This article was originally presented at the Fractured-Rock Aquifers 2002 Conference, March 13-15, 2002, Denver, Colorado. It has been updated and revised for presentation at the Colorado Professionals in Onsite Wastewater 2008 Educational Conferences. This revision includes additional test data, with an emphasis on the cold-weather performance of the polishing sand filter. This is not a peer-reviewed article.

Use of a Recirculating Textile Filter followed by a Polishing Sand Filter for Onsite Wastewater Treatment in Colorado's Fractured Bedrock Environment

Roger J. Shafer, P.E.[*]

ABSTRACT

In a cooperative effort with Park County Health Department, an onsite wastewater system (OWS) was installed at an existing residence in May 2001. The system was installed to demonstrate an innovative alternative to the current standard of practice. The system consists of a recirculating textile filter followed by a polishing sand filter. The system provided a high level of treatment, in a relatively small area, at a viable cost. The system was re-visited, and additional test data collected after 6.5 years of operation. This article discusses the original construction and current condition. Test data from the original system, the textile filter, and the sand filter are presented. Emphasis is given to the system's cold weather performance.

BACKGROUND

An existing residential home in Park County, Colorado was chosen for the installation of an OWS upgrade to demonstrate an alternative to the current standard of practice. The home is located at an elevation of 8450 feet, in an area of shallow, highly fractured igneous and metamorphic bedrock. The current standard of practice for OWS installation in this area is to install a conventional septic tank followed by an "over-excavated" drain field. The drain field is constructed by excavating into the fractured bedrock to a minimum depth of six feet. A typical residential drain field is 600 to 1200 square feet in area. Once the 6-foot excavation is made, four feet of the material is placed back into the excavation. The material is assumed to be satisfactory for wastewater treatment; however, there is little site-specific testing to verify the assumption.

The water supply well serving the site is located in excess of 100 feet topographically upgradient from the drain field and greater than 200 feet from all neighboring drain fields. The depth of the well is unknown, however, on December 18, 2000 the static water level was measured at 32 feet below the ground surface, and the well production rate was measured at 6.9 gallons per minute (GPM) with a four-foot drawdown.

Samples of the well water were collected on nine occasions between the dates of December 18, 2000 and March 20, 2007 and tested for nitrates. The average nitrate (as nitrogen) level was 13.2 mg/l, which exceeds the EPA Drinking Water Standard limit of 10 mg/l. Since it is not unusual for groundwater nitrate levels to be elevated in this area, a treatment system, with nitrogen reduction abilities, was chosen for the site.

The home was occupied by two adults and 1-2 children throughout the study period.

TREATMENT SYSTEM UPGRADE

The OWS serving the home originally consisted of a 1250-gallon, two compartment septic tank followed by a 12-foot by 50-foot drain field bed installed in 1979. The treatment system upgrade consisted of adding a

---

[*] Roger J. Shafer, P.E. is the President of SCG Enterprises, Inc. – P.O. Box 1411, Conifer, CO 80433

recirculating textile filter to the existing 1250-gallon, two compartment septic tank. Effluent treated by the textile filter flows to a discharge pump basin, which doses a sand filter. The sand filter is lined with a 30-mil PVC liner to aid in the collection of sand filter effluent samples. Effluent from the sand filter then flows to the existing drain field. The system layout is depicted in Figure 1.

Recirculating Textile Filter

Installation of the system consisted of placing a screened-vault effluent pumping system in the second compartment of the existing 1250-gallon septic tank, and installation of a ball-type splitter valve in the first compartment of the septic tank. Two, 10 ft^2 fiberglass assemblies, with hanging sheets of non-woven textile fabric (AdvanTex® AX10's), were installed on top of the septic tank. Non-woven textile fabric has been found to be an excellent wastewater treatment media primarily due to its high porosity, specific surface area, and water holding capacity (Roy et al., 1998; Ball et al. 1999; Leverenz et al., 2000; Bounds, 2002; Vassos and Turk, 2002).

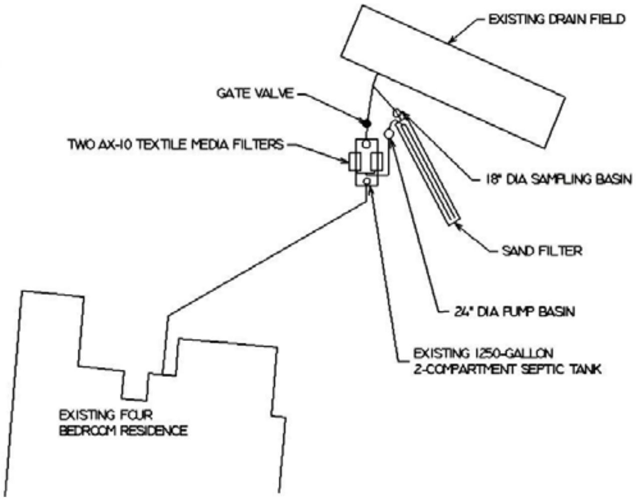


Figure 1 – Site Plan showing septic tank, textile filter, sand filter, and existing drain field.

The pump system operation is controlled by a programmable unit within a control panel mounted on the exterior of the residence. The recirculation pump is set to provide periodic doses of effluent to the textile filter assembly. For this site, the dose frequency is 0.5 minutes on and 19.5 minutes off. Aerobic bacteria in the filter assemblies treat the wastewater by reducing the organic material and nitrifying the ammonia. After passing through the textile filter media, the effluent returns to the inlet end of the septic tank for recirculation. The inlet of the septic tank (first compartment) contains organic solids, which maintain an anoxic environment and a carbon source needed for denitrification. As the water level in the septic tank rises, the ball-type splitter valve closes, which sends effluent to a discharge pump basin located adjacent to the septic tank. Within the pump basin is a second effluent pump that doses the textile filter effluent to the surface of a "polishing" sand filter.

Polishing Sand Filter

The sand filter was constructed by building a 3-foot by 25-foot wood-frame box and installing a 30-mil PVC liner. The purpose of lining the sand filter was to enable the collection of treated effluent for sampling and testing. ***In actual practice, the sand filter would not be lined, making it an "open-bottom" sand filter where the treated effluent continues into the fractured bedrock.*** Two feet of sand, with a coefficient of uniformity of 3.3 and an effective size of 0.3, was used as treatment media. A two-foot sand depth was chosen as an alternative to the currently required four feet of treatment media receiving septic tank effluent. Duncan et al (1994) found that very high levels of treatment can be obtained from sand filters receiving pretreated effluent as a substitution to soil depth.

For a collection underdrain, a row of plastic chambers was installed within the liner. Washed “pea” gravel was installed along the sides, to the top of the chambers. Another row of chambers was installed on the surface of the sand media. Four chambers were installed for an infiltrative surface area of 62 square feet (ft^2) using the 15.5 ft^2 interior footprint of each chamber. Along the surface of the sand, two distribution laterals were installed with 1/8-inch orifices spaced two-foot on center.

The discharge pump was set to dose approximately one half gallon per orifice, per dose. Small doses were chosen to maintain an unsaturated, thin film flow through the sand filter to improve treatment performance as shown by Emerick et al (1997). The dosing pump was sized to maintain a minimum five-foot residual head at each orifice, while maintaining less than 2% flow differential between the first and last orifice in each lateral. Effluent from each orifice sprays against the underside of the chamber for distribution across the sand filter surface. Effluent exiting the sand filter flows to a sampling basin, and then to the existing drain field for groundwater recharge.

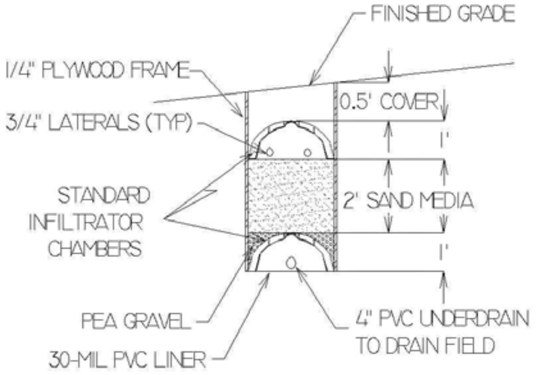


Figure 2 – End view of the polishing sand filter

METHODS

Flow monitoring

A water meter using an analog display with an odometer-type totalizer was installed on the water supply system to measure cumulative flow to the residence. Meter readings were periodically recorded throughout the study period. After the treatment system upgrade was installed, dose counter readings were recorded for the discharge pump basin. The flow volume through the system was calculated by using a known dose volume. Water meter readings, and water use measurements obtained from the dose counter readings, remained comparable throughout the test period.

Sampling Procedures

The recirculating textile filter returns treated effluent back to the inlet end of the septic tank for denitrification, thereby complicating the collection of “influent” samples while the system is in operation. As an alternative to influent samples, five septic tank effluent samples were collected from the system between the dates of April 5, 2001 and May 2, 2001 (prior to installation of the upgrade) using a ¾-inch, clear plastic tank sampler. Samples were collected from the outlet tee of the septic tank. The results are presented in Table 1.

A total of 13 sampling events took place over three separate sampling periods. The periods were between the dates of July 18, 2001 - August 16, 2001 (a few weeks after placing the system into operation); January 10 – 22, 2002 (the first winter); and December 13, 2007 – January 17, 2008 (6.5 years after placing the system into operation).

Effluent samples from the recirculating textile filter were collected from the discharge pump basin using a 16 ounce, long handled dipper. Sand filter effluent samples were collected from the sampling basin located at the outlet of the sand filter underdrain using a 16 ounce, long handled dipper.

RESULTS AND DISCUSSION

Testing Period 1

For the wastewater sampling and testing period between April 5, 2001 and August 16, 2001 the daily flow from the residence averaged 209 gallons per day (GPD). This hydraulic loading rate equated to an approximate 7:1 recirculation rate through the textile filter assembly and an application rate of 10.5 GPD/ft^2 to the surface of the textile media filters. This also equates to an application rate of approximately 3.4 GPD/ft^2 to the surface of the sand filter. During this period, a total of 5 sampling events occurred (n=5). Testing results for this period, and for the septic tank sampling period, are shown in Table 1.

Table 1 – Summary of testing results for testing from April 5, 2001 to August 16, 2001.

Flows average 209 GPD with 4 occupants			
Parameter	**Septic Tank Effluent**	**Textile Filter Effluent**	**Sand Filter Effluent**
BOD_5 (mg/l) (range)	154 (140-210)	5.1 (2.3 – 8.5)	<1 (ND* - 1.1)
TSS (mg/l) (range)	96 (78-120)	6.2 (<5 – 11)	<5 (ND – 5.0)
TKN (mg/l) (range)	38 (29-56)	4.4 (3.1 – 6.5)	1.0 (0.2 – 1.6)
NO_3-NO_2 (mg/l) (range)	<0.1	8.5 (7.4 – 10.4)	11.0 (9.1 – 13.0)
Total Nitrogen (mg/l) (range)	38 (29-56)	12.6 (10.5 – 16.9)	12.0 (9.3 – 14.6)
Total Phosphorous (mg/l) (range)	8.9 (7.5-11.0)	7.2 (6.3 – 8.1)	6.9 (5.7 – 7.9)
Fecal Coliform (col/100ml) (range)	>1X10^4	4522 (210 – 9000)	7 (ND – 23)
Alkalinity (mg/l as $CaCO_3$) (range)	N/A	248 (240 – 260)	224 (200 – 240)

* ND = None Detected. Detection Limits are: BOD = 6.0 mg/l; TSS = 5.0 mg/l; Fecal Col. = 2 MPN/100 ml

Testing Period 2

For the wastewater sampling and testing period January 10 – 24, 2002 the daily flow from the residence averaged 230 gallons per day (GPD). This hydraulic loading rate equated to an application rate of 11.5 GPD/ft^2 to the surface of the textile media filters. This also equates to an application rate of approximately 3.7 GPD/ft^2 to the surface of the sand filter. During this period, a total of 3 sampling event occurred (n=3). Testing results for this period are shown in Table 2.

Table 2 – Summary of testing results for testing January 10-12, 2002.

Flows average 230 GPD with 4 occupants		
Parameter	**Textile Filter Effluent**	**Sand Filter Effluent**
BOD5 (mg/l) (range)	3.2 (2.6 – 3.9)	<1 (ND - 1.1)
TSS (mg/l) (range)	6.7 (<5 – 10)	3.1 (ND – 7.0)
TKN (mg/l) (range)	1.6 (1.3 – 1.8)	1.0 (0.6 – 1.3)
NO3-NO2 (mg/l) (range)	12.2 (11.2 – 13.2)	12.8 (11.1 – 14.1)
Total Nitrogen (mg/l) (range)	13.8 (12.5 – 15.0)	13.7 (11.7 – 15.2)
Total Phosphorous (mg/l) (range)	1.5 (1.3 – 1.9)	1.8 (1.2 – 2.8)
Fecal Coliform (col/100ml) (range)	16,333 (9,000 – 16,000)	18 (14 – 30)

Testing Period 3

For the wastewater sampling and testing period December 13, 2007 – January 17, 2008 the daily flow from the residence averaged 145 gallons per day (GPD). This hydraulic loading rate equated to an application rate of 7.3 GPD/ft^2 to the surface of the textile media filters. This also equates to an application rate of approximately 2.3 GPD/ft^2 to the surface of the sand filter. During this period, a total of 5 sampling events occurred (n=5). Testing results for this period are shown in Table 3.

Table 3 – Summary of testing results for testing December 13, 2007 – January 17, 2008.

Flows average 145 GPD with 3 occupants		
Parameter	**Textile Filter Effluent**	**Sand Filter Effluent**
BOD5 (mg/l) (range)	ND	ND
TSS (mg/l) (range)	ND	ND
TKN (mg/l) (range)	3.3 (2.13 – 5.77)	0.60 (0.55 – 0.64)
NO3-NO2 (mg/l) (range)	11.9 (6.0 – 16.0)	16.8 (8.9 – 23)
Total Nitrogen (mg/l) (range)	15.3 (8.62 – 19.4)	17.4 (9.5 – 15.2)
Total Phosphorous (mg/l) (range)	7.3 (5.9 – 8.5)	7.4 (5.2 – 8.8)
Fecal Coliform (MPN/100ml) (range)	2,376 (680 – 6,000)	ND

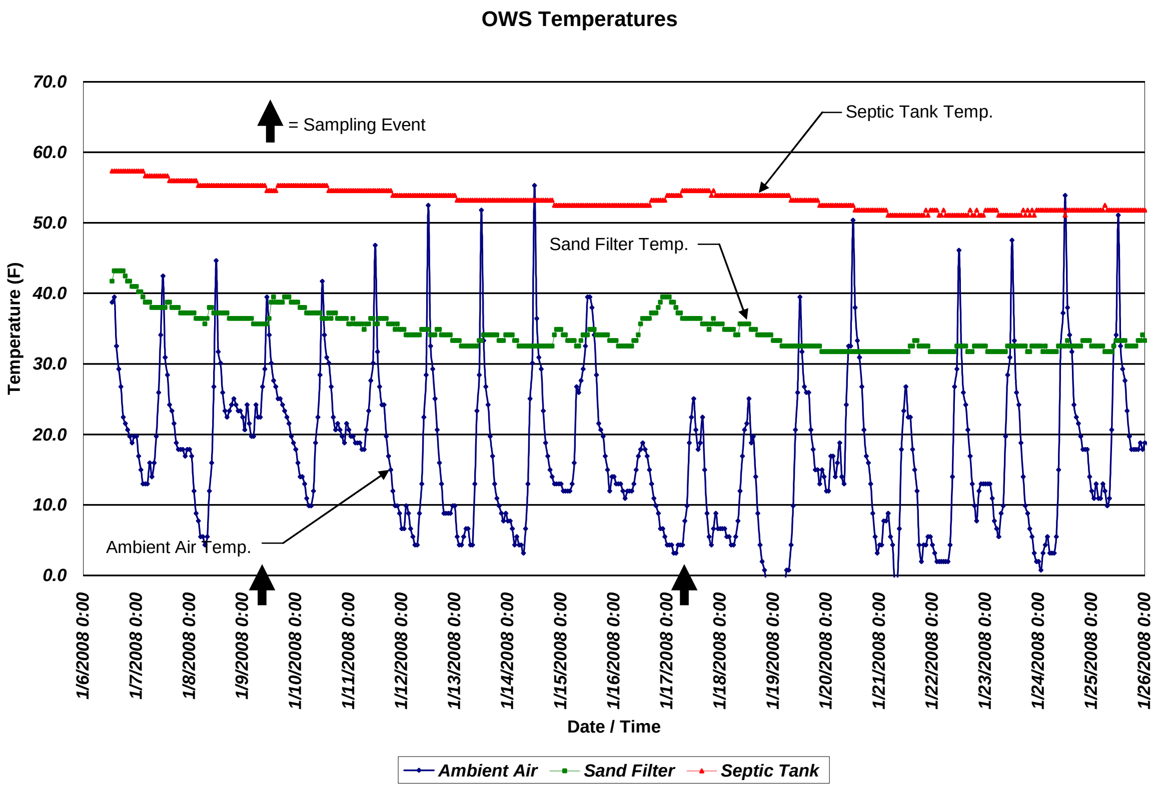
Review of the test results for the three testing periods indicate there was not a decrease in the ability of the system to treat wastewater. If anything, there might be an improvement over time. However, this apparent improvement may be related to the decreased water usage during the third test period.

During the course of the testing period the sand filter surface was observed periodically for signs of plugging. There does not appear to be any plugging at the surface of the sand filter, after 6.5 years of operating, while receiving an approximate average of 193 GPD. This equates to an overall loading rate of 9.7 GPD/ft^2 to the textile filter and 3.1 GPD/ft^2 to the sand filter.

Temperature Measurements

The third sampling period was chosen during the coldest time of year. The intent was to measure the treatment performance of the system during worse-case conditions, when temperatures were below the annual average. During the last three weeks of this period, temperature measurements were collected every hour at three locations: 1) in the liquid of the septic tank; 2) approximately one inch below the surface of the sand filter; and 3) the ambient air. Measurements were taken using a Nomad® OM-42 data logger by Omega® and an Omega® OM-40-C-HT-B Temperature Sensor. Figure 3 shows the results of the temperature measurements.

Figure 3 – Temperature Measurements



The temperature measurements show the septic tank (processing tank) maintained a relatively constant temperature during the three week measuring period. The temperature in the tank ranged from a high of 57.4° F to a low of 51.1 ° F. The ability to maintain the relatively constant temperature is presumably due to the depth of the tank at three feet below ground surface. Maintaining a moderate temperature is important for maintaining a temperature in the textile filter suitable for biological treatment. Since the textile filter is buried at grade (within frost depth), it appears (based on test results) the periodic dosing of septic tank effluent helps keep the textile media at a temperature suitable for treatment. In effect, the septic tank appears to act as a “heat sink”.

The sand filter temperature fluctuated more than the septic tank, with a high of 43.2° F and a low of 31.7°F. The trend for the sand filter generally follows the ambient air trend. This is to be expected since the sand filter is buried so shallow. However, the sand filter temperature is also presumably influenced by the temperature of the textile filter effluent being dosed to it. This appears particularly noticeable from January 16 to January 19.

As expected, the ambient air temperature fluctuated daily with a high of 54.5° F and a low of -4.4° F. The average temperature for the three week period was 17.0° F. Two of the sampling events occurred during the temperature measurement period, as shown on the graph.

Alkalinity and Nitrates in the Tap Water

The scope of this project did not originally include nitrate testing of the tap water or any alkalinity testing. However, since they can be factors affecting overall performance, some data was collected, and the results are worth noting.

Nitrate contamination of groundwater is a concern in this area. Biological nitrogen removal in wastewater treatment is primarily a two-step process. First, ammonia is converted to nitrates, which consumes 7.01 mg per mg of alkalinity (Crites and Tchobanoglous, 1998). The tap water from the residence (which is served by an onsite well) was periodically tested for alkalinity. The average alkalinity concentration was found to be approximately 60 mg/l. This is characteristic of the bedrock wells in this area. With such low alkalinity in the drinking water, it is surprising to achieve nearly complete nitrification in the treatment system.

The wastewater was also tested for alkalinity during the first test period – see Figure 1. The results show higher alkalinity levels in the wastewater, indicating alkalinity is added to wastewater from normal household water-use practices.

Some of the alkalinity is returned to the system in the second step in the nitrogen removal process. This step is the conversion of nitrates to nitrogen gas. This step is completed in the carbon-rich, anoxic zone of the septic tank. In this step, 3.57 mg of alkalinity are returned with the conversion of each mg of nitrate nitrogen (Crites and Tchobanoglous, 1998).

During the 6.5 year period, a total of nine tap water samples were collected and analyzed for nitrates. The nitrate concentration in the tap water averaged 13.2 mg/l. The quantity of nitrates in the tap water did not seem to have any adverse affect on the system's overall ability to remove nitrogen. In fact, it is possible the nitrates in the tap water were converted to nitrogen gas as they entered the septic tank, slightly increasing the alkalinity, which may have aided in the nitrification if ammonia, thereby improving overall nitrogen removal. It is interesting to note the total nitrogen concentration in the wastewater effluent (14.5 mg/l average) was not much different than in the tap water (13.2 mg/l).

CONCLUSIONS

This project successfully demonstrated an alternative to the current OWS practices in the fractured bedrock areas of Colorado's Front Range. The treatment system concept can be applied to any area where in-situ soil conditions are highly permeable, making them poorly suitable for treatment.

Consideration is also given to the fact that water use practices and environmental conditions will vary from site to site, thereby allowing the potential for treatment performance to vary from site to site. The success of this project is indicated by the following observations and conclusions:

- This project demonstrated a very high treatment capability of an OWS utilizing a relatively small area, eliminating the need for large "over-excavated" fields that are often disruptive to the natural site conditions, often dangerous to construct on very steep hillsides, and whose treatment ability is questionable.

- In practice, the cost of the demonstrated system is approximately $15,000 (2007) including all materials and labor. The current standard of practice, consisting of installing a septic tank followed by an "over-excavated" drain field, generally costs $10,000 to $16,000 (depending on site conditions) for a four-bedroom residence.
- The OWS used in this project maintains a higher level of quality control by utilizing an engineered, manufactured pre-treatment system followed by an imported sand filter of specified gradation requirements. This is opposed to the variability of the filter material used in the "over-excavated" drain fields.
- Testing performed to date indicates the ability of the demonstrated system to achieve a high level of treatment in Colorado's high altitudes, during the winter months.
- After 6.5 years of operation, high levels of treatment occurred with no visible sign of sand filter plugging. This suggests that considerable field-size reductions may be given for sand filters receiving treated effluent.

ACKNOWLEDGEMENTS

Tom Eisenman with Park County Health Department provided recommendations during the project definition, design, and permitting stages. CHURCH & Associates, Inc. donated engineering design and permitting services. David Trenkle and Stephen Dix with Infiltrator® Systems, Inc. donated chambers and labor during the installation of the system.

REFERENCES

Ball, E.S., H.L. Ball, and T.R. Bounds, 1999, *A New Generation of Packed Bed Filters*. Proceedings of the 10th Northwest Onsite Wastewater Treatment Short Course and Equipment Exhibition. Seattle, Washington.

Bounds, Terry R., 2002, *Performance of Textile-Based Packed Bed Filters,* Proceedings of the 11th Onsite Wastewater Treatment Short Course and Equipment Exhibition, Seattle, Washington.

Crites, R. and G. Tchobanoglous, 1998, *Small and Decentralized Wastewater Management Systems, pp. 436-444,* WCB MCGraw-Hill Publishers.

Duncan, C.S., R.B. Reneau, Jr., and C. Hagedorn, 1994, *Impact of Effluent Quality and Soil Depth on Renovation of Domestic Wastewater,* Onsite Wastewater Treatment: Proceedings of the 7th National Symposium on Individual and Small Community Sewage Systems. ASAE, Atlanta, Georgia.

Emerick, R.W., R.M. Test, G. Tchobanoglous, and J. Darby, 1997, *Shallow Intermittent Sand Filtration: Microorganism Removal*. The Small Flows Journal. 3(1):12-22.

Leverenz, H., L. Ruppe, G. Tchobanoglous, and J. Darby, 2001, *Evaluation of High-Porosity Medium in Intermittently Dosed, Multi-Pass Packed Bed Filters for the Treatment of Wastewater,* Small Flows Quarterly. Vol. 2 No. 2.

Roy, C., R. Auger, and R. Chenier, 1998, *Use of Non-Woven Fabric in Intermittent Filters*, Onsite Wastewater Treatment: Proceedings of the 8th National Symposium on Individual and Small Community Sewage Systems. ASAE, Orlando, Florida.

Vassos, T. and O.S. Turk, 2002, *Technology Verification Report, Orenco-AdvanTex™ Model AX10 onsite Treatment System,* NovaTec Consultants, Inc., Vancouver, B.C. Canada.