARKS Report: "RV Waste Treatment Facilities Assessment" - Moore & Gerst

Appendix B

Grant Co and WERF charts

2016 grant county numbers.xlsx WERF Raw WW.pdf WERF STE.pdf

Bibliography

Benson, Richard, WA DOH. High Strength Waste, WSEHA 2018 Annual Education Conference, May 2018

Chen, X. et al. Separation of Pollutants from Restaurant Wastewater by Electrocoagulation. Separation Purification Technology. 2000. Elsevier Science, B.V.

Crites, R. and Tchobanoglous, G. Small and Decentralized Wastewater Management Systems. 1998

Gunn, Ian Septic Tank Effluent Quality Notes. August 2014

Hager, Sara. High Strength Wastewater Literature Review. Univ. of Minn., Water Resource Center, Onsite Sewage Treatment Program, St. Paul, MN
CIDWT, Consortium of Institutes for Decentralized Wastewater Treatment. Second Edition. 2009

Hammerlund, D., Glotfelty, B. Onsite Sewage disposal Of High Strength Wastewater, MDE – Water Management Administration, Onsite Systems Division

Lesikar, B., Stuth Sr., W., et al. Analyzing Wastewater Treatment Systems. 2008, Texas AgriLife Extension Service.

Lowe, Kathryn S. et al. Influent Constituent Characteristics of the Modern Waste Stream from Single Sources 04-Dec-01. 2009. Water Environment Research Foundation (WERF)

Moore and Gerst, RV Waste Treatment Facilities Assessment. 1999 Parks Report.

Metcalf and Eddy, Inc. revised by Tchobanoglous, G. and Burton, F.L, Wastewater Engineering, Treatment Disposal and Reuse. 1991

Muirhead, W.M., Farmer, G., et al. Study of Raw Wastewater BOD_5 and $CBOD_5$ Relationship Yields Surprising Results. 2006. WEFTC Water Environment Foundation.

Stuth Sr., William L., Aqua Test Inc., Maple Valley, WA

Wecker, C.S and Stuth, W.L System Failure Analysis

WEF (Water Environment Federation) Manual of Practice #8. Engineering Practice No. 76. Design of Municipal Wastewater Treatment Plants, Fifth Edition 2018

Treatment Levels, Loading Rates and Vertical Separation

Leslie Turner
May 2019

On May 16, 2019, the WA Technical Advisory Group (TAG) recommended that the Vertical Separation remain as in the current WAC 246-272A. The Treatment Levels are being reworked by the On-Site Rule Revision Technical Subcommittee. Based on the attached Tyler 2001 Table 1, they advise increasing the Hydraulic Loading Rates (HLR) for Soil Types 1 - 5 by a factor of 0.2 gallons per square foot per day when Treatment Level B is applied.

Wastewater treatment by soil

This paper will attempt to address soil treatment of residential strength wastewater. The factors examined are the treatment level that must be achieved to minimize harmful microorganisms, how much effluent a given soil can process (hydraulic loading rate) and how much of a given soil is needed to complete the treatment and liquid dispersal (vertical separation).

Most onsite sewage systems include soil as the final wastewater treatment. "Soil surfaces are chemically reactive sites on soil particles where a host of treatment mechanisms can take place." (Loomis 1996).

The effluent moves to the drainfield which develops a biomat. A biomat, also known as a "clogging layer" is a beneficial thin, living filter with anaerobic conditions and a high population of microorganisms that develops at the trench/soil interface. It slows the migration of effluent, causing slight ponding. On the upper trench side, the biomat provides an ideal habitat for anaerobic microorganisms that digest effluent particles and other microorganisms.

The soil beneath the biomat is the soil treatment area. This area, commonly referred to as the vadose zone is aerated, undisturbed and unsaturated native soil. Aerobic microorganisms prevail in this area. Equilibrium between the flow through the biomat and soil interface is often referred to as the long-term acceptance rate (LTAR). If the biomat becomes too dense for oxygen flow, or if the effluent application exceeds the infiltration ability of the biomat, it acts as a barrier to the vadose zone and the effluent will likely surface.

The State of WA soil hydraulic loading rates are assigned with the assumption that a biomat will be formed.

The effluent is adsorbed (attaches) to soil particles. Microorganisms take up residence in the micropores consuming the suspended solids in the effluent and the associated pathogens traveling in it. The soil micro and macropores provide aeration supporting aerobic bacteria which then out compete the anaerobic bacteria. These processes are sensitive to temperature, pH, oxygen levels and moisture content of the soil.

Nitrogen

Nitrification is the biological conversion of ammonium to nitrate. In the septic tank, an anaerobic environment, with long solids retention time, ammonium and organic nitrogen is converted to ammonia; a dissolved gas. The aqueous solution travels to the soil; an aerated environment. The dissolved ammonia is converted by Nitrosomonas bacteria to nitrite in the drainfield. Nitrite is readily converted to nitrate by Nitrobacter bacteria. Nitrate dissolves in and travels in the water.

$$1\mathrm{NH_4^+} + 1.9\mathrm{O_2} + 0.1\ \mathrm{CO_2} + .03\ \mathrm{HCO_3^-} \rightarrow 0.02 + \text{New cells} + 1\ \mathrm{NO_3^-} + 0.09\ \mathrm{H_2O} + 1.98\ \mathrm{H^+}$$

Nitrate has been proven to be a detrimental compound to humans. (EPA 2002)

Denitrification is the biological reduction of nitrate to nitrogen gas by facultative heterotrophic bacteria. Nitrogen gas is a harmless gas comprising 78% of the earth's atmosphere. Heterotrophic bacteria need an organic carbon source as food to live. Denitrification occurs in an anaerobic environment making nitrate the primary oxygen source for microorganisms. When bacteria break apart nitrate to gain oxygen, the nitrate is reduced to nitrous oxide and nitrogen gas. Nitrogen gas has low water solubility, so it escapes into the atmosphere as gas.

$$C_{10}H_{19}O_3N + 10NO_3^- \rightarrow 5N_2 \uparrow + 10CO_2 + 3H_2O + NH3 + 10\ OH-$$

Denitrifying bacteria require alkalinity, organic carbon, and lack of oxygen. This process takes place to some degree at the biomat when ponding occurs.

Phosphorus

The vadose zone can be an area of phosphorus accumulation. Some phosphorus passes through and into groundwater, but this is minimal. Overall, phosphorus is tightly bound by soil and is effectively retained in the vadose zone below the drainfield. When the soil holding capacity of phosphorus is reduced – all attachment sites on the minerals are in use - the phosphorus travels progressively with the flow of water.

Pharmaceuticals
This is a contaminant of concern that is in the infancy of evaluation in effluent. Conn et al. finds them to be not very pervasive and occurring at low levels.

Viruses, bacteria and other pathogens
Viruses are retained in the soil primarily by chemical and physical adsorption to clay or hydrous oxide surfaces. (Loomis 1996). These processes are temperature, pH, and water sensitive. The retention is not necessarily permanent. They may become resuspended during heavy rain events or ground water flooding. More movement of viruses occurred in a strongly structured clay than a less structured clay (Pang et al 2008.) This may be due to the easy passage of water in the macropores surrounding the peds. Due to the small size of viruses, they are not considered to be filtered by the biomat as are many bacteria and protozoa.

In aerated conditions, survival of the septic (anaerobic) bacteria and viruses is low because they do not compete well with the aerobic microorganisms. Acid soils increase the die off of septic bacteria but encourage viral persistence likely due to increased adsorption. (Loomis 1996).

The correct onsite sewage system treatment design is critical as we continue to develop smaller properties closer together with a greater population. "Poorly designed, built or maintained onsite wastewater treatment systems accounted for 23% of groundwater-related disease outbreaks in the United States between 1971 and 2008. (Wallender et al., 2014)" Amador and Loomis 2018.

In Washington, the maintenance of onsite sewage systems is spotty and under-regulated. As a result, ongoing performance of proprietary products and public domain technologies is not known. Therefore, the soil is heavily leaned on to assure final effluent treatment as well as dispersal.

In the following tables vertical separation (VS) requirements are listed from 1990 and 2014 for various states. The table from 1990 is based on investigation of the state's web posted regulations. The table from 2014 is from a national survey response. Some states currently allow a smaller VS with greater treatment of BOD and TSS. One state allows a VS reduction based on the fecal count. The duration of the fecal testing was not specified. One state requires 10 mg/L BOD, 10 mg/L TSS and disinfection to allow for a 6 to 12 inch VS. One state listed treatment and type of dispersal as factors. Soil textures and structures and hydraulic loading rates are not mentioned. The VS assigned in WA appear to be much less stringent than most of the other states in the charts. However, WA has treatment levels, hydraulic loading rates and distribution methods defined.

In the FC (fecal coliform) Reductions table, soil texture, amount of vertical separation and hydraulic loading rates are given with the removal efficiency. The systems studied were gravity or pressure distribution. One study included sites which were fully saturated at times.

Water Environment Research Foundation (WERF) 2009 State of the Science: Review of Quantitative Tools to Determine Wastewater Soil Treatment Unit Performance publication sums up factors which primarily control the fate of viruses, bacteria, and protozoa in soil. The report finds that virus treatment is not dependent on soil texture or depth. However, pH and clay mineralogy, organic matter in the effluent and the presence of unsaturated soil below the infiltrative surface are significant factors. Protozoa are primarily removed by mechanical filtration.

Bacteria are primarily removed by mechanical filtration which is controlled by soil texture and structure, treatment depth and the presence of unsaturated soil below the infiltrative surface. The WERF report did not find that the HLR was a consistent factor in bacterial removal. Studies by Ausland et al., 2002, Potts et al., 2004, Stevik et al., 1999 indicate that an increase in HLR corresponds with a decrease in bacterial removal. However, Van Cuyk et al., 2001 found equal removal rates for varied HLRs. The WERF Report goes on to state that "other factors, such as oxygen availability, and system age, may be more important than HLR in controlling bacterial removal." This statement does not speak to maintaining a LTAR at the biomat to prevent surfacing. Siegrist points out that a maximum HLR for a given soil should recognize that even a highly treated effluent can cause clogging and permeability loss if the HLR exceeds the clean-water hydraulic conductivity of the native soil (Van Cuyk et al., 2005)

Other factors that should be considered are the two extremely varied ecosystems on each side of Washington. The westside is generally a wetter, more acid environment, the eastside is generally drier and more alkaline. Climate change will also have an impact on the microorganisms and in some areas, the amount of vertical separation to a water table.

There is quite a bit of current research which is ongoing that should provide greater insight into the movement and treatment of effluent through the soil. The conclusions of the studies will be helpful for future evaluation for Washington rule application.

It is recommended that the current WAC 246-272A treatment levels, vertical separation and hydraulic loading rates do not change at this time.

Table 1.
Vertical Separation Requirements in Various States, 1990

(Vertical Separation, Selden Hall, WA DOH 1990)

"The amount of vertical separation required in various states is highly variable. Where the separation is allowed to be less than two feet, there is no statement of the technical justification for doing so. The following data were extracted from the regulations from the listed states."

Alabama	1.5 feet	Minimum
Colorado	4 feet	May be reduced if designed by a registered engineer and approved by the local board of health (where local regulations permit such variances for exclusively domestic wastes).
Florida	3.5 feet 2 feet	To impervious layer. To highest level of the water table.
Idaho	3-6 feet 4 feet	To water table or fractured bedrock, depending on soil type. To an impervious layer
Louisiana	2 feet 4 feet	To the maximum level of water table. To impervious layer.
Maine	1-2 feet	Depending on soil and subsoil
New Jersey	4 feet	
North Carolina	1 foot	

Oregon	4 feet .5 foot 0 feet	To permanent water table To impervious layer when bottom of trenches are in rapidly or very rapidly permeable soils. To temporary water table (dries up for period of time each year) or permanent water table where it is determined by groundwater study that degradation of the groundwater and public health hazard will not occur and where water table is 2 feet below the ground surface.
Pennsylvania	4 feet	
South Dakota	4 feet	
Utah	2 feet	
West Virginia	3 feet	
Wisconsin	3 feet	
Wyoming	4 feet	

Table 2. Vertical Separation Requirements in Various States and Alberta, Canada, 2014, State Onsite Regulators Alliance (SORA 2014)

Alberta	2 feet	25 mg/L BOD, 30 mg/L TSS, NSF standard 40, pressure distribution with low loading rates. Linear loading is considered
Colorado	2 feet 3 feet	Sand filter media with Std. 40 effluent and pressure dosed. STE is pressure dosed
Delaware	3 feet 18 to 36 inches	 Treatment and type of dispersal are considered in the separation requirements
Kansas	4 feet	To impervious layer
Massachusetts	4 feet 2 feet	Depending on soil and subsoil If variance is granted

Minnesota	1 foot 1.5 feet 3 feet	=<1,000 fecal coliform 1,001 – 10,000 fecal coliform 10,001+ fecal coliform
Nebraska	4 feet 1 foot	 Mound with the sand fill providing at least 4 feet of separation between the bed and the restrictive layer
New York	2 feet 4 feet	State minimum Some jurisdictions
Oklahoma	2 feet 10 inches	Sands and loamy sands (not coarse) Clay loams and silty clay loams
Pennsylvania	4 feet 20 inches	 Mound. The sand makes up the difference of the 48 inches to bedrock.
South Dakota	4 feet	If the 4 feet cannot be met then a holding tank or mound on a liner designed for total evaporation
Vermont	4 feet 2 feet	Conventional systems 30 mg/L BOD and 30 mg/L TSS with pressure dosing
Virginia	1.5 feet 1 foot 6 – 12 inches	Conventional system with STE Secondary treatment 10/10 BOD/TSS effluent with disinfection If less than 18 inches then a mounding analysis is required, O&M is required on all alternative systems, loading rates vary with effluent quality and dispersal type
West Virginia	3 feet 2 feet	Conventional systems Secondary treatment
Wyoming	4 feet	

Table 3.

"Tyler (2001) prepared a table (see Table 1) for estimating hydraulic loading rates into the soil from septic tank effluent (>30 mg/L BOD) or low organic strength wastewater (<30 mg/l BOD) based on field described soil characteristics of texture, structure, consistence, and mineralogy. The logic and trends in values presented in the table fit with scientific basis and with experience and were prepared for field practitioners. Values assume wastewater volume of >150gpd/bedroom. If the horizon consistence is stronger than firm or any cemented class or the clay mineralogy is smectitic, the horizon is restrictive regardless of other soil characteristics. The authors indicated further research and testing were needed to verify the values." (Eliasson, 2002)

Table 1. **Suggested Hydraulic Loading Rates for Sizing Infiltration Surfaces (After Tyler, 2001)**

TEXTURE	**STRUCTURE**		**HYDRAULIC LOADNG (gpd/ft^2)**	
	SHAPE	**GRADE**	**BOD>30 mg/L**	**BOD<30 mg/L**
Coarse sand, Sand, Loamy coarse sand, Loamy sand	Single grain	Structureless	0.8	1.6
Fine sand, Very fine sand, Loamy fine sand, Loamy very fine sand	Single grain	Structureless	0.4	1.0
Coarse sandy loam, Sandy loam	Massive	Structureless	0.2	0.6
	Platy	Weak	0.2	0.5
		Moderate, Strong		
	Prismatic, Blocky, Granular	Weak	0.4	0.7
		Moderate, Strong	0.6	1.0
Fine sandy loam, Very fine sandy loam	Massive	Structureless	0.2	0.5
	Platy	Weak, Mod., Strong		
	Prismatic, Blocky, Granular	Weak	0.2	0.6
		Moderate Strong	0.4	0.8
Loam	Massive	Structureless	0.2	0.5
	Platy	Weak, Mod., Strong		
	Prismatic, Blocky, Granular	Weak	0.4	0.6
		Moderate	0.6	0.8
Silt Loam	Massive	Structureless		0.2
	Platy	Weak, Mod., Strong		
	Prismatic, Blocky, Granular	Weak	0.4	0.6
		Moderate, Strong	0.6	0.8
Sandy clay loam, Clay loam, Silty clay loam	Massive	Structureless		
	Platy	Weak, Mod., Strong		
	Prismatic, Blocky, Granular	Weak	0.2	0.3
		Moderate, Strong	0.4	0.6
Sandy clay, Clay, Silty clay	Massive	Structureless		
	Platy	Weak, Mod., Strong		
	Prismatic, Blocky, Granular	Weak		
		Moderate, Strong	0.2	0.3

Table 4.

Soil FC Reductions

complied by John Eliasson, 2018

Contaminant	Influent				Effluent			
	Loading rate (gpd/ft^2)	**n**	**Median** Fecal Coliform CFU (100 ml) $^{-1}$	**Range**	**n**	**Median**	**Range**	**Removal Efficiency**
Karathanasis et al. (2006)			**Septic Tank Effluent**					
Loamy Sand (**Soil Type 3**) 18" vertical separation	1.0	15	9.4 x 10^{5*}	±4.85 x 10^5	15	1,100*	±1.7 x 10^3	99.9%
Loamy Sand (**Soil Type 3**) 24" vertical separation	1.0	15	9.4 x 10^{5*}	±4.85 x 10^5	15	100*	±100	99.98%
Loamy Sand (**Soil Type 3**) 18" vertical separation	1.0	15	3.3 x 10^{5*}	±1.82 x 10^5	15	3.22 x 10^{4*}	±4.38 x 10^4	93.8%
Loamy Sand (**Soil Type 3**) 24" vertical separation	1.0	15	3.3 x 10^{5*}	±1.82 x 10^5	15	7.28 x 10^{4*}	±5.9 x 10^4	77.9%
Anderson et al. (1994) 24" vertical separation			**Septic Tank Effluent**					
Fine Sand (**Soil Type 4**) Pressure Dosed	0.75	11	3.7 x 10^{4*}	3.9 x 10^3 - 2.5 x 10^5	24	ND	<1	>99.9%
Ausland et al. (2002) 48" vertical separation								
Fine Sand (**Soil Type 4**) Pressure Dosed	0.98	10	2.0 x 10^{6*}	2.5**	10	1*	1**	>99.9%
Fine Sand (**Soil Type 4**) Gravity Dosed	0.5	10	2.0 x 10^{6*}	2.5**	10	ND	<1	>99.9%

Contaminant	Influent				Effluent			
Cogger et al. (1988) Pressure Distribution Drainfield								
Fine Sand (**Soil Type 4**) 12"-18" vertical separation (50% of the time)	0.245	13	2.5 x 10^{6*}	±3.98 x 10^{6}**	11	6.3 x 10^{3*}	NR	99.7%
24"-36" vertical separation (72% of the time)	0.245	13	2.5 x 10^{6*}	±3.98 x 106**	11	<20*	NR	>99.9%
Alhajjar et al. (1988) 36" vertical separation								
Sandy Loam (**Soil Type 4**) Gravity Flow Drainfield		29	6.3 x 10^{4}	2.0 x 10^{3} – 5.5 x 10^{8}	10 5	<1	<1- 4.0 x 10^{3}	>99.9%
Karathanasis et al. (2006)			**Septic Tank Effluent**					
Sandy Loam (**Soil Type 4**) 18" vertical separation	0.7	15	6.47 x 10^{5*}	±6.06 x 10^{5}	15	6.9 x 10^{3*}	±1.51 x 10^{4}	98.9%
Sandy Loam (**Soil Type 4**) 24" vertical separation	0.7	15	6.47 x 10^{5*}	±6.06 x 10^{5}	15	2.3 x 10^{3*}	±5.5 x 10^{3}	99.6%
Loam (**Soil Type 4**) 18" vertical separation	0.7	15	6.33 x 10^{5*}	±6.29 x 10^{5}	15	3.9 x 10^{3*}	±1.18 x 10^{4}	99.38%
Loam (**Soil Type 4**) 24" vertical separation	0.7	15	6.33 x 10^{5*}	±6.29 x 10^{5}	15	600*	±1.9 x 10^{3}	99.8±%
Sandy Loam (**Soil Type 4**) 18" vertical separation	0.7	15	7.58 x 10^{5*}	±3.21 x 10^{5}	15	2.02 x 10^{5*}	±1.67 x 10^{5}	70.8%
Sandy Loam (**Soil Type 4**) 24" vertical separation	0.7	15	7.58 x 10^{5*}	±3.21 x 10^{5}	15	9.1 x 10^{3*}	±1.84 x 10^{4}	98.2%
Hepner et al. (2007)	0.17		**Septic Tank**					

Contaminant	Influent				Effluent			
12"- 24" vertical separation			**Effluent**					
Silty clay loam (**Soil Type 5**) Drip Dispersal	0.17	20	2.7 x 10^6	90 – 1.2 x 10^8	18 3	91	2,450 – 2.2 x 10^5	99.99%
Cooper et al. (2014)			**Sand Filter Effluent**					
Silt Loam (**Soil Type 5**) 12" vertical separation Pressurized shallow Drainfield and GeoMat	2.77	49	3.0 x 10^2	6.0 x 10^0 – 3.9 x 10^4	49	ND	<1	>99.9%
Karathanasis et al. (2006)			**Septic Tank Effluent**					
Silt Loam (**Soil Type 5**) 18" vertical separation	0.5	15	2.35 x 10^{5*}	±1.4 x 10^5	15	1.07 x 10^{4*}	±1.35 x 10^4	94.4%
Silt Loam (**Soil Type 5**) 24" vertical separation	0.5	15	2.35 x 10^{5*}	±1.4 x 10^5	15	2.9 x 10^{3*}	±5.2 x 10^3	98.9%
Silt Loam (**Soil Type 5**) 18" vertical separation	0.5	15	9.8 x 10^{4*}	±9.3 x 10^4	15	100*	±200	99.9%
Silt Loam (**Soil Type 5**) 24" vertical separation	0.5	15	9.8 x 10^{4*}	±9.3 x 10^4	15	100*	±200	99.9%
Clay Loam (**Soil Type 6**) 18" vertical separation	0.5	15	8.86 x 10^{5*}	±1.03 x 10^6	15	1.42 x 10^{5*}	±2.4 x 10^5	87.4%
Clay Loam (**Soil Type 6**) 24" vertical separation	0.5	15	8.86 x 10^{5*}	±1.03 x 10^6	15	3.12 x10^{5*}	±3.73 x 10^5	63.7%

* Indicates situations where mean values are given

**Indicates situations where standard deviation values are given

Table 5. From Siegrist, et al. 2014

Wastewater constituents and treatment expectations from a well-designed and properly operated soil treatment unit treating 1 to 5 cm/d of domestic septic tank effluent (Siegrist et al., 2012).

Constituents of concern	Basis for concern over wastewater constituent	Example unit of measure **(units)**	Domestic **septic tank effluent'**	Treatment efficiency in a **STU** [2]
Oxygen demanding substances	Can create anoxic or anaerobic conditions and can contribute to soil clogging	BOD_5 (mg/L)	140 to 200	>90%
Particulate solids	Contributes to soil pore filling and accelerated soil clogging	TSS (mg/L)	50 to 100	>90%
Nitrogen	Can contribute to oxygen demand, can be toxic Via drinking water ingestion, can unset ecosystems	Total N (mg-N/L)	40 to 100	!0to20%
Phosphorus	Can cause increased productivity in sensitive surface waters	Total P (mg-P/L)	5 to 15	I 00 to 0%[3]
Bacteria	Infectious disease transmission via drinking water, contact with seepage. or recreational waters	Fecal coliforms (org./100 mL)	10^6 to 10^8	>99.99%
Virus	Infectious disease transmission via drinking water, contact with seepage, or recreational waters	Specific virus (pfu/mL)	0 to 10^5 (episodically high levels)	>99.9%
Heavy metals	Potential toxicants to humans by ingestion in drinking water or to ecosystem biota	Individual metals (ug/L)	0 to low levels	>99%
Trace organic compounds	Potential health effects to humans by ingestion of drinking water or vapor inhalation during showering or effects to ecosystem biota	Organics in consumer products, pharmaceuticals, pesticides, flame retardants (ng/L or ug//L)	0 to trace levels	Low to >99.o/o[4]

Note. STE concentrations given are representative of those for residential dwelling units. However, commercial sources such as restaurants can produce STE that is markedly higher in some pollutants (e.g., BOD_5, COD, TSS, trace organics) while other sources can produce STE that is markedly lower in some pollutants (e.g., laundry can have lower total nitrogen and pathogen levels). [2]Efficiencies given are representative of concentrations in soil solution at 60 to 90 cm (2 – 3 feet) depth in a well-designed, installed and operated STU. [3]P-removal is highly dependent on media sorption capacity and P loading rates and time of operation. [4]Removal of trace organic compounds (e.g., nonylphenol, Triclosan, EDTA, caffeine) is highly dependent on the properties of the organic compound and conditions within the soil treatment unit (e.g., conditions conducive to sorption and biotransformation during adequately long hydraulic retention times).

Bibliography

Alhajjar et al. 1988. Modelling of biological tracers from septic systems
Water Research 22(7):907-915

Amador, Jose A. and Loomis, George W. Soil – Based Wastewater Treatment. Dept. of Natural Resources Science, Univ. of Rhode Island. American Society of Agronomy, Inc. copyright 2018.

Anderson, D. L., et.al. 1994. In-Situ lysimeter investigation of pollutant attenuation in the vadose zone of a fine sand. p. 209-218. In: E. Collins (ed.) OnSite Wastewater Treatment, Vol. 7, ASAE Publ. 18-94. Proc. 7th Intl. Symp. On Individual and Small Comm. Sewage Systems, Atlanta, GA. December 11-13, 1994. American Society of Agricultural Engineers, St. Joseph, MI.

Ausland G, et al. 2002. Intermittent filtration of wastewater - removal of fecal coliforms and fecal streptococci. Water Res., 36, 3507– 3516.

Cogger, C. 1988. On-site septic systems: the risk of groundwater contamination. Journal of Environmental Health Vol. 51, No. 1, pp. 12-16

Conn, K.E. et al. 2010a. Occurrence of Pharmaceuticals and Consumer Product Chemical in Raw Wastewater and Septic Tank Effluent from Single-Family Homes. Env. Eng. Sci., 27:347-56

Eliasson, John 2002. Hydraulic Loading. TRC Research Paper. WA DOH

Hall, Selden 1990. Vertical Separation. TRC Research Paper. WA DOH

L.D. Hepner et al. 2007. Reduction of Bacteriologic and Chemical Constituents of Septic Tank Effluent with Depth Using a Drip Dispersal System. Eleventh Individual and Small Community Sewage Systems Conference Proceedings.

Karathanasis, A.D., Mueller, T.G., Boone, B., and Thompson, Y.L. 2006. Effect of soil depth and texture on fecal bacteria removal from septic effluents. Journal of Water and Health: 4 (3) 395-404.

Loomis, George. Soil Based Wastewater Treatment, Eleventh Annual On-Site Wastewater Treatment Conference 1996.

Siegrist, R.L. 2014. Engineering Design o a Modern Soil Treatment Unit. Innovations in Soil-based Onsite Wastewater Treatment, Proc. Soil Society of America conference, Albuquerque, NM April 2014.

Siegrist, R.L. et al., Soil Treatment Units Used for Effluent Infiltration and Purification within Onsite Wastewater Systems: Science and Technology Highlights

Water Environment Research Foundation (WERF) 2009. State of the Science: Review of Quantitative Tools to Determine Wastewater Soil Treatment Unit Performance. Contributing authors from the CO School of Mines, Univ/Georgia, and Univ./Rhode Island