On-Site Wastewater
Technical Advisory Group

March 4, 2020
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
Bob Gaulke, Spokane Regional Health District LHJ
Justin Hartmann, CPSS, Wahkiakum County LHJ
Dave Hilton, Okanogan County LHJ

Core Group Members Not Present

Season Long, Cowlitz County LHJ

Guests

Bill Stuth

DOH Staff Present

Leslie Turner, OSS - LHSP
Andrew Jones, LOSS
Kathryn Hayden, LOSS
Randy Freeby, OSS - LHSP

INTRODUCTION:

The meeting began at 9:30 AM on March 4, 2020.

SUMMARY OF TECHNICAL DISCUSSIONS

TAG Business

The 3 year time commitment for new members of the group will begin on the date of their first meeting.

The newly revised TAG Participant Roles SOP was approved. An item for the next agenda is a discussion about the possibility of voting by email.

Recirculating Gravel Filter followed by Anoxic Woodchip Bed: List as TLN

Based on the issue paper (attached) and discussion, the WA Technical Advisory Group (TAG) recommends that the sequence of a recirculating gravel filter followed by an anoxic woodchip bed when constructed as per the State of WA Recommended Standards and Guidance (RS&G) document should be listed as meeting TL N.

The following caveats will be added to the document:

"Testing may be required by LHJ'

"Replace woodchips as needed"

Question to explore: what other types of woodchips can be used?

Recirculating Gravel Filter (RGF) nitrogen reduction credit

Based on the issue paper (attached) and discussion, the TAG recommends that when constructed as per the Recirculating Gravel Filter RS&G a 50% nitrogen reduction credit may be given to the RGF. The RS&G is currently under review for revision in the near future.

Pressure Distribution (PD) RS&G items This document is currently under revision.

2.3.2.2 – require septic tank outlet screening

2.4.1.4 – delete. The outlet baffle screen/filter will be required. A pump vault screen is optional. The information box below this item will be amended.

2.4.2.2.3 – remove minimum wetted area

2.8.3.3 – remove "trench"

Figure 4: Tee to Tee configuration – remove

Figure 8B add "secured"

Appendix C: change 5.a. from 7 times the volume to 5 times the volume of the liquid that drains after a dose (6 o'clock position)

Mound RS&G chamber illustration

It was agreed that an illustration utilizing chambers in a Mound be added to the Mound RS&G

WRAP UP:

The meeting ended at 2:45pm, March 4, 2020.
The next meeting will be in September 2020.

The Sequence Train of a Recirculating Gravel Filter with Vegetative Denitrifying Woodchip Bed (VDWB) should be listed as Achieving TL N

January 2020
Leslie Turner

The Washington Department of Health and University of Washington conducted a study of 3 denitrifying onsite sewage systems for residential sewage treatment from June 2012 to August 2013. This paper proposes placing the two-step process of the recirculating gravel filter (RGF) followed by a vegetative denitrifying woodchip bed (VDWB) with cattails on the List of Registered On-site Treatment and Distribution Products as meeting TL N. The WA DOH defines TL N as achieving 20 mg/L of total nitrogen or less.

Residential effluent contains approximately 60 mg/L of nitrogen. After some chemical reactions, the form of nitrogen eventually becomes nitrate. The EPA drinking water limit for nitrates is 10 mg/L.

Nitrification is the (microbiological) conversion of ammonium to nitrate nitrogen. In the anaerobic sewage tank, the ammonium and organic nitrogen is converted by bacteria to ammonia – a dissolved gas. When the effluent (with ammonia) travels to the aerated soil, the ammonia is converted to nitrite and then nitrate. The nitrate dissolves in and travels with water.

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

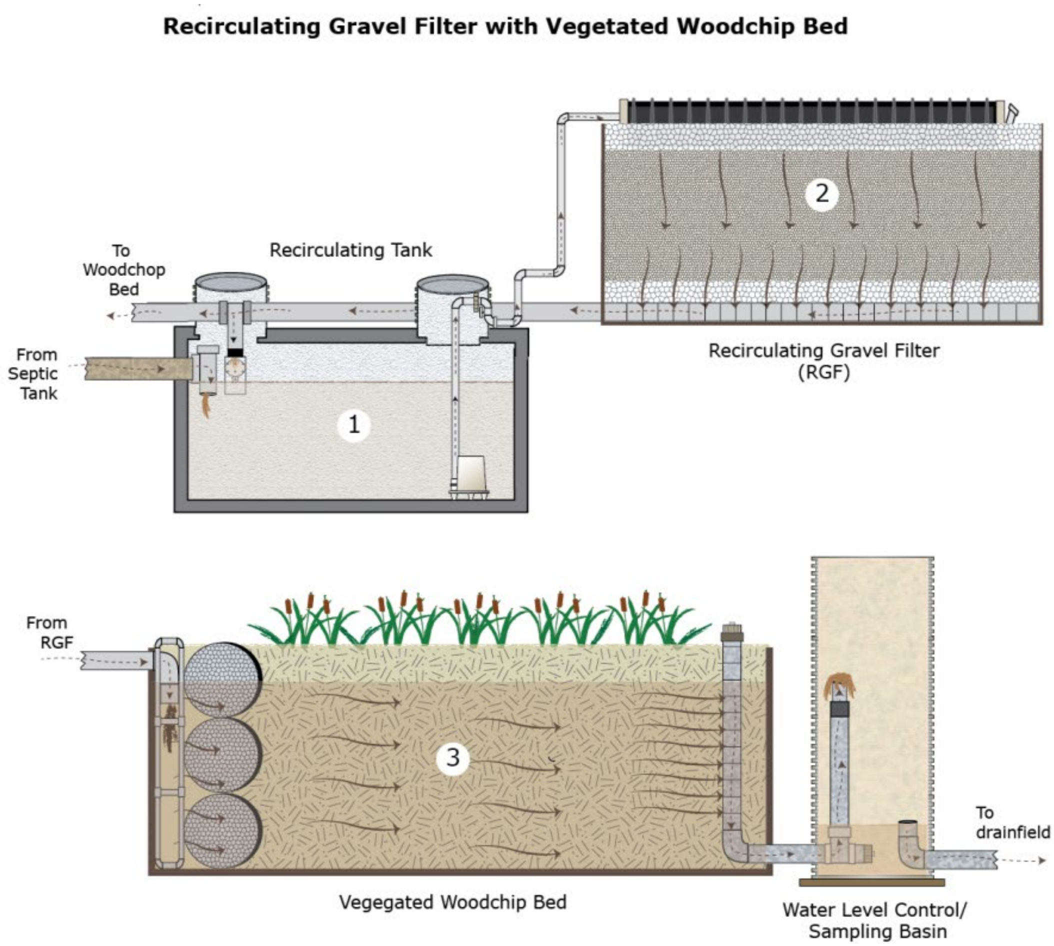
In order for nitrification to occur, 7.1 mg of alkalinity such as $CaCO_3$ (calcium carbonate) for every mg of ammonium to oxidize is required (Oakley, 2004). If 40 mg/L of ammonium were to nitrify, 284 mg/L of $CaCO_3$ is needed. This assures that the correct pH is being maintained for the denitrification process. The wastewater must contain enough alkalinity to support nitrification. (Oakley, 2004). Typically untreated domestic wastewater contains 50 to 200 mg/L of $CaCO_3$ (Metcalf and Eddy 1991).

The more completely the effluent is nitrified, the more completely it will be denitrified.

Denitrification is also a microbiological process. The nitrate is reduced by heterotrophic bacteria to nitrogen in the form of nitrous oxide or nitrogen gas. The heterotrophic bacteria we selected for need an organic carbon source for food and an anaerobic environment. The nitrate becomes the primary source of oxygen for the bacteria. The bacteria break apart the nitrate molecule to get the oxygen and the nitrate is reduced to nitrous oxide and gas. Denitrification occurs when the dissolved oxygen is less than 0.5mg/L. If there is more oxygen, the microbes will use that instead of the nitrate.

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

The recirculating gravel filter with the VDWB and cattails configuration:



The US EPA Environmental Technology Verification Program Residential Nutrient Reduction (ETV) nitrogen testing is currently the required nitrogen testing for proprietary products in WA, per WAC 246-272A-0110. To evaluate the system nitrogen reduction of the project, the ETV protocol was followed for the entire year of the experiment testing. Nitrogen parameters were analyzed by the University of WA UWCEE laboratory using the Standard Method for the Examination of Water and Wastewater, 2005.

The influent source was the Snoqualmie wastewater treatment plant, which is approximately 30 miles east of Seattle. The influent wastewater was primarily domestic, and had no industrial discharges. One year of influent wastewater data was evaluated it was confirmed that the wastewater characteristics met the wastewater characteristics criteria given in the ETV protocol. Total Kjeldhal nitrogen (TKN) concentrations were not measured for the Snoqualmie WWTP so they were estimated from the measured ammonia-N (NH3-N) values using a typical NH3-

N/TKN ratio of 0.60 for domestic wastewater. With this assumption the estimated influent TKN concentrations ranged from 37 to 70 mg/L, which is within the ETV protocol criteria. (Grinnell 2013). The testing period was from August 2012 to July 2013. Quality assurance/quality control procedures included performance evaluation, blind samples, and field duplicates (Grinnell 2013).

Total nitrogen influent concentrations averaged 48.9 +/- 9.5 mg-N/L, varying throughout the year with VDWB system was 4.0 +/- 3.8 mg-N/L with an average nitrogen removal of 91.8 +/- 7.8%. The ambient temperatures ranged from averages of 35F to 76F. (US Climate Data). The average influent temperatures were 41F to 62F.

The process was affected by temperature (Jones, A. 2015).

- During the cold periods with ambient temperatures averaging 35F, the average total nitrogen effluent concentration was 4.8 +/- mg-N/L. The total nitrogen removal averaged 85.7%. An increased detention time may compensate for the slowdown of reactions for denitrification.

- In the warmer months with ambient temperatures averaging 76 degrees F, The average total nitrogen effluent concentration was 0.1 +/-0.2 mg-N/L. The total nitrogen removal averaged 96.8%.

The average performance of the sequence train (RGF and VDWB) over a year:

Washington State Department of Health

Average Performance for RGF-Woodchip Bed Over 12-Month Test Period

(91.8% TN Removal and 960 CFU/100 mL effluent fecal coliform)

Parameter	units	Influent	RGF Effluent Average	Woodchip Effluent
Total N	mg/L	48.6 (9.5)	23.9 (5.4)	4.0 (3.8)
NH_3-N	mg/L	29.3 (5.3)	0.7 (0.4)	0.5 (0.5)
NOx-N	mg/L	-	21 (5.5)	2.4 (3.7)
Org-N	mg/L	-	2.2 (1.2)	1.1 (0.3)
BOD/CBOD*	mg/L	314 (97.8)	4.7 (2.6)	10.8 (14.1)
TSS	mg/L	354 (137)	10.1 (12.7)	2.1 (2.0)
VSS	mg/L	324 (131)	5.8 (5.5)	0.9 (2.3)
COD/SCOD*	mg/L	715 (223)	21.6 (5.5)	37.6 (20.7)
Total Phosphorus	mg/L	5.8 (1.3)	-	3.4 (1.9)
Fecal Coliform**	CFU/100 mL	8.4E+6	1.6E+05	0.96E+03
Alkalinity as $CaCO_3$	mg/L	231 (36)	84 (28)	154 (36.6)
pH		7.4 (0.3)	6.8 (0.3)	6.6 (0.2)

*Effluents, **Geometric mean, ( ) is standard deviation

PUBLIC HEALTH

There were two other experiments with the RGF and VDWB sequence train. The duration of these two systems was 24 months and they were located at the Hood Canal Salmon Enhancement

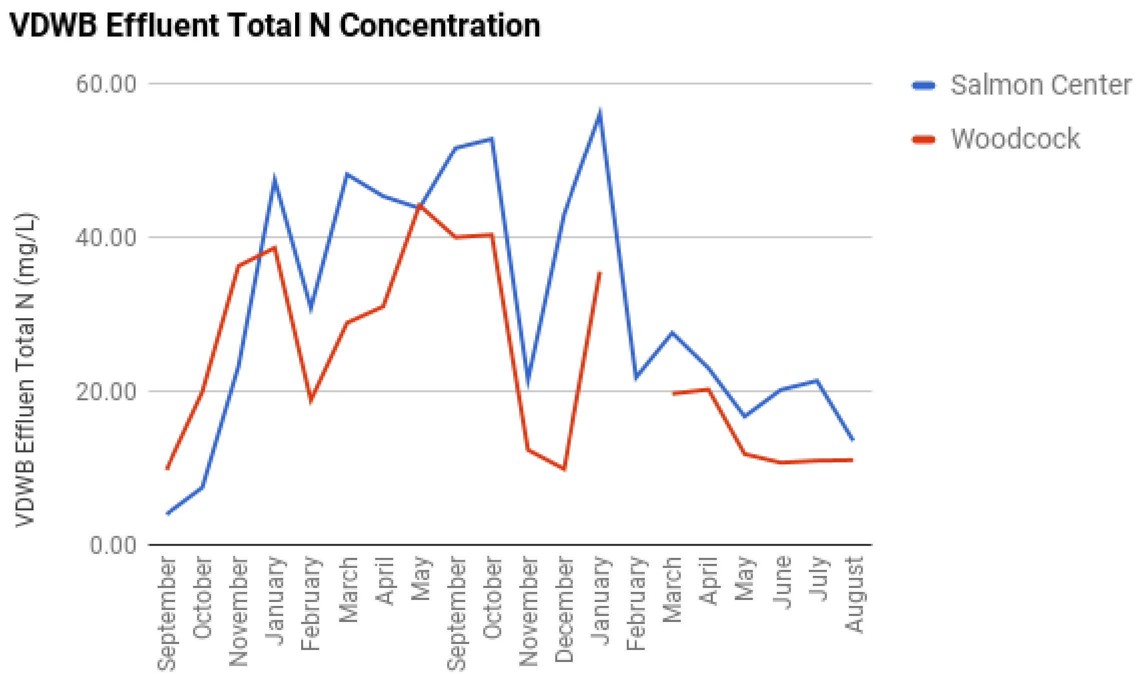
Center on the Hood Canal in Belfair and the Woodcock residence (bed and breakfast) located on the Hood Canal. In both situations, approximately 10-20% of the effluent was discharged from the RGF to the VDWB and then finally discharged to a drainfield.

June, 2017
Hood Canal Salmon Enhancement Group

If the required alkalinity is not available, nitrification and denitrification are negatively affected due to the reduced pH of the wastewater (DOH, 2005). Nitrification must occur in order for denitrification to occur. (Oakley 2004)

"Low pH measurements were observed throughout the study, indicating insufficient alkalinity. There was a consensus among the review committee that the limiting factor for nitrification in this study was alkalinity. The average RGF effluent ammonium concentration was 14.4 mg/L and 7.1 mg/L at the Salmon Center and Woodcock sites, respectively, with 83% and 90% of the ammonium nitrified by the RGF, respectively. After the study, the review committee presented a recommendation to further reduce the recirculation rate to the RGF in order to improve nitrification. Denitrification in the VDWB's performed inconsistently; during the first 14 months when average effluent Nitrate-Nitrite concentrations were 22.2 and 19.8 mg/L, with average denitrification efficiencies of 44.6% and 44.9% at the Salmon Center and Woodcock site, respectively.

During the final 10 months of the study denitrification improved dramatically, with average Nitrate-Nitrite concentrations of 6.9 and 2.5 mg/L, and average removal efficiencies of 83.7% and 90.3% at the Salmon Center and Woodcock sites, respectively. The review committee did not have a consensus on what may have caused the improved denitrification. Finally, the systems were very effective at removal *of TSS and FC, with average removal efficiencies of 95.1% and 99.9%, respectively, at the Salmon Center, and 98.3% and 99.8%, respectively, at the Woodcock site.*



31

The systems typically operated at half of their designed flow rate (excluding months with excessive water entering Woodcock system through an undetermined leak, which may have contributed to poor nitrification. The combination of insufficient alkalinity, flow variability, and low flows, are likely causes of the increased effluent concentrations of the RGF in comparison to the 2012 study." (Report to the EPA and WA Dept. of ECY 2017).

If the required alkalinity is not available, nitrification and denitrification are negatively affected due to the reduced pH of the wastewater (DOH 2015). Nitrification must occur in order for denitrification to occur. (Oakley 2004).

Recirculating gravel filters (RGF) are typically a lined bed with 2 - 4 feet of gravel media. Wastewater is pretreated in the septic tank converting organic sources of nitrogen to ammonia. This effluent is then evenly distributed across the top layer of gravel via pressure distribution. As the effluent moves through the filter, it becomes oxygenated and forms nitrate. The bottom of the recirculation tank provides an anoxic condition with effluent containing organic carbon. Some denitrification occurs there. After the effluent trickles down and collects, it is then sent to a recirculation tank or the septic tank and pumped to the top of the gravel. The effluent recirculates several times before finally flowing to the woodchip bed. During the nitrification process, bacteria attach to the gravel and convert ammonia to nitrite and then nitrate. The nitrified effluent then flows to the woodchip bed. Some denitrifying occurs in the recirculating gravel filter and some of the nitrate is taken up by the cattails. The remaining nitrate laded effluent is denitrified in the woodchip bed where heterotrophic bacteria convert the nitrate into nitrous oxide and nitrogen gas. The atmosphere is 78% nitrogen gas. The denitrifying heterotrophic bacteria need an oxygen free environment with an organic carbon source for food. In this case, the woodchips provided the necessary organic carbon. From the woodchip bed, the denitrified effluent then travels to the drainfield. The experimental site at Snoqualmie Falls did not include a soil component.

RGFs can perform both nitrification and denitrification in the same bed. Some studies have assigned solitary RGFs a 50% total nitrogen reduction. (Adler, et. al.)(Crites, 1998) "A recirculation system has an advantage in areas where nitrogen contamination is a problem." (Gouguen)

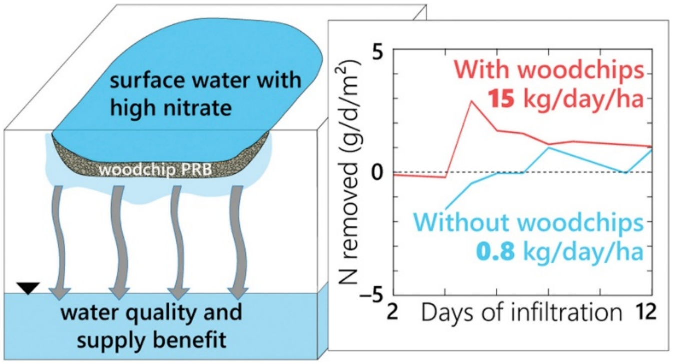
The 2010 WERF report on the "Development of Design Criteria for Denitrifying Treatment Wetlands" concluded that woodchips are an "effective source of carbon for the denitrification of nitrified septic tank effluent." This report also concluded that denitrifying wetlands reduced nitrate concentrations as high as 97 mg/L as NO3 (22mg/L as N) to effluent an concentration below the EPA drinking water standard of 10 mg/L as N."

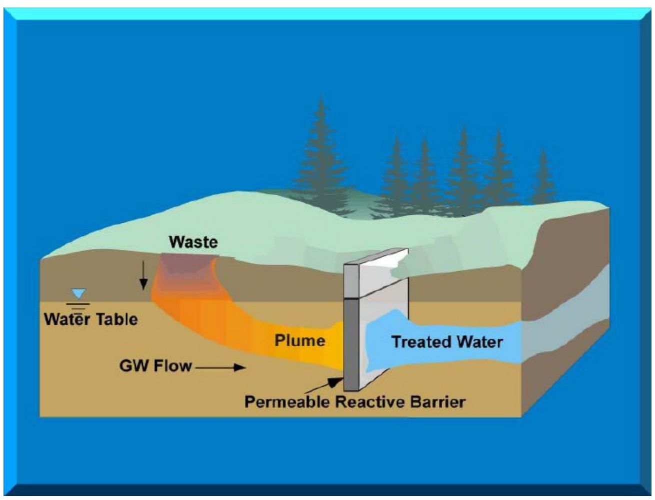
Fuchs, 2009, determined from literature reviews that "all of the upflow wetlands reported were able to achieve >50% removal of total N (ammonium and nitrate)". She also concluded from her literature review that there is not enough "performance basis" to determine the surface area, wetland volume or depth, or plants specific to nitrogen removal.

Lingua, et al. 2015, conducted a study of wetlands with pollutants, using Phragmites australis (common reed) inoculated with bacteria or arbuscular mycorrhizal fungi. They concluded that those plants inoculated with arbuscular mycorrhizal fungi yielded the greatest reduction in nitrates. Due to the inoculations, the size of the plants and their root system was enlarged, allowing for greater reduction in nitrate. They also found that only the plants inoculated with the fungi were able to decrease nitrates as high as 90 mg/L to a mean of 16.1 mg/L. The fungi form a symbiotic relationship with plants that contribute nitrogen and other nutrients to the plant in exchange for carbon. The fungi also reduced the tannins in alder woodchips. (Stamets).

The life span of the woodchips varies with different studies. Included in this paper are studies using denitrifying bioreactors. A bioreactor adds carbon, often in the form of woodchips, into the flow path of nitrate laden water. Bioreactors are now being used in agriculture to abate the nitrates in irrigation return water and other situations such as storm water, where nitrates are an issue.

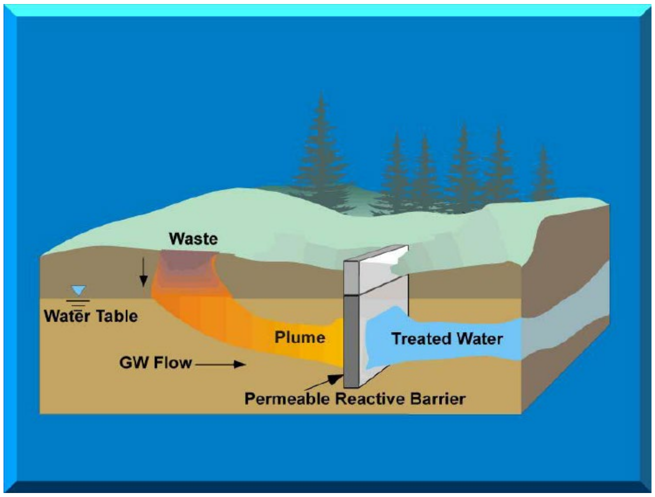
Permeable reactive barrier:





Schipper, et al, 2005, found that "wood-particle" media has shown the ability to deliver consistent nitrate removal with minimal maintenance may be effective for 5 – 15 years. The oldest bioreactor in their study was constructed in 1992 for a septic system plume. It was examined in 2007 (15 years later) yielding a nitrate removal rate of 50% lower than year 1. Schipper et al 2005 found that a 7 year denitrification bed was limited by nitrate rather than carbon. Jaynes et al 2008, found that there was a 60% removal in years 1 and 2. The following 6 years had just over 50% removal. After 8 years, 25% of the carbon in the woodchips remained but the woodchips in the saturated zone had >80% carbon remaining.

Robertson, et al 2008 found that a 2 and 7 year old bioreactor removal rates of nitrates remained at 50-75% rates of nitrate removal in fresh woodchips. The woodchips that were only periodically saturated had a t½ life of 4.6 years. The woodchips located in anoxic conditions had a t½ life of 36.6 years. Half-life ($t_{1/2}$) is the time required for a quantity to reduce to half of its initial value. They concluded that the sustainability of nitrate removal and provision of an ongoing woodchip carbon source depends on the level of saturation.



Specific Criteria for the Woodchip Bed per the revised RS&G:

Alder chips, free of bark, leaves, twigs, dirt, rock and foreign material and not treated wood.

Particle size = 0.5 to 3 inches in length, not less than 0.375 inches in width, and not less than 0.0625 inches thick. At least 85% of the media must conform to these specifications.

A minimum depth of 40 inches of woodchip media must be placed in all VDWBs. The water level should be maintained at least 6 inches below the surface of the woodchips at all times to prevent odors and for disease vector control. The water level must be set at least 34 inches above the VDWB bottom (see Figure 8). The woodchip media should be level. (RS&G)

Please see the amended 2015 Recirculating Gravel Filter Systems for more information.

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Recirculating Gravel Filter and Nitrogen Reduction

Leslie Turner
February, 2020

This literature review concludes that:

1. Recirculating gravel filters (RGF) can reduce the nitrogen concentration in the sewage tank effluent by approximately 50%.
2. Influent alkalinity must be at least 200 mg/L as $CaCO_3$ to ensure adequate buffering for nitrification. If necessary, the drinking water supply will need treatment to achieve this. The final effluent alkalinity levels must be at least 50 mg/L of $CaCO_3$.
3. To maximize denitrification the filtrate may be returned to the second compartment of the sewage tank. It may also be returned to the recirculating tank.

Nitrogen in the form of nitrate is a problem for drinking water, surface and ground water. The USEPA has limited this constituent to 10 mg/L in drinking water. Raw residential effluent is typically 60 mg/L (Toor et al 2014) (Tetra Tech).

Nitrification is the process of microorganisms converting ammonium to nitrate. The sewage tank is an anaerobic environment providing the retention time of sewage. Anaerobic microorganisms convert the ammonium to ammonia. Effluent flows from the sewage tank to the aerated soil where aerobic microorganisms convert the ammonia to nitrite then to nitrate. Nitrate dissolves in water and is carried wherever the water flows.

Denitrification is the process of microorganisms converting nitrate to nitrogen gas in an anaerobic environment. Ultimately in denitrification, bacteria break apart the nitrate (NO_3^-) to gain the oxygen (electron) and the nitrate is reduced to nitrogen gas (N_2) – a common gas in our atmosphere.

The more completely the effluent is nitrified, the more completely it will be denitrified. Nitrification must occur in order for denitrification to occur. (Oakley 2004).

The recirculating gravel filter is capable of both nitrification and denitrification.

In the nitrification process, 7.1 mg of alkalinity such as CaCO3 (calcium carbonate) is required for every mg of ammonium to oxidize. (Oakley 2004). To nitrify 60 mg/L of ammonium, 426 mg/L of CaCO3 is needed. Tetra Tech finds that to ensure the correct pH for nitrification, 50 mg/l should be maintained in the final effluent and there should be 200 mg/l as CaCO3 in the influent. In some locations, calcium carbonate may need to be added to the water supply to achieve optimal nitrification.

The alkalinity concentration is also critical and a limiting factor for denitrification to occur. If the alkalinity and therefore the pH are wrong, the specific microorganisms needed will not survive.

Lowe, K.et.al 2009, found a significant increase in alkalinity in the septic tank effluent (STE) at all sites their study monitored in all regions of the country during 4 seasons of the year. The alkalinity values ranged from 172 to 862 mg-CaCO3/L, with an average of 410 mgCaCO3/L, and a median value of 411 mg-CaCO3/L. A WERF literature review cited STE values ranging from 316 to 946 mg-CaCO3/L. The reason for this is unknown but the increase in alkalinity and they theorized that this may in part be due to a combination of the leaching of concrete tank materials into the STE.

The typical configuration of a RGF system in Washington consists of a septic tank, recirculation tank, recirculating gravel filter and drainfield. Effluent is timed pressure dosed over the media filter surface, percolates down through the media, collects at the base of the filter and flows back to the recirculating tank for further treatment or is diverted from there to the drainfield for final dispersal by a splitter.

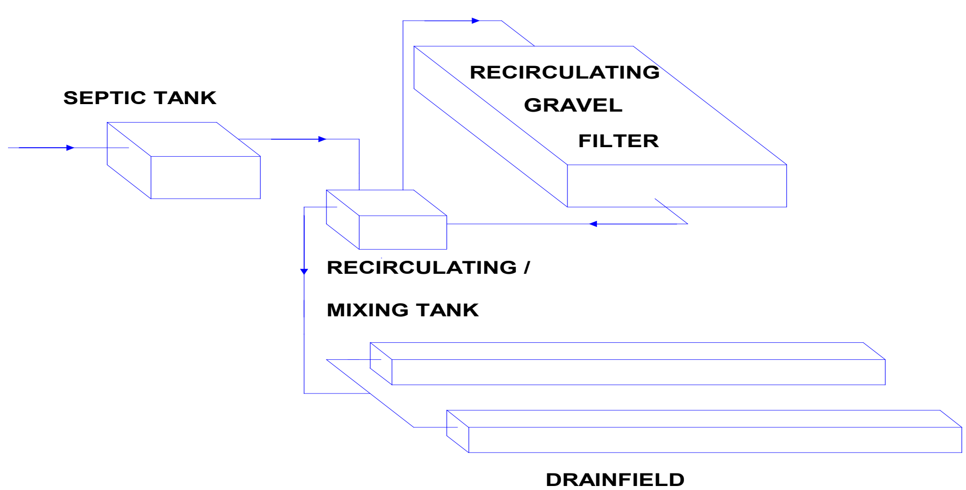

Figure 1 from WA DOH RGF RS&G

Wastewater is treated by mixing effluent that has passed through the media bed with raw septic tank effluent. Currently the guidance in WA returns a portion of the filtrate from the RGF to the recirculation tank however, the septic tank should be listed as an option. Both provide carbon for food and an anaerobic environment.

Some literature recommends that the return portion be directed to the septic tank rather than directly to the recirculating tank.

The Florida Passive Nitrogen Removal Study final report, 2008 states that recirculation of RGF treated effluent to a septic tank or dosing tank enhances denitrification. The "RGF with this configuration can reduce TN by 60% or greater."

The Nitrogen Reduction Technology Expert Review Panel for the Chesapeake Bay study indicates that if the septic tank is used as the recirculating unit there will be a "greater organic - carbon to nitrate ratio" which may permit a more complete denitrification.

Tchobanoglous (1999) identified that a key part of the sequence is good pre-clarification of wastewater prior to it being dosed onto the filter bed. The solids load to the filter bed is lowered, thereby avoiding bed clogging. Dr. Tchobanoglous found that reducing the particle size is highly beneficial to the biofiltration treatment process because microbes can consume and process smaller particles more quickly.

Five recirculating sand/gravel systems were evaluated by Venhuizen at the WA Island Demonstration Project in Wisconsin for 1 year (2008). The nitrified filtrate from the recirculating media filter returned a portion back to the second chamber of the septic tank rather than in the recirculating tank. If there are no problems with alkalinity or toxicity, there should be sufficient "indigenous carbon in domestic wastewater from septic tanks to have almost complete nitrogen removal." (Oakley 2004).

Another important factor when using a RGF is the recirculation ratio. The recirculation rate is the amount of the effluent that is delivered back into the system proportionally to the wastewater effluent that is to be dispersed.

The WA RGF RS&G requires a recirculation rate of at least 5:1. This means that it is designed to recirculate about 85 percent of the flow and discharge about 15 percent. Six times the influent flow is actually going through the RGF. Missouri Dept. of Natural Resources finds that an increase to 6:1 minimizes the dissolved oxygen present and maximizes denitrification.

The consequences of an increased ratio may include depletion of alkalinity due to complete nitrification, low pH which can impact microorganisms and treatment components, and filamentous organisms may form and clog the system. There is a potential need to supplement carbon for the denitrification. The Missouri Dept. of Natural Resources found that if a facility experiences periods of extremely low flow, treatment could be inhibited if the system does not utilize flow equalization.

Several studies have been conducted resulting in the assignment of substantial nitrogen reduction credit to RGFs.

Stephanie Wei (2013) cited 2 RGF total nitrogen (TN) reduction studies in La Grange County, IN conducted by Garcia-Perez et al.:
2006 - Single family home = 83%
2009 - Animal Shelter = 83%

The California Regional Water Quality Control Board (1997) assigned a 15 – 84 % TN removal. The RGF effluent tested had 10 to 47 mg/l N.

The December 1999 final report for the Burnett, WA on-site demonstration project system #12 consisted of a RGF with a subsurface drip drainfield. This was a 4 bedroom home with 3 adults and 2 teenagers. The measured flow was 235 gpd. The data collection from April to June, 1999 had the following range results:
TKN STE: 17.4 – 28.1mg/l
TKN of recirculation tank second chamber (pump chamber) : <1.0 - 2.2 mg/l
TKN immediately next to the drainfield: <1.0 – 2.2 mg/l
TKN 2 feet from the drainfield: <1.0 mg/l
TKN 10 feet from the drainfield: N/A

Fourteen RGFs followed by a Z-Cell wetland treatment were tested for nitrogen removal in a study by Byers, M.E. et al, 2004. The media was 3/8 inch pea gravel. They found that the RGFs prior to the wetland treatment were removing at least 50%.

Byers, 2004 Conducted a study of septic tank effluent and RGF effluent monitoring data IN and KY 2001-2004. Tables 1 and 2 from this study:

14 systems sampled, n=181

	pH	DO Mg/L	FC Col/dl	BOD Mg/L	FOG Mg/L	NH3-N Mg/L	NO3-N Mg/L	TSS Mg/L
Average STE	7.4	0.51	165664	215	36.9	40.7	1.22	75
SD	0.22	0.54	1405774	82	14	20.3	1.14	48.5
Average RGF	7.4	2.4	4723	12.3	1.9	6.1	14.6	7.3
SD	0.2	1.2	5097	5.4	0.8	3.4	9.9	3.7

The media used was 3/8" pea gravel with an average water load of 205 gpd.

The ammonia and nitrate combined RGF average discharge was 20.7 mg/l
The average discharge from the septic tank was 42 mg/l. The average nitrogen removal was 50%.

Crites and Tchobanoglous (1998) cited four studies and found the percent of total nitrogen removal ranged from 44 to 82 percent;

Oregon, Ronayne, 1984; Influent = 58 mg/l
Effluent = 32 mg/l; *45%*
Loading at 1.5 gpd/ft2
Paradise, CA, Nolte and Assoc. 1992;
Influent = 63 mg/l
Effluent = 35 mg/l; *44%*

Loading = 4.3 gpd/ft2

Paradise, CA, Nolte and Assoc. 1992;

Influent = 57 mg/l
Effluent = 26 mg/l; *54%*
Loading rate = 2.6 gpd/ft2

Florida, Sandy et al., 1988;

Influent = 55 mg/l
Effluent = 9.6 mg/l; *82%*
Loading rate = 3.8 gpd/ft2

The EPA Guidance for Federal Land Management in Chesapeake Bay Watershed, 2010 concluded that recirculating media filters have a high nitrification rate with a 50 – 70% total nitrogen reduction. This reduction was occurring when the treated effluent was recirculated back to either the septic tank or recirculation tank.

Based on an extensive literature review, the final report submitted to the Chesapeake Bay Partnership (2014) has the following criteria for RGFs to acheive nitrogen removal in range of 50%:

> "Preceded by properly sized /designed septic tank (minimum of 48 hour HRT in most states) retention time
> Properly sized recirculation pump tank (greater than or equal to 1.5 x HRT)
> Timer-based flow equalization controls to dose 24-48 times per day
> Organic load – less than or equal to 5 lb BOD/1000sq-day
> Gravel media:
>> Effective Size = 2 to 20 mm (3/16 to 25/32)
>> Uniform Coefficient = less than or equal to 2.5
>> HLR = less than or equal to 15 gpd/sf (5gpd/ft2 in WA)
>> OLR = less than or equal to 15 lbs. BOD/1000sf/day
>> #200 sieve = less than or equal to 0.5% passing
>
> Media depth = 2 feet
> Uniform, pressurized distribution providing 4 to 6 sf per orifice (2' x 2' or 2' x 3' grid)
> Recirculating device capable of recirculating 3 to 5 times forward flow back to separate anoxic recirculating tank or second compartment of the septic tank.
> Installation within a water tight tank

The recirculation rate is between 3 and 5 times the forward design flow to optimize denitrification.

Dosing every 30 to 60 minutes"

LOSS engineering note: If you do the same calculation for hydraulic loading using 0.0096 lb BOD/sf as we did for the 15 lb BOD/1000 sf, we get a hydraulic loading rate of 9.2 gpd/sf.
If we then apply a safety factor of 1.5, we end up with a maximum hydraulic loading rate of 6.13 gpd/sf, or 6 gpd/sf.

Per the Chesapeake Bay study, the additional safety factor of 1.5 may be excessive?

The WA large onsite sewage system (LOSS) program had two systems that monitored the total nitrogen at the septic tank inlet and the effluent from the dosing tank pump chamber.
The Machias Elementary School monitoring was from 04/25/13 through 03/13/14. This system was specifically designed as a nitrifying RGF.

The average removal was: 74%

The average influent was: 168 mg/l
The average effluent was: 30 mg/l
The maximum influent was: 299 mg/l
The minimum influent was: 38 mg/l
The maximum effluent was: 84 mg/l
The minimum effluent was: 22 mg/l

The Vashon Island High School LOSS measured the septic tank influent and the drip field dosing tank from 03/01/13 through 11/01/13.

The average nitrogen removal was: 54%

The average influent was: 105 mg/l
The average effluent was: 27 mg/l
The maximum influent was: 134 mg/l
The maximum effluent was: 34 mg/l
The minimum influent was: 77 mg/l
The minimum effluent was: 20 mg/l

It is recommended that:

- The RGF RS&G be modified assigning a potential 50% nitrogen reduction with the condition that the influent alkalinity is at least 200 mg/L as CaCO3 to ensure adequate buffering for nitrification. If necessary, the drinking water supply will need treatment to achieve this. The final effluent alkalinity levels must be at least 50 mg/L of CaCO3.
- Should the loading rate be increased?
- Allow the second chamber of the septic tank as an option for recirculation

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Of note: this paper only reviewed studies that did not include recirculating sand filters.

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