EFFECTIVENESS OF PASSIVE TREATMENT COMPONENTS FOR ONSITE SYSTEM WASTEWATER RENOVATION

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Abstract. More than 40% of the homes in Georgia use onsite systems to manage household wastewater. Because of water quality concerns as the number on onsite systems increases, advanced wastewater treatment components to reduce biological oxygen demand (BOD), total suspended solids (TSS), and nutrients are more commonly used.. The objective of this study was to evaluate passive, low-maintenance onsite system treatment components. Two complete onsite systems were installed at existing homes bordering or near Lake Sidney Lanier in Hall County, GA. Both systems included a 6,000 l two-compartment septic tank with an effluent filter, two anaerobic upflow filters (AUF), and either a Fe-based or Fe-Al-Ca based P removal system. Wastewater samples were collected monthly for 14 months at multiple locations in the system and were analyzed for pH, dissolved O, BOD, TSS, total N, NH_4^+, NO_3^-, total P, and dissolved reactive P. The septic tank and two AUFs reduced BOD, TSS, and total P by 84, 96, and 58%, respectively. The Fe-based P treatment system further reduced total P and dissolved reactive P concentrations by 63 and 51%, respectively. The Fe-Al-Ca based P treatment system unit was less effective. These results suggest that passive low-cost advanced treatment components can be used to enhance wastewater treatment in onsite systems.

INTRODUCTION

Because of the abundance of onsite systems to manage household wastewater, there is growing concern about their potential impact on ground and surface water quality, especially in environmentally sensitive areas of the state. Components of greatest concern are biological oxygen demand (BOD), total suspended solids (TSS), bacteria and viruses, and the nutrient elements N and P.

Most wastewater components are filtered, immobilized, or otherwise denatured by 60-90 cm of unsaturated soil (USEPA, 2002). The exception is N. Organic N and NH_4^+ in wastewater are converted to NO_3^- in unsaturated soil. Because it is negatively charged, NO_3^- is mobile in most soils and may move to ground water with the percolating wastewater although denitrification may reduce NO_3^- concentrations in water in certain environments. (Anderson, 1998).

Wastewater P is removed in the soil by adsorption to Fe and Al oxides and/or precipitation as variscite ($AlPO_4 \cdot 2H_2O$), vivianite ($Fe_3(PO_4)_2 \cdot 8H_20$), or strengite ($FePO_4 \cdot 2H_2O$). Adsorption of PO_4^{3-} onto Fe and Al oxides is a specific adsorption reaction instead of electrostatic and thus, is very slowly reversible (Spositio, 1989). Additionally, the Fe and Al phosphate minerals that may precipitate are only slightly soluble in soil environments. Thus, high Fe and Al contents typically found in most Georgia soils are expected to immobilize P added with wastewater. Installation of onsite systems in sandy soils or in relatively unweathered saprolite that have low Fe and Al contents, however, may result in P movement to ground and surface water, especially considering the P load that would occur over a 30-50 year system life. These soils are also most conducive to movement of N.

The most common advanced treatment component installed in on site systems is an aerobic treatment unit which effectively reduces BOD and TSS. However, these components have minimal effect on other wastewater components and also have high maintenance requirements. Thus, the objective of this study was to evaluate the effectiveness of passive, low-maintenance onsite system treatment components for onsite wastewater treatment.

METHODS

Two sites, Site 1 and Site 2, located in Hall County, Georgia were selected for installation and evaluation of the experimental onsite systems. The home at both sites had three bedrooms, and design wastewater flow was 1,700 l d^{-1} (450 gpd). Both had experienced problems with the existing onsite systems because of unsuitable soils or lack of system maintenance.

The soils at both sites were Pacolet (fine, kaolinitic, thermic Typic Kanhapludults). The design drainfield size at Site 1 was 93 m^2 (1,005 ft^2) and consisted of five 0.9 X 21 m (3 X 67 ft) conventional gravel-filled trenches. Because of site limitations, the drainfield at Site 2 was at a higher elevation than the septic tank which required pumping of the wastewater to the drainfield. Wastewater flow was equally split into the five trenches with a pressurized flow directing valve.

At Site 2, the design drainfield size was 100 m^2 (1,100 ft^2). Because chambers were used in the drainfiled, however, the actual drainfield area was 50 m^2 installed as five 0.9 X 11 m (3 X 36 ft) trenches. Wastewater flow was equally split into the five trenches with a distribution box.

Onsite system components

The onsite systems at each site consisted of a 5,680 l (1,500 gal) two compartment septic tank with a commercial effluent filter, two anaerobic upflow filters (AUF), and a phosphorous treatment system (PTS) (Fig. 1). Because the wastewater was pumped to the drainfield at Site 1, the system at this site also included a 1,000 l pump tank between the second AUF and the PTS.

Anaerobic upflow filters. Each of the two AUFS installed in series consisted of a 1.2 m diameter X 0.9 m high concrete manholes (1,000 l volume) filled with 2-3 cm diameter granite gravel. Wastewater inflow was routed to the bottom of each of these filters and outflow was from the top of the gravel (Fig 1). This wastewater routing maintained the wastewater in an anaerobic condition.

Phosphorous treatment systems. The PTS at Site 1 as the PhosRid™ System (Fe based P removal media) which consisted of a 1.2 m diameter X 0.9 m high concrete manholes (1,000 l volume) filled with P removal media. As with the AUFs, the wastewater entered from the bottom and exited at the top of the media to maintain an anaerobic condition. Following the PTS was a passive sand filter (1,000 l sand filled chamber) in which the wastewater was aerated as it trickled through sand and exited to the drainfield. Only 20% of the total wastewater flow passed through the PTS before moving to a dedicated drainfield trench.

Design of the PTS at Site 2 was the same as that a Site 1 with two exceptions. The PTS was the PhosPhex™ System (Fe-Al-Ca based P removal media). In addition, a peat chamber (1,000 l peat filled chamber) was installed instead after the P removal chamber to aerate the wastewater before discharging to a dedicated drainfield trench.

Monitoring of component performance

Monitoring of onsite system and component performance was initiated in June, 2004 and has continued to date. Samples were collected from five locations in the system at Site 1 and four locations in the systems at Site 2 (Fig. 1). Initially, sampling frequency was monthly but frequency has been reduced to approximately bi-monthly since January, 2005. Samples were placed on ice in the field, and BOD analysis was initiated within six hours of sample collection. In addition to sample collection, wastewater pH and dissolved oxygen (DO) was measured in situ at the time samples were collected.

Parameters measured on the wastewater samples included BOD, TSS, NH_4^+, NO_3^-, total keldhal N (TKN), dissolved reactive P (DRP), and total keldhal P. All wastewater analyses were made by standard procedures (Greenberg et al., 1998).

RESULTS AND DISCUSSION

B**OD and TSS.** The two compartment tank and two AUFs in series reduced mean wastewater BOD and TSS by about 85% and 92% respectively (Table 1). As expected, mean BOD and TSS were related and generally varied together among sites and sample locations. A large proportion of the reduction in BOD and TSS occurred between the inlet and outlet sides of the septic tank which is attributed to enhanced settling of solids in quieter water on the outlet side of the septic tank baffle. The trend was for the AUF's to provide additional reduction in

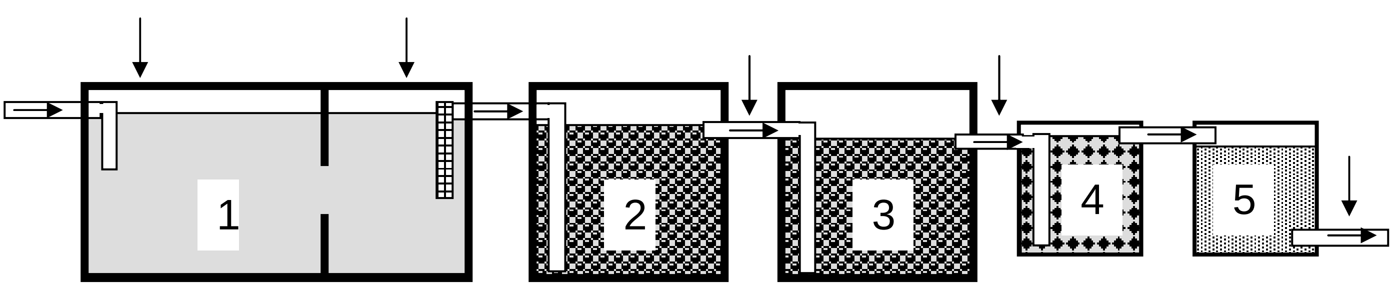

Figure 1. Treatment components of the onsite systems. 1 – two compartment septic tank with effluent filter; 2 and 3 – anaerobic upflow filters (AUF); 3 – phosphorous treatment system (PTS); 5 – aeration chamber. Vertical arrows indicate locations of sampling points. Samples were not collected after the first AUF (2) at Site 2.

BOD and TSS although these reductions were not significant. The BOD and TSS varied considerably among sampling dates which likely masked statistical significance of addition reductions beyond the septic tank. The effect of the septic tank commercial effluent filter on BOD and TSS could not be evaluated since samples were not collected between the effluent filter and the AUFs.

Mean BOD of wastewater discharged to the drainfield was 66 and 70 mg l^{-1} for Sites 1 and 2, respectively, as compared to 610 and 307 mg l^{-1} measured in the outlet end of the septic tank. The BOD values measured in the tank outlet are higher than the 150 to 200 mg l^{-1} that is commonly reported for septic tank effluent (USEPA, 2002) which may be due to sample collection from the tank instead of from the outlet pipe, especially since an effluent filter was installed in the tank.

Quality of wastewater as measured by BOD and TSS has a major effect on function and life of the drainfield. Accumulation of organic matter at the trench-soil interface results clogging of soil pores and formation of a biomat which reduces the wastewater infiltration rate (Siegrist, 1987; Finch and West, 2006). Reduction in wastewater BOD retards biomat formation and helps to maintain wastewater infiltration rates. In fact, aerobic treatment of wastewater to reduce BOD is often used to renovate onsite drainfields experiencing hydraulic failure.

Estimates are that if BOD input into the drainfield is less than 0.4 to 1.2 g m^{-2} d^{-1}, biomat formation would be minimal and wastewater infiltration rate would be maintained at near the initial rate (USEPA, 2002). Wastewater with a BOD of 200 mg l^{-1} would equate to a BOD loading of about 4 g m^{-2} d^{-1}. Reducing the BOD to about 50 mg l^{-1} which is similar to levels observed in these experimental systems equates to a BOD loading of about 1 g m^{-2} d^{-1} which is within the upper end of the range of desirable BODs. Greater BOD reduction is achieved with aerobic treatment units, but these units require regular and specialized maintenance to remain effective. Even though the reduction was less with the AUFs, BOD levels observed would be expected to extend drainfield life with minimal maintenance requirements.

N and P. At Site 1, mean total N was significantly reduced from 92 mg l^{-1} in the septic tank inlet to 38 mg l^{-1} after the PTS (53% reduction) (Table 1). The mean total N reduction at Site 2 was about 35%. Since the components were not designed to remove N from wastewater, relatively low N reductions were expected. Most of the reductions observed are attributed to retention of organic solids in the system components.

The dramatic increase in NO_3^- associated with the PTS at Site 1 is because of aeration of and nitrification in the sand filter after the PTS (Table 1). A similar increase in NO_3^- was not observed after the peat filter at Site 2. Reasons for this difference were not determined but may be related to greater water retention by the peat coupled with peat decomposition maintaining the system in an anaerobic state.

At Site 1, mean total P was reduced from 19 to 2 mg

Table1. Wastewater analysis means for the two sites.

Sample Location[1]	**pH**		**Dissolved Oxygen**		**BOD**		**TSS**		**NO_3^-**		**NH_4^+**		**Total N**		**DRP**[2]		**Total P**	
			mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		mg/l	
								Site 1										
Tank inlet	7.1	BC[3]	0.34	B	610	A	1619	A	0.1	B	52	A	81	A	19	A	19	A
Tank outlet	7.3	AB	0.09	B	221	B	208	B	0.1	B	51	AB	61	B	11	AB	10	B
AUF 1	7.2	ABC	0.12	B	147	B	84	B	0.1	B	56	A	58	BC	10	AB	8	B
AUF 2	7.4	A	0.30	B	82	B	48	B	0.5	B	42	B	47	BC	8	AB	6	BC
PTS	7.0	C	2.28	A	66	B	50	B	22.6	A	15	C	38	C	4	B	2	C
								Site 2										
Tank inlet	7.3	B[2]	0.10	A	307	A	740	A	0.1	A	61	A	92	A	13	A	13	A
Tank outlet	7.3	B	0.09	A	195	B	455	AB	0.2	A	66	A	75	A	11	A	10	AB
AUF 2	7.8	A	0.14	A	35	C	43	B	0.8	A	55	A	62	A	9	A	7	B
PTS	7.9	A	0.11	A	70	C	62	B	0.3	A	57	A	59	A	9	A	7	B

[1] Refer to Fig. 1 for sampling locations.
[2] DRP – dissolved reactive P.
[3] Means followed by the same letter are not significantly different at P = 0.05.

l^{-1} (90%) (Table 1). A lower reduction, 13 to 7 mg l^{-1} (47%) was observed at Site 2. The magnitude of reduction in mean DRP was slightly lower; 19 to 4 and 13 to 9 mg l^{-1} for Sites 1 and 2, respectively. Much of the reduction in total P and DRP occurred in the outlet compartment of the septic tank which is attributed to P retention in the septic tank sludge.

Additional reduction in total and DRP was observed in the two AUFs in each system (Table 1). Most of the P in the wastewater was inorganic which may precipitate as Fe or Al compounds if wastewater chemistry is favorable. Precipitation and settling of particulate P compounds would be favored in the low turbulence environment of the outlet compartment of the septic tank and the AUFs.

The Fe-based media in the PTS at Site 1 reduced mean total P concentration from 6 to 2 mg l^{-1} (67%) and mean DRP from 8 to 4 mg l^{-1} (50%) (Table 1). The removal of P in this PTS is attributed to the anaerobic wastewater inducing a sufficiently low redox potential in the treatment unit to solubilize Fe^{2+} which precipitated with PO_4^{3-} as vivianite. Aeration of the wastewater in the sand filter (Fig. 1) would result in oxidation of the Fe^{2+} to Fe^{3+} and precipitation of remaining Fe and PO_4^{3-} in the wastewater as strengite. Both vivianite and strengite have low solubility (K_{sp} of 10^{-36} and 10^{-26}, respectively) (Parkhurst et al., 1980), and P precipitated in these minerals would be expected to remain in immobile forms in the soil environment.

The PTS with Al-Ca-Fe media was not effective in removing additional P from the wastewater stream. Reasons for the ineffectiveness of this media are unknown but may be due to coatings of the media particles by organic matter or other precipitants which interfered with dissolution of the media and precipitation of PO_4^{3-} minerals.

SUMMARY

Results of this study indicate that passive, low maintenance onsite system components may extend the life on the system and are effective in removal of potential ground and surface water contaminants. The combination of a two compartment septic tank with an effluent filter, anaerobic upflow filters, and a P treatment system reduced BOD and TSS in two onsite systems by 85 to 90%. The effluent does not meet standards for Class I wastewater, but the BOD and TSS reductions appreciably reduced organic loading to the drainfield and thus, would be expected to extend the drainfield life. Total N was reduced by 35 to 50% although N removal was not an objective of the overall system design. The system components reduced P content of the wastewater by 50 to 90%. The Fe-based P treatment system component effectively reduced wastewater P content. The Al-Ca-Fe based P removal component was less effective. As with all onsite systems, this system design requires periodic (4-7 year cycle) professional maintenance to remove solids that may accumulate in the septic tank and AUFs.

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