Nutrient Treatment By Onsite Wastewater Systems in Clayey Soils of the North Carolina Piedmont

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Abstract

Major water resources in the Piedmont of North Carolina including Falls Lake, Jordan Lake, and the Tar River are impaired due to excess nutrient loading. State regulatory agencies have implemented strategies to reduce point and non-point sources of nutrient pollution to the impaired waters. However, the nutrient contributions from onsite wastewater systems (OWS) were not addressed, because there is a lack of research regarding OWS nutrient treatment efficiency, especially in the Piedmont of North Carolina. The goal of this project was to gain a better understanding of the nutrient treatment efficiency of OWS installed in clayey soils of central North Carolina. Four volunteered, residential sites with OWS were studied. The four OWS included two conventional and two single-pass sand filter systems. Septic tanks, groundwater near the OWS, effluent from the sand filters, and adjacent surface waters were sampled each season during 2015 and 5 times overall. Samples were analyzed for total dissolved nitrogen (TDN), phosphate phosphorus (PO_4-P), dissolved organic carbon, chloride, and environmental parameters. Two component mixing models using septic tank effluent and background groundwater chloride and nutrient concentrations were used to estimate reductions in the mass of OWS derived nutrients. Average TDN and PO_4-P concentrations in groundwater 35 m down-gradient from the two conventional OWS were 98% and 99% lower respectively, than septic tank effluent. Mixing model results showed nutrient mass reductions of 70% (TDN) and 95% (PO_4-P) in groundwater 35 m down-gradient from the OWS. Sand filter effluent concentrations of TDN and PO_4-P were 80% and 90% lower respectively, than septic tank concentrations. The mass of TDN and PO_4-P were reduced by 50 and 83% in the sand filter OWS. Additional treatment of sand filter effluent prior to surface water discharge is suggested to reduce nutrient loading from OWS.

Introduction

- Nitrogen and phosphorus often limit primary production in aquatic environments, and nutrient loading to surface waters can stimulate algae blooms.
- Some algae blooms are toxic and are thus public health hazards.
- Algae decomposition in surface waters can deplete dissolved oxygen, leading to fish kills and water use impairment.
- Wastewater contains elevated concentrations of nutrients and other pollutants, therefore wastewater systems need to be efficient at reducing concentrations of pollutants before effluent is discharged to groundwater or surface water.
- Nitrogen is dynamic in the environment and may undergo various transformations which influence the fate and transport of the nutrient.
- Phosphorus mobility in the soil environment is influenced by redox potential, pH, presence of iron, aluminum and calcium in soils, and phosphorus content of soil.
- There are many different potential sources of nutrients in watersheds including human wastewater, wildlife and livestock waste, and fertilizers.
- Prior studies suggest that groundwater nutrient concentrations can be elevated near on-site wastewater systems in sandy soils.
- The piedmont region of NC is growing rapidly, is characterized as having clay rich soils, and much of the population uses onsite systems.
- Major water supply lakes and reservoirs in central NC are nutrient sensitive and onsite may be a contributing source of nutrients to waters in the piedmont of NC
- More field research is needed to quantify the nitrogen dynamics beneath onsite systems in clayey soils.
- Conventional style onsite systems are commonly used throughout NC (Figure 1A)
- Single pass sand filter systems are common in areas with unsuitable clay mineralogy (Figure 1B)

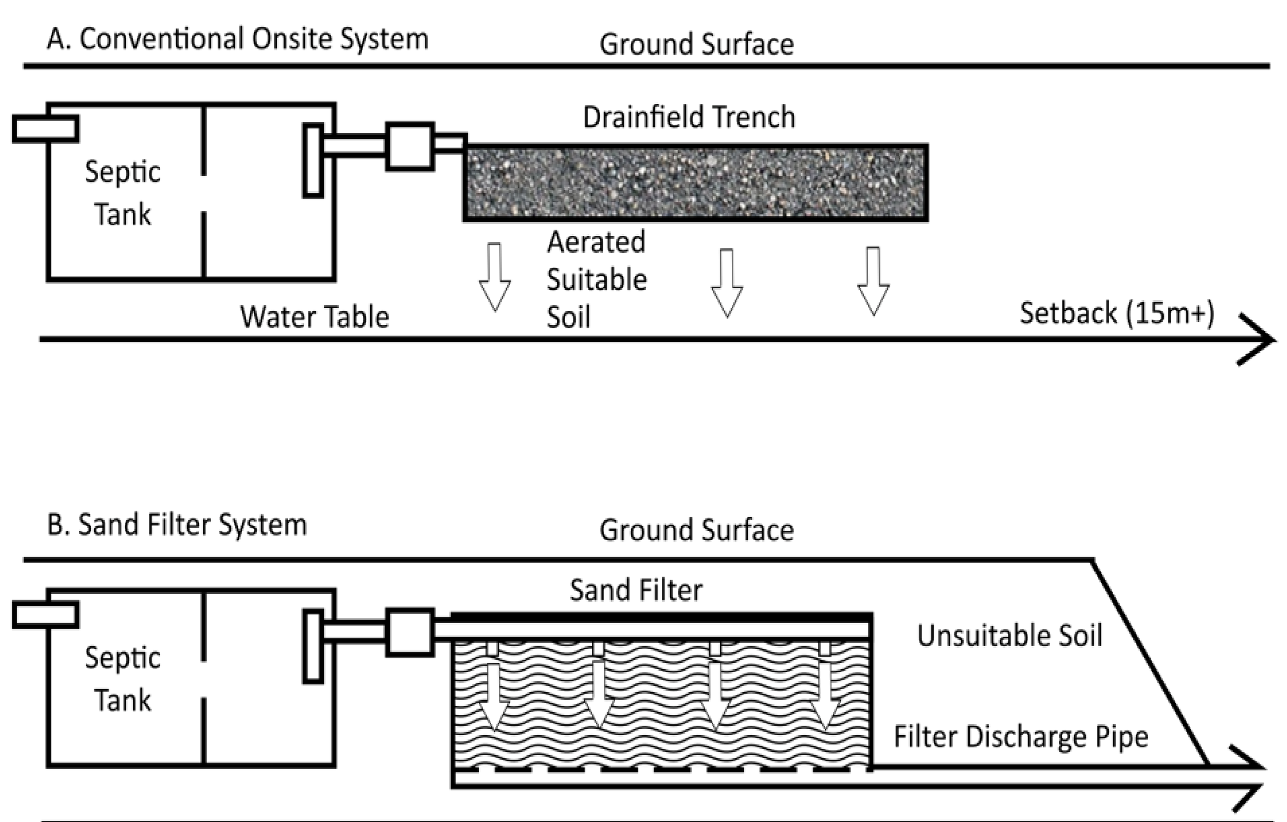

Figure 1. Diagram of subsurface (A) and surface discharge (B) septic systems. Subsurface systems discharge effluent into the soil beneath trenches, whereas surface discharge systems discharge effluent to a stream/ditch via a filter discharge pipe.

Materials and Methods

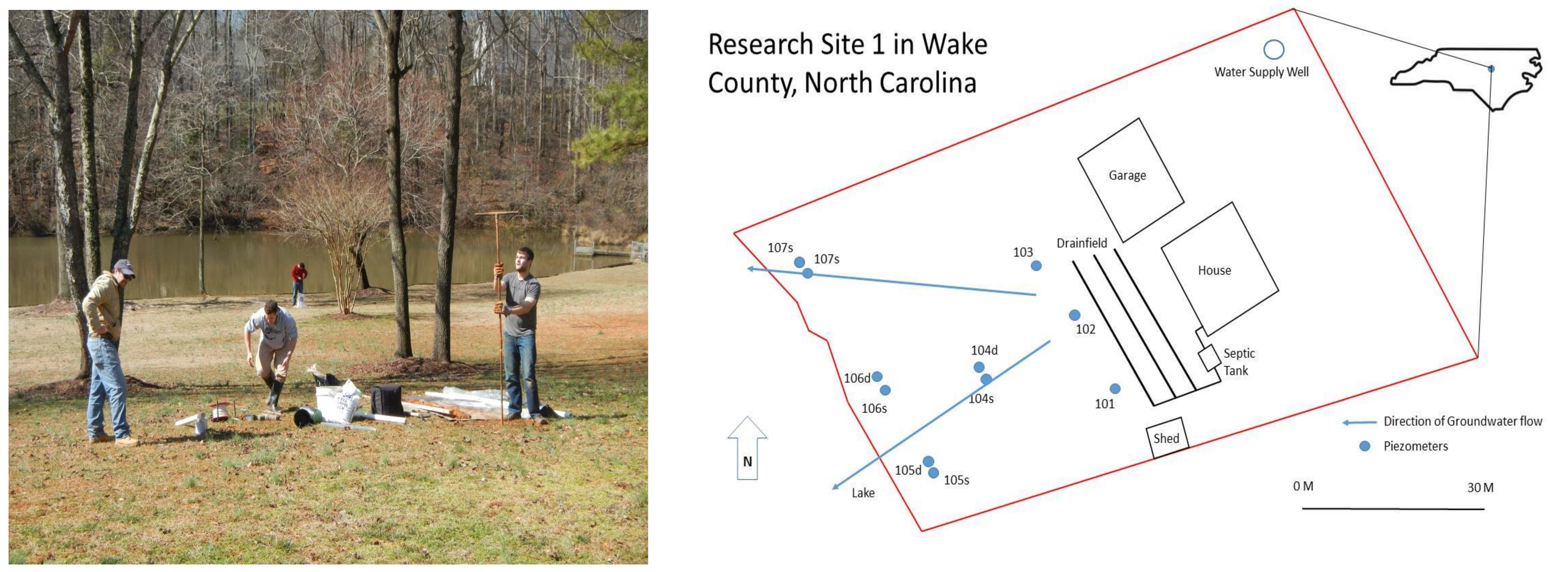

Figure 2. Piezometers were installed down-gradient from conventional style onsite systems to allow for collection of groundwater samples for nutrient analyses and environmental readings at different distances along a groundwater flow path. Soil samples were collected during the piezometer installations for particle size analyses, CEC, and pH.

Figure 3. Piezometers were installed near the sand filter beds of the single pass sand filter systems and away from the beds to determine if effluent from the sand filter was influencing groundwater quality near the filter bed.

Figure 4. Septic tanks, piezometers, background wells, sand filter outlet pipes and surface waters adjacent to the onsite systems were sampled 5 times during the study for nutrient analyses and environmental readings. Environmental readings included depth to groundwater, pH, specific conductance, temperature, redox potential, and dissolved oxygen concentrations.

- A two component mixing model using septic tank effluent and background groundwater chloride concentrations was used to determine the percentage of groundwater and wastewater at each piezometer down-gradient from the onsite systems. These data helped to determine mass load reductions of nutrients leaving the septic tanks.
- Isotopic analyses of $\delta^{15}N$ and $\delta^{18}O$ in NO_3 in groundwater was used to help determine the source of NO_3 and if denitrification was occurring along a groundwater flow path.
- Groundwater pH, redox potential, and soil characteristics near the onsite systems were used to help determine if phosphate treatment via adsorption and/or mineral precipitation were likely mechanisms of attenuation.

Table 1. Soil and onsite system characteristics of the four research sites.

Site	System Type	Tank Size (L)	Drainfield / Filter Area (m2)	Install Date	System Users	Soil Series	Subsoil % Sand/silt/clay	ECEC (cmol/kg)	Subsoil pH
Site 100	Conventional	3780	90	1997	5	Cecil	26/9/65	4.1	5.5
Site 200	Conventional	3400	30	1930	2	Georgeville	21/37/42	6.7	6.3
Site 300	Sand Filter	3400	30+	1968/2014	2	Chewacla	31/49/20	17.5	5.6
Site 400	Sand Filter	(2)3780	36	1973	3	Chewacla	52/23/25	9	5

Results and Discussion

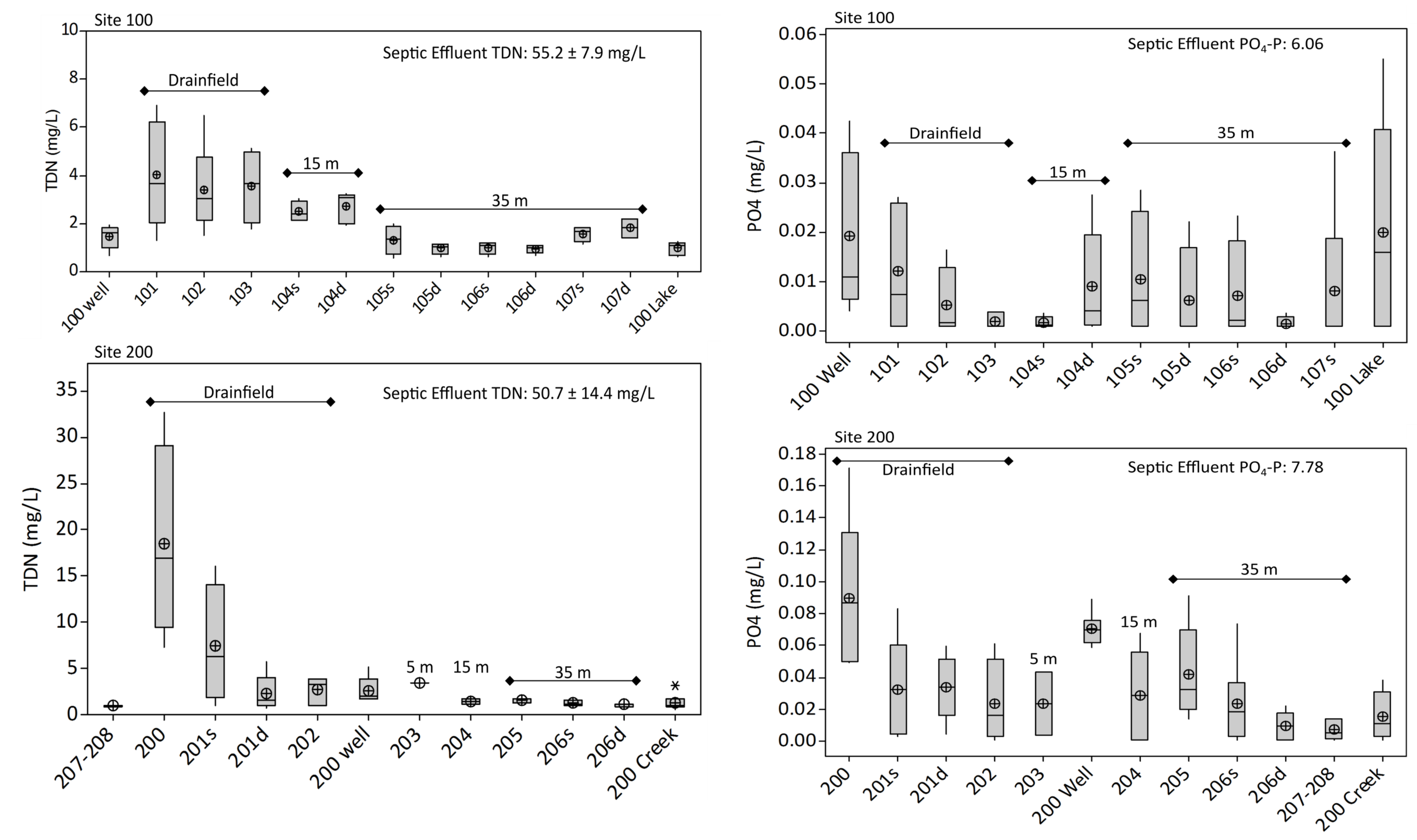

Figure 5. The concentrations of TDN and PO_4-P in septic effluent were reduced by an average of 98% and 99% in groundwater 35 m down-gradient from the conventional systems (100 and 200). Mass load reductions of TDN and PO_4-P averaged 70% and 95%, respectively at these sites.

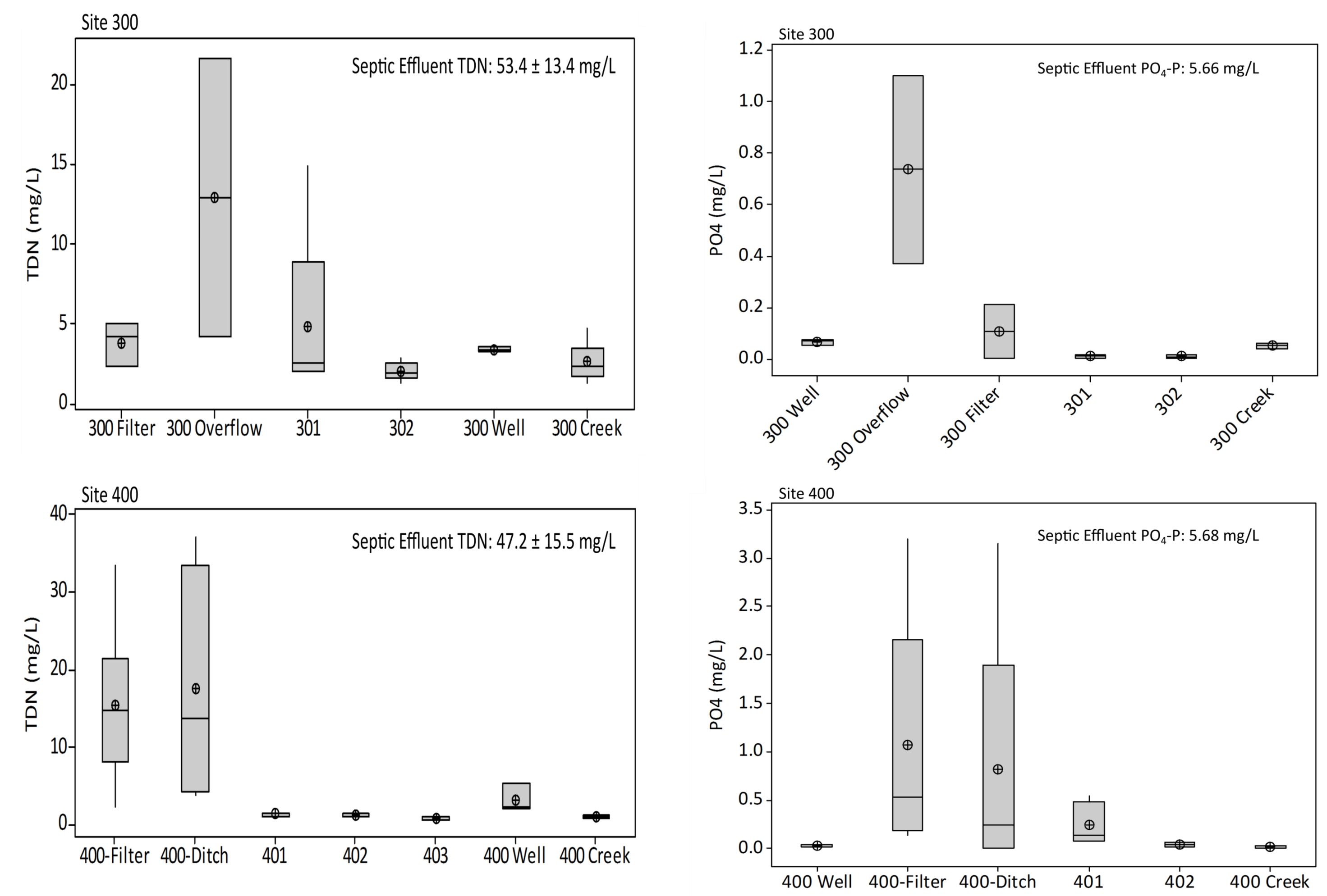

Figure 6. The concentrations of TDN and PO_4-P in septic effluent were reduced by an average or 80% and 90% after passing through the sand filters at sites 300 and 400. Mass load reductions of TDN and PO_4-P were 50 and 83%, respectively for the sand filter.

Conclusions

•Nutrient (TDN and PO_4) treatment was typically better for the conventional style onsite systems relative to single pass sand filter systems.

•Watersheds served by a high-density of single pass sand filter systems may be susceptible to elevated nutrient loading.

•Water quality may be improved by implementing retrofit best management practices to the discharge sand filters. Examples include passing sand filter effluent through reactors with reactive media such as slag to sorb phosphate and woodchips to promote denitrification. Another option would be to discharge sand filter effluent into a treatment wetland.

•More field-based research is needed to identify retrofit best management practices for onsite systems that are affordable, and relatively low-maintenance.

References

Humphrey, C.P., Jernigan, J., Iverson, G., Serozi, B., O'Driscoll, M., Pradhan, S., and Bean, E. (2016). Field evaluation of Nitrogen Treatment by Conventional and Single-Pass Sand Filter Onsite Wastewater Systems in the North Carolina Piedmont. Water Air & Soil Pollution. doi: 10.1007/s11270-016-2958-0

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