Small Recirculating Sand Filters For Individual Homes

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ABSTRACT

Maryland's Anne Arundel County Health Department has pioneered the use of small, recirculating sand filters for residential septic systems. Free-access recirculating sand filters just 4.2 m^2 (45 ft^2) in area can provide signifcant treatment of wastewater from individual homes with little required maintenance. The recirculating sand filters, using a 3:1 recirculating ratio, produce effluent with average BOD's of 5 mg/L (98% reduciton), suspended solids of 8 mg/L (90% reduction), and total nitrogen of 20 mg/L (64% reduction). Because of the superior quality of sand filter effluent, septic systems using sand filters are being approved in Anne Arundel County for: 1) the repair of failing septic systems when otherwise only holding tanks could be recommended because of slowly permeable soil or an inadequate unsaturated-soil buffer zone, 2) for limited additions to houses on sites not suitable for modern conventional systems, and 3) in certain cases, for new housing construction when smaller than normal drainfield or drainfield replacement area is desired.

Keywords. Sand fitlers, Denitrification system, Onsite sewage disposal, Sewage treatment.

BACKGROUND

Maryland's Anne Arundel County is the home of Annapolis and th eU.S. Naval Academy and has about 700 km (430 miles) of shoreline along the Chesapeake Bay and its tributaries. Approximately 25 percent of the 150,000 individual homes with both individual wells and septic systems on small lots that are now considered unsuitable for conventional septic systems. Concerned abouth the impact of substandard septic systems, the Anne Arundel County Health Department has pioneered the use of small, recirculating sand filters for residential septic systems.

For soils to effectively treat septic tank effluent, there should be a sufficient amount of relatively permeable soil between the bottom of the soil absorption system and the maximum seasonal elevation of the groundwater. The separation allows for the unsaturated flow of septic tank effluent through the soil. Unsaturated flow promotes filtration, adsorption, and biological degradation of most of the contaminants in septic tank effluent (Canter and Knox, 1986).

For sites lacking soils to adequately treat septic tank effluent, it is possible to construct sand filters to treat the effluent before it is discharged. Sand filters are very effective in reducing the levels of fecal coliform, viruses and organic matter in wastewater (EPA, 1978; Gross and Mitchell, 1984).

Sand filters can also be very effective in nitrifying septic tank effluent (EPA, 1978). The ammonia and organic nitrogen in septic tank effluent is converted to nitrates by nitrifying bacteria in the aerobic environment of a sand filter. If nitrates enter an anaerobic environment in which organic matter is available, denitrificaiton, the reduction of nitrate to oxygen gas by denitrfying bacteria, may occur.

Reciruclating sand filters were developed to provide improved treatment of septic tank effluent before disinfeciton and surface water discharge (Hines and Favreau, 1974). In these system nitrified sand filter effluent mixes with septic tank effluent in a recirculaiton tank where denitrificaiton may occur. The septi ctank effluent provides the required organic matter. Loudon et al. (1984) have reported that nitrogen removals of 40-60% could be achieved with recirculating sand filters.

Although recirculating sand filters can treat septic tank effluent to a high degree, their use for the treatment of wastewater from individual homes has been very limited. The goal of the Anne Arundel County Health Department was to provide recirculating sand fitlers for the treatment of wastewater from individual homes that are generally acceptable to homeowners.

SAND FILTER DESIGN

The sand filters that are typically used in Anne Arundel County to treat the wastewater from single family homes hae only 4.2 m^2 (45 ft^2) of sand filter surface area. The idea of being able to use such small sand filters to treat wastewater was derived from a table in the EPA onsite wastewater design manual (EPA 1980, p. 122). That table listed various features of intermittent sand filters. One of the sand filters was able to achieve excellent treatment of primary wastewater and requred no maintenance for over a 54 month period with a hydraulic loading rate of 570 L/m^2-day (14 gal/ft^2-day). The sand used in this filter had an effective size of 1 mm and was dosed 24 times a day.

At 570 L/m^2-day (14 gal/ft^2-day) a sand filter for a single family home with even an unusually high water usage of 1900 L/day (500 gal/day) would require only a 3.2 m^2 (35 ft^2) sand filter. In Anne Arundel County halft of a 7570 L (2,000 gal) center seamed concrete septic tank was selected as the container for the sand filter because it was readily available and a concrete tank could be placed completely out of the ground if required on sites with extremely high water tables. The inside dimensions of the concrete tanks are 3.0 x 1.4 x 1.1 m high (10.0 x 4.5 x 3.5 ft).

Figure 1 shows two views of a typical sand filter in Anne Arundel County. The sand filters are free access and have removable, insulated wooden covers made of tongue-and-groove lumber with foam insulation. The lumber should be treated to avoid water damage and the insulation should be resistant to moisture. After shrinkage, gaps between boards should be avoided and the top should fit snugly to the top of the concrete walls. The avoidance of gaps will greatly reduce the potential for offensive odors.

A brick and mortar wall approximately 10 cm (4 in) high extends directly across the width of th etank and divides the bottom area so that approximately 75 percent of the area is on one side of the wall and 25 percent on the other side. The purpose of the internal wall is to divide the flow as it moves down through the sand filter. If the flow is applied evenly over the length of the sand filter, approximately 75 percent of the flow to the sand filter can recirculate back to mix with anaerobic wastewater for a 3:1 recirculation ratio. The mixing of nitrified sand filter effluent with anaerobic wastewater can create conditions for denitrification and therefore nitrogen reduction.

The underdrain pipes are 10.2 cm (4 in) diameter PVC pipes with rows of approximately 1.6 cm (5/8 in) holes along the bottom third of the pipes and slots across the top third. The slots help provide aeration and should be narrow enough to keep pea gravel from entering the underdrains. The ends of the underdrains are capped. The underdrains lay directly on the bottom of th etank and exit the tank through holes that are precast in the tank. Pipes should be sealed in the exit holes to prevent leakage from around the pipes.

Approximately 15 cm (6 in) of pea gravel, approximately 0.6-1.3 cm(1/4-1/2 in) in size, covers the bottom of the tank and the underdrains. The pea gravel should be washed and be free of fines.

Outside the sand filter, a 10.2 cm (4 in) diameter vent pipe with a P-trap at the bottom is attached to the underdrain pipe of the recirculating flow. Since flow recirculates back to the septic end of the system, the P-trap prevents septic odors from exiting the vent pipe and th event allows air to enter the bottom of the sand filter.

Approximately 0.6 m (2 ft) of coarse, uniform sand covers the pea gravel. The sand that is used in the sand filters has an effective size of about 1 mm and a uniformity coefficient of less than 2.5. It is a processed material and is used locally to pack around screens in water wells. The use of filter fabric between the sand and the pea gravel is not recommended.

One of the major concerns that homeowners have concerning their septic systems is odor. Since the effluent that is pumped to a recirculating sand filters is a 3:1 mixture of sand filter and septic tank effluents, the offensive odors in the sand filter are much less than what would be expected with undiluted septic tank effluent. Nevertheless, even with the use of covers and P-traps, slight odors were occasionally detected while pumping to the recirculating sand filters if the pressure distribution system was not buried. By covering the pressure distribution network with sand, the concern of offensive odors has been almost completely eliminated.

The sand filter in Fig. 1 shows Eljen indrains placed on top of the sand bed. The Eljen indrains units are approximately 18 cm (7 in) high and consist of cuspated plastic spacers approximately 13 cm (1/2 inch) thick wrapped in nonwoven, synthetic fabric. Although the use of the Eljen indrains is not critical to the treatment in sand filters, the indrains provide a lightweight wastewater distribution network that can be covered with material such as sand to control odors.

Wastewater is pumped into the sand filter through a small diameter PVC lateral that rests on the indrains. The pipe to the lateral enters the bottom end of the tank through a hole that can be precast in the tank. The end of the lateral is directed up and has a screw cap to allow flushing of the line.

Eight, 9.5 mm (3/8 in) diameter holes are typically drilled evenly spaced along the top of the lateral. the use of relatively large holes is an attempt to prevent clogging of the holes.

The pressure lateral is covered by a 15.24 cm (6 in) diameter pipe that is cut in half lengthwise. Wastewter is pumped up through the holes in the lateral, hits the underside of the half of pipe, and is distributed fairly evenly over th elength of the sand filter. The lateral runs perpendicular to the supated, plastic spacer in the indrains.

A layer of nonwoven filter cloth covers half of pipe and extends over the Eljen indrains. Additional sand of the type used for filtering is packed along the sides of the indrains and is placed over the layer of filter fabric.

Figure 2 shows a schematic flow diagram of an entire septic tank- sand filter system. Typically the wastewater from the house first enters a 5680 L (1,500 gal) two-compartment septic tank and then flows to a 1893 L (500 gal) pump chamber. With a two- compartment septic tank the second compartment can be used as a denitrification, however the increased flow through the tank may affect the hydraulic design of the septic tank. Mixing and denitrification could also be accomplished in the pump chamber if it is of sufficient size.

A pump chamber of at least 1893 L (500 gal) capacity is recommended to allow for the use of a timer with the pump. By having holding capacity in the pump chamber, it is possible to store the wastewater surges from a home and dose the sand filter briefly throughout the entire day. For example, the timer could be set to apply a one minute dose every half hour. A low level float is used to ensure that the pump does not run dry and a high water level alarm is used to signal the homeowner that either an abnormally high volume of water is being pumped or there is a pump problem.

If possible, the sand filter should be placed so that both the return an dforward lines from the sand filter flow by gravity. With this arrangement, only one effluent pump is required for the system. The effluent pump should be sized to deliver at least 0.6 m (2 ft) of head pressure at the distal end of the lateral in the sand filter.

Treatment in the sand filter depends upon microorganisms and the process can be adversely affected by cold temperatures. the treatment process has performed well throughout a month that had an average daily temperature of -2 °C. For areas that would experience colder monthly temperatures, additional precautions could be taken such as increasing the r-value of the top, adding insulation to the sides of the sand filter, placing earth around the sides, or, if site conditions allow, placing the filter deeper in the ground. Insulation could also be added around the top and sides of the septic tank and pump chamber.

TREATMENT RESULTS

More than 100 recirculating sand filters have been installed in Anne Arundel County. Two sand filters were installed as early as 1987 and have worked for several years without needing maintenance. Performance data for one of these systems and two other newer systems are shown in Table 1. System A is for a house with seven residents whose water usage is approximately 1290 L/day (340 gpd). Systems B and C are for houses with only two residents whose water usage is estimated to be approximately 380 L/day (100 gpd). (These three systems are different from teh three systems monitored by the National Association of Home Builders. For the results from those systems see Bruen and Piluk in these proceedings.)

	Pollutant[a]	**System A**[b]	**System B**[c]	**System C**[d]	**Average**
Septic Tank	BOD	215	124	366	235
	Susp. Solids	72	56	97	75
	Total Nitrogen	54	45	71	57
	Fecal Coliform	$3.9X10^6$	$1.7X10^5$	$1.0X10^7$	$1.8X10^6$
Sand Filter	BOD	4	2	8	5
	Susp. Solids	8	5	10	8
	Total Nitrogen	22	17	21	20
	Fecal Coliform	$3.4X10^4$	240	$9.5X10^4$	$9.2X10^3$
Percent Reduction From Septic Tank	BOD	98	98	98	98
	Susp. Solids	89	90	90	90
	Total Nitrogen	59	62	70	64
	Fecal Coliform	99.1	99.86	99.0	99.3

[a]Fecal coliform is presented as geometric average in organism per 100 ml. All other units are mg/L.
[b]Average of 28 sampling dates from August 1992 to March 1994.
[c]Average of 22 sampling dates from July 1990 to October 1993.
[d]Averge of 39 sampling dates from June 1987 to June 1993.

On the average of saqnd filters included in Table 1 produced effluent with BOD's of 5 mg/L (98 percent reduction beyond septic tank), suspended solids of 8 mg/L (90 percent reduction), total nitrogen of 20 mg/L (64 percent reduciton), and fecal coliform of 9000 organisms/100 ml (over 99 percent reduction).

Since 1993 several system ahve been installed in which the first compartment of the septic tank is used for mixing and denitrification. Only limited data are available for these systems, but five sampling between two sites indicate average BOD's of 7 mg/L, suspended solids of 5 mg/L, and total nitrogen of 18.9 mg/L. These results are very similar to the results obtained when mixing is performed at a later stage in the system.

OBSERVATIONS

More experimental design modifications have been attempted that can be recounted here, but a few of the experimental designs, and routine observations of the systems stand out as being particularly instructive:

In two of the early sand filters submerged gravel filters in which sand filter effluent mixed with unfiltered septic tank effluent were used for denitrificaiton. These submerged gravel filters clogged, so now, generally, no special media is used in the denitrification area of these systems.

For another system, two layers of non-woven filter cloth were embedded at different depths in the sand of a non-recirculating sand filter. Within a year the wastewater began ponding on the sand and most of teh sand turned black. The filter cloths were dug-up and removed, and the sand returned to the box. within a few days the sand regained a golden-brown color. A couple of months later the sand filter ponded again, so this time new sand of the same type was put in the filter and a recirculation line was installed. That system has now worked over two years without requiring maintenance (it is "system A" in Table 1). this suggests that besides making denitrification feasible, recirculating the sand filter effluent may enhance aeration and reduce filter clogging.

The pumps in the sand filters are programmed to pump no more than a certain amount of water per day. When the flow exceeds that amount the pump chamber will fill and the high water alarm will be activated. Because of this feature it has become apparent just how prevalent groundwater infiltration is into the top- seamed septic tanks and pump chambers used in Anne Arundel County. Because of the numerous problems with groundwater infiltration, new specification regarding th econstruction of concrete septic tanks have been adopted.

Having pumps on timers can warn homeowners of plumbing problems such as leaking toilets.

Although the sand filters require a pump, operting permits have not been required for these system based on the assumption that if a pump failed it would be replaced or wastewater would backup or overflow. However it has been ovserved that when wastewater rises above the top seam in concrete septic and pump tanks, it can simply leak out without causing a backup or overflow.

SAND FILTER UTILIZATIOIN

Anne Arundel County has been able to experiment with small sand filters in the repair of failing septic system because Maryland State regulations allow for the use of new technology or experimental systems to correct existing failing systems when public sewer is not available and a conventional on-site design cannot alleviate the problem.

Before the use of sand fitlers, the only option for many homes with failing septic systems was holding tanks. The use of sand fitlers has broadened the options.

For repair sites lacking soils to adequately treat wastewater, sand filters enhance on-site treatment. For repair sites with suitable soils but lacking room to install the required final absorption area, the use of sand fitlers allows the installation of much smaller final absorption areas. Also,k on repair sites lacking room to install any additional final absorption area, by metering sand filter effluent into systems that have failed hydraulically, failures have been corrected.

from working with a few small sand filters to correct failing septic systems, the Anne Arundel County Health Department realized the benefits of these filters and has found a number of ways to promote the use of sand fitlers for individual homes.

Sand filters are used to allow limited additions to homes that have septic systems that work hydraulically, but may not adequately treat the wastewater. By incorporating a sand filter into the old system, sand filter effluent instead of septic tank effluent is discharged into the ground. Granting limited home additions on sites unsuitable for conventional systems is an incentive for homeowners to upgrade their septic systems. In order to insure the upgrade of the septic system, it is required that the sand filter is installed before th ehome addition permit is issued.

this policy should become very popular in Anne Arundel County, due to the large number of small, older waterfront homes in the county. Not only does this practice improve the quality of the effluent that is discharged into the ground but also in most cases it reduces the quantity of effluent discharged. Maryland requires water saving plumbing fixtures for all new construction. When homes are added on to, bathrooms are often remodeled with new plumbing fixtures.

Local codes typically can bemore stringent than State codes, and this is the case in Anne Arundel County which has its own plumbing code. Drainfields designed using the Anne Arundel County plubing code are twice as large than is required by Maryland State code. For new homes on older recorded lots, Anne Arundel County allows a 50 percent reduction in the size of drainfields for a new home if a sand filter is installed.

Although the savings realized by a 50 percenbt reduction in the sizing of drainfields typically will not offset the cost of a sand filter, it is a start. Some researchers indicate that over an 80 percent reduction in absorption areas may be possible through the use of sand filters (Jenssen and Siegrist, 1991). If such reductions prove acceptable, small sand filters could provide a means of reducing nitrogen loadings and allow for less site disturbance at minimum extra costs for many sites.

The utilization of advanced onsite wastewater treatment systems is possible in Anne Arundel County because of the thorough evaluation of sites for proposed septic systems. If septic systems were routinely approved without concern for the protection of groundwater and surface waters, there would be no incentive to advance the treatment of onsite systems.

CONCLUSIONS

Anne Arundel County's goal to develop recirculating sand filters that provides excellent treatment and that are generally aceptable to homeowners has been accomplished with a design that incorporates the following features:

- sand filter enclosure is precast concrete, material commonly used for septic tanks
- minimization of the potential for offesive odors, aerosols, infiltration, and freezing
- small size
- easy installation

- minimum maintenance
- maintainable without site distrubance
- standard design with one size suitable for the treatment of wastewater from most individual homes
- the services of a professional engineer is not necessary for specific site approvals
- requres the use of only one small effluent pump
- fail-safe design with watertight septic and pump tanks

The Anne Arundel County Health Department will continue to foster sand filters as a means of improving septic systems. Due to the difficulty of extending sewers in the county, there will be a growing need for onsite wastewater treatment systems that reduce nitrogen loadings into the environment, require less room to install, and that are readily maintainable. Small, free-access, recirculating sand filters address those needs.

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