Onsite Wastewater System Effects on Groundwater Quality

By
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ABSTRACT

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More than 40,000 onsite wastewater systems (OSWWS), also known as septic systems, are installed in North Carolina each year, with residents depending on the systems for treatment and disposal of wastewater effluent. The transfer of wastewater from septic systems through the soil profile can pose public and environmental health risks if the system is not efficiently treating the effluent. The potential for groundwater and surface water contamination related to OSWWS can be dependent on soil types and groundwater depth. A groundwater-monitoring network located adjacent to the septic system of a school located in the coastal plain of North Carolina was used during this study to observe the pH, nitrate, ammonium, dissolved oxygen, and electric conductivity levels in the OSWWS drain field to determine the treatment provided by the OSWWS. Samples were also collected from the holding tank to compare the nutrient reduction from the tank to the drain field. A background well located up gradient of the OSWWS was also monitored to observe the groundwater quality on site distanced from the OSWWS.

Current water quality regulatory efforts focus on nutrient loading from stormwater and agricultural runoff, as well as municipal wastewater treatment discharge, without addressing the billions of gallons of nutrient rich water being released into the ground by septic systems. While the study revealed a decrease in nutrients from the holding tank to the drain field for this individual site, the results substantiate that potential pollutant contributions from septic systems should be included in water quality regulatory efforts.

BIOGRAPHY

I am a native of eastern North Carolina, and my heart is directly tied to the coastal plains of this great state. I was born and raised in rural Wayne County and graduated with a B.S. in Environmental Science from UNC at Wilmington in 2006. After graduation I accepted a position with the Pitt County Soil and Water Conservation District as an Environmental Specialist, where I directly worked with farmers to implement best management practices to improve and protect our local water quality. I transitioned from county to state government, and along the way I discovered that teaching allowed a new outlet to share my passion for our natural resources. I have recently accepted a position as a Science Teacher at The Oakwood School in Greenville, where I am given the freedom to share my passion for our environment and teach future generations how important our actions are to the future of others.

Participating in the Master of Environmental Assessment program at North Carolina State University has allowed me to further develop my passion and knowledge for all things environmental.

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First and foremost I would like to thank my husband Allen Hales for his constant love and support during this daunting process, because I certainly did not make it easy on him. Words cannot describe the commitment, patience, and support he has given me over this three-year process while I accomplish this goal.

I want to thank my grandmother and parents for always encouraging me to do more, work harder, and never stop learning. Thank you Bryan Evans for teaching me that there is nothing you can't accomplish without hard work.

My deepest gratitude goes to Dr. Charlie Humphrey of East Carolina University for giving me the opportunity to work with him to fulfill this professional project and for guiding me through this process.

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INTRODUCTION

Onsite Wastewater Systems

Onsite Wastewater Systems (OSWWS), commonly known as septic systems, are used to treat wastewater produced by homes and businesses where centralized sewer service is not available. The wastewater produced from the bathroom, laundry, and kitchens of homes and businesses undergo an onsite treatment process before the sewage effluent is released into an drain field.

Nearly 50 percent of the homes in North Carolina rely on OSWWS to treat wastewater. It has been estimated that more than 40,000 OSWWS are installed each year in North Carolina (Hoover and Konsler, 2004). For these systems to work effectively, it is important that they are properly designed, installed, and maintained (Hoover and Konsler, 2004).

For an OSWWS to work properly, adequate soils must be present on the site to handle the hydraulic and organic load of the released effluent. Conventional OSWWS consist of three main parts: the septic tank, the drain field, and the soil beneath the drain field (Hoover and Konsler, 2004). The location of the tank and drain field lines are dependent on adequate soils found during a site survey. The septic tank is a sealed watertight tank located underground outside of the residence. The tank is used to catch all wastewater exiting the home and is sized based on the estimated flow and/or the number of bedrooms within the home. The septic tank allows for pretreatment of the waste before effluent enters the drain field and subsequently the groundwater.

While there is some pretreatment of the waste within the tank, the major effluent treatment happens once the fluid leaves the tank and enters the drain field. Drain lines, consisting of perforated pipes, are installed within gravel bed trenches and allow for slow release of the wastewater into the soil profile, as seen in Figure 1 (Catawba Riverkeeper Foundation, 2005).

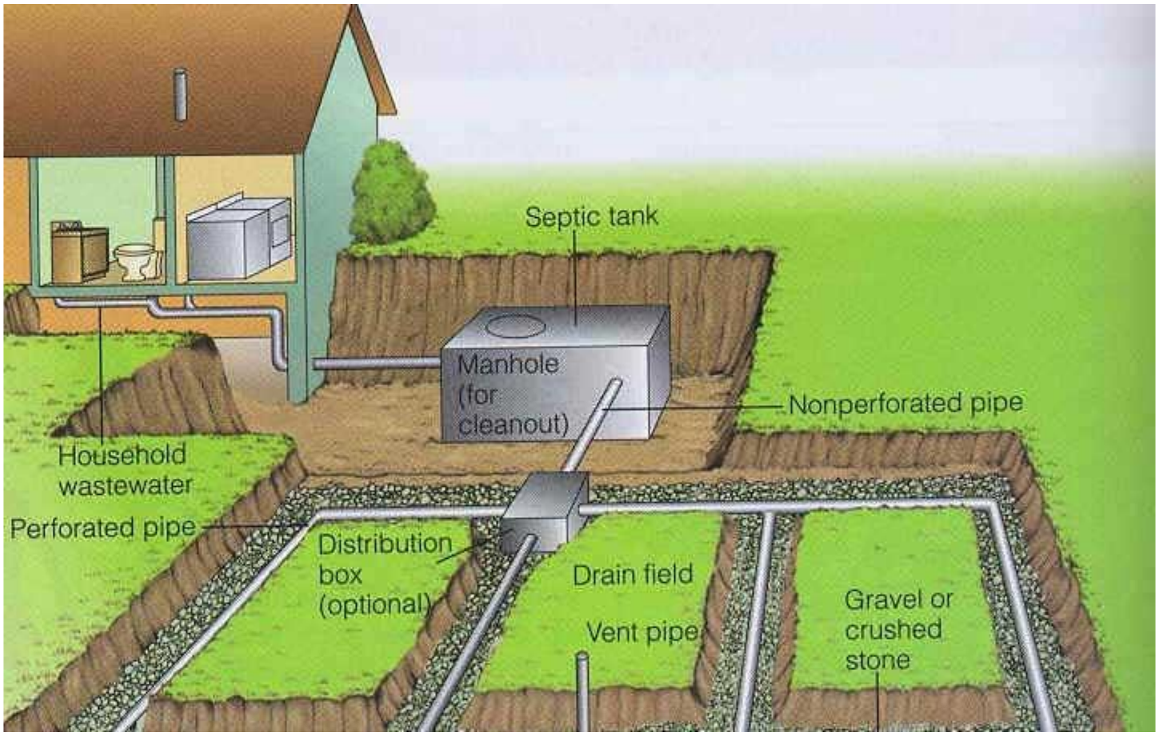

Figure 1. Septic system diagram

The site for the trenches is pre-established by an environmental health specialist who takes into consideration the soil type and water table level when selecting the site. The trench location should allow for adequate percolation through the soil, aiding in the filtration of pathogenic microorganisms and other environmental pollutants. However, systems that are not functioning properly can result in wastewater backing up in the home/business or ground surface in the drain field. Proper soil conditions are vital for OSWWS to effectively treat wastewater. This is especially true when wells used for drinking water are in the vicinity of the treatment system. Failing OSWWS can pose a health risk to humans, as well as to surrounding wildlife and the environment within the contaminated area.

Wastewater must be treated effectively to protect the quality of groundwater. Monitoring these treatment systems is important as 90% of rural households and 75% of cities within the United States depend on groundwater as a drinking water source (Pradhan, Hoover, Austin, & Devine, 2007). OSWWS that do not provide adequate treatment can affect groundwater and/or surface water; when not properly treated, serious health problems such as dysentery, hepatitis, typhoid fever, and acute gastrointestinal illness have been related to failing septic systems (Massachusetts Department of Environmental Protection, 2013). Failing septic leachate is the most frequently reported cause of ground water contamination (Yates, 1985), and the spread of phosphorus, nitrogen, and pathogens pose both environmental and human health risks associated to OSWWS.

Currently in North Carolina, the potential for water quality degradation due to nutrient loading related to OSWWS is not being accounted for through water quality initiatives or regulatory actions. The presence of this additional nitrogen source into the states waters should be monitored closely and further studied to identify the proper maintenance and compliance needed to ensure that OSWWS are treating wastewater efficiently. While the North Carolina regulations were put into place to enhance the water quality of the state, current regulations focus on the issues related to municipal / industrial wastewater treatment, stormwater runoff, and runoff related to agricultural production (Humphrey, Driscoll, & Armstrong, 2012); more emphasis should be placed on septic system regulatory efforts.

This study provides a snap shot of the effect that an onsite wastewater system can have on groundwater quality related to nutrient inputs. Over the course of four months, data was collected from the OSWWS of an independent school located in Greenville, North Carolina within the Tar-Pamlico River Basin. The study was performed to grasp a better understanding of the efficiency of OSWWS and to determine the need of OSWWS regulatory standards as related to ground and surface water quality.

Nitrogen Sources within the Environment

Nitrogen is a common nutrient found throughout the atmosphere, and is the most important nutrient for governing plant growth and reproduction. However, an excessive amount of nitrogen can become problematic. Approximately 78% of the Earth's atmosphere is composed of nitrogen; it is also found as parts of organic matter and hummus within the Earth's crust (University of Missouri, 1993). Although the atmosphere is made up of nitrogen, it is in the gaseous form of dinitrogen (N_2); a form not readily used by plants (University of Missouri, 1993). Rainstorm events directly deposit inorganic N_2 into the soil where microorganisms begin to convert dinitrogen into usable forms of nitrogen for plants. Through nitrogen fixation, N_2 is converted to other forms of nitrogen that continue to rotate through the nitrogen cycle.

Nitrogen enters the atmosphere through both anthropogenic and natural sources and circulates through the nitrogen cycle and is released by the atmosphere by deposition.

Just as the water cycle keeps water moving through various locations of the atmosphere, so does the nitrogen cycle. Unlike the water cycle there is constantly new sources of nitrogen being injected into the N-cycle in ever increasing amounts.

The use of commercial fertilizers has greatly increased in the recent years. In 1960 a total of 2,738,000 tons of nitrogen was used in agriculture in the United States, and within 50 years, that total skyrocketed to a total use of 12,840,000 tons in 2011 (United States Departmen of Agriculture, 2013). Nitrogen that is not used by crops/plants is subject to leeching, surface runoff, and/or transport through wind erosion during application.

Agricultural uses are not the only sources of nitrogen being introduced into ecosystems; urban sources of nitrogen including emissions from automobiles and industry, and use of lawn fertilizers also contribute to the overloading of nitrogen into the Earth cycles. With growth and industrialization comes an increased release of nitrogen into the atmosphere. Currently the most developed countries, Asia, Europe and North America account for almost 90% of human-generated reactive nitrogen (Fields, 2004).

Denitrification plays a significant role in wastewater treatment. Microorganisms found within the soil profile gain energy through the use organic matter as an electron source and oxygen as a terminal electron acceptor. However, as oxygen is depleted in the soil, some microorganisms can use other electron acceptors such as nitrate (NO_3). As wastewater effluent enters the drain field soils, ammonium (NH_4) is converted to nitrate (NO_3) through the nitrification process. Microorganisms can use NO_3 as an electron thus reducing NO_3 to N_2 or N_2O gases that escape to the atmosphere (University of Missouri Extension, 1993).

Denitrification allows for the release of nitrogen gases back into the atmosphere, resulting in a nitrogen loss within the soil, reducing the amount of NO_3 that leech into groundwater. Nitrates move readily with water and are a threat to groundwater quality and nearby surface water quality. As NO_3 leeches through the soil they can move past the root zone of plants and become a direct contamination to groundwater. Denitrification takes place in soils that are saturated, anaerobic, and have a supply of labile organic matter and NO_3. A system that has consistent use will have wastewater with NO_3 and dissolved organic matter flowing through it on a constant basis, which push effluent into the soil. If system usage and flow is increased beyond its design capacity the result will be an overloading of wastewater into the soil. This could decrease the nitrification and denitrification that can occur near the OSWWS. Soils that experience hydraulic loading may result in NH_4 rich water being pushed through the soils quicker, reaching groundwater before nitrification can occur.

Nitrogen Effects on Water Quality

The most common forms of nitrogen are dinitrogen (N_2), Nitrate (NO_3), Ammonium (NH_4), and organic nitrogen ($C\text{-}NH_2$). Nitrate and ammonium are the common nitrogen sources related to OSWWS. Ammonium tends to cling to soil more than nitrate, which makes nitrate more susceptible to leaching to groundwater. Nitrogen becomes the biggest threat to water quality when it takes the form of nitrate that is mobile in hydric situations.

Nitrates naturally occur within the soil due to decomposition and organic matter. Additional nitrates are added through the use of fertilizers, manure and wastewater. Both NO_3 and NH_4 are readily used by plants, however, an over loading of nitrogen into soils can result in nitrogen moving past the root zone of plants and leeching into groundwater.

When NO_3 makes its way into groundwater the potential for drinking wells to be contaminated is much more likely. The result of this contamination can be detrimental to human health. When the water table is shallow in areas like the coastal plains of North Carolina, nitrogen rich water does not have a great distance to travel in order to reach groundwater aquifers. As water passes through the soil profile, the soil types present greatly affect the amount of nutrients that remain in suspension before it reaches the shallow aquifers (Humphrey et al., 2012).

Nitrogen contamination of groundwater can have direct effects on humans. Most susceptible are children one year or younger that ingest NO_3 rich drinking water. Ingesting elevated levels of NO_3 can lead to methemoglobinemia, commonly referred to as blue-baby syndrome. This reduces the oxygen carrying capacity of blood. The ingestion of nitrogen rich water can also have a negative effect on young livestock that receive drinking water from groundwater wells. In order to monitor the NO_3 levels in drinking water, the Environmental Protection Agency has set the maximum contaminant level of nitrate in drinking water at 10 mg/L (U.S. Environmental Protection Agency, 2012).

As ammonium and nitrate travel through the soil profile and enter groundwater plumes, they can then be transported into other water sources such as ponds, streams, lakes or rivers. Excess nutrients that enter into open waters can lead to eutrophication. Eutrophication occurs when bodies of water acquire a high concentration of nutrients, which in turn, lead to increased plant growth. The excess plant growth causes the depletion of dissolved oxygen (USGS, 2013). Eutrophication is commonly linked to newsworthy algal blooms that spread quickly, leading to fish kills throughout fresh water and marine environments.

The Oakwood School Site

The Oakwood School is an independent school located in Greenville, North Carolina and located within the Tar-Pamlico River Basin. In early 1996, 42 founding families committed resources to create a non-sectarian independent school in Pitt County. By 1998, a donor contributed 25 acres of land on MacGregor Downs Road to establish a permanent location for the school. The land had historically been used for row crop agriculture and remained in agricultural use until the two first buildings were completed in 2001. Through donor support the original 25 acres has expanded to 42 acres. The original ditch drainage design was later modified to handle the drainage of the impervious surface that resulted from the school's development (The Oakwood School, 2008). Figure 2 shows the Oakwood School site in as agricultural land in1993 (outlined in red), prior to being donated.

Figure 2. The Oakwood School site in 1993 prior to development.

By 2013, The Oakwood School had established three buildings on their main campus and one building on their Upper School campus on an adjacent parcel.

The campus began with a small enrollment of approximately 80 students spanning from Pre-Kindergarten through eighth grade. Oakwood has since expanded with the most recent expansion increase resulting in 390 students. When the data was collected for this study (beginning in the spring of 2013) there was an enrollment record of 382 students. By spring 2013, the existing OSWWS was operating over its standard flow capacity due to the increased enrollment. From an environmental assessment perspective it spurred an interest in the effects the septic system was having on the groundwater quality on campus.

The school is located in the Tar-Pamlico Watershed and is approximately 3,000 meters from the Tar River as seen in Figure 3. The Tar-Pamlico Watershed was placed on the N.C. Division of Water Quality's 303d list, listed as "Nutrient Sensitive Water" in the mid 1980's. Throughout the next decade, effort was put into reducing the nutrient loading of the waters through the implementation of best management practices (BMP). The successful implementation of these BMP's resulted in a reduction in nutrient loading and sections of the Tar-Pamlico being removed from the 303d list. A major component to the water quality improvement initiative was BMP installation on agricultural lands to reduce nutrient input from non-point source agricultural practices. No regulatory efforts were directed towards septic system influences on groundwater. Recent studies have shown that the Greenville portion of the Tar-Pamlico Watershed has the highest OSWWS density in North Carolina, presenting a potential nitrogen-loading rate of 741 $lb/mi^2/yr$ (Pradhan, Hoover, Austin, & Devine, 2007).

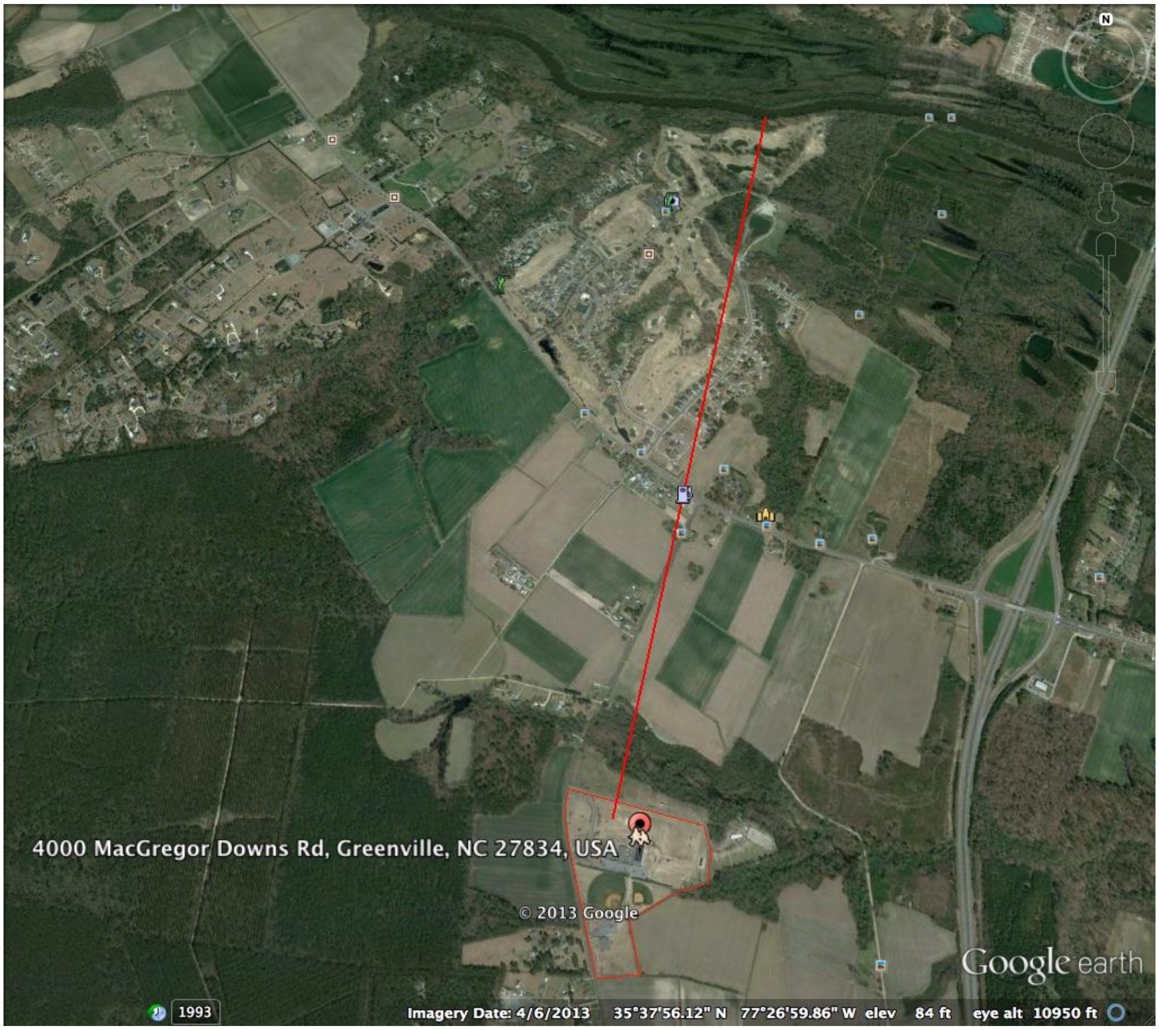

Figure 3. An aerial measurement of the Oakwood site to the Tar River equaling 3,100 meters.

Septic System Design

The Oakwood School is located near Greenville's medical campus, however, the school is located just outside the reach of city sewer. In 2001, the school had secured a permit to install a septic system that would meet the enrollment needs, up to 300 occupants.

By 2013 the enrollment of the school had reached 382, well above the recommended capacity of the system. This usage exceeded the recommended flow rate and spurred the thought of the environmental assessment issues that may be directly related to the over usage of the system, inspiring this project.

The system is comprised of one reinforced concrete septic tank and one concrete pump tank that together would store up to 3,000 gallons of effluent. A pump was installed in the pump tank to disperse effluent into the drain field via a pressure manifold. The drain field consisted of 24 trenches, each approximately 26 meters in length and 0.9 meters wide. Twelve trenches were located on each side of the manifold. To collect representative groundwater readings for the entire system, three piezometers were installed on each side of the manifold, as seen in Figure 4. Aerial maps and installation permits allowed for trench lines to be located onsite prior to installation.

Methods and Materials

Groundwater Monitoring Network

To obtain groundwater samples and measurements, modified piezometers were installed between the trenches of the existing OSWWS. A piezometer is a device used to measure static liquid pressure at a specific point, allowing the observation of the height of water rising within the pipe against gravity. We used modified piezometers that had 0.9 m screen sections. Observing the height of the water relative to the drain field trenches, allowed us to observe the separation distance between groundwater and the OSWWS.

A hand auger was used to excavate the columns for the piezometers to be housed; some holes were nearly 3 meters in depth. The goal was to auger down to the water table to allow for water collection, yet, not to go further down than necessary to collect the samples. Drain fields in North Carolina are required to have 30 cm of vertical separation distance from the trench bottom to the seasonal high water table for systems installed in coarse loam and finer soil types, with 45 cm of separation for sandy soils, according to the North Carolina Division of Environmental Health, On-site Wastewater Section (N.C. Department of Health and Human Services, 2013).

Figure 4. Piezometer locations within septic system drain field.

The piezometers were 5 cm diameter polyvinyl chloride pipes cut to appropriate size according to the water table that had been reached during excavation. The bottoms of the pipes were capped to prevent an influx of water from being pushed upward within the pipe. Above the capped end was a screened portion of the pipe to allow the natural flow of groundwater to enter the piezometer. Once the piezometers were installed in the excavated columns a mixture of bentonite and sand was used to fill the column around the piezometer. This design is to prevent surface water from seeping down and influencing the readings. After the bentonite / sand mixture was added, soil that had been augured from the hole was used to backfill the rest of the space. The goal of the piezometer is to collect groundwater moving laterally through the ground while not disturbing water flow moving up and down through the ground. Finally, the piezometers were marked and capped to keep debris from entering.

One piezometer was installed in the background section of the drain field that was away from the drain lines, as seen in Figure 4. Installing a background-monitoring well would allow for baseline water samples to be captured and used for comparison of the total dissolved nitrogen, pH and electric conductivity levels that were observed in the trench line groundwater.

Soil Analysis

Figure 5. Soil profile observation during excavation.

As the piezometers holes were excavated, soil was collected from the column of the wells and carefully placed on a tarp. This provided an opportunity for a more in depth look at the soil types surrounding the system and to compare the findings to the soil survey. The "texture by feel" method was used to determine the soil type for each horizon (Brady & Weill, 2004). Pictures of the soils were taken with a camera, and are shown in Figure 5. Soil colors were determined for each soil horizon using a Munsell Soil Color Book. As seen in Table 1, the soil from wells 1, 3, and 4 exhibited sandy loam features as described in the Pitt County Soil Survey. Most wells were excavated an average of 3 meters in depth, while some wells, such as well 4 were not as deep because the water table was encountered at a shallower depth.

Table 1. Soil profile descriptions from wells 1, 3, and 4 according to the Munsell Soil Color Book.

Well 1 Profile Description	**0-18"** 2.5Y 4/2 ***Sandy Loam***	**18-26"** 2.5Y 6/4 ***Sandy Loam***	**26-34"** 2.5Y 5/6 ***Sandy Loam***	**34-72"** 2.5Y 6/6 with common 2.5Y 7/2 ***Sandy Loam***	**72"+** 10YR 6/2 ***Sandy Clay Loam***
Well 3 Profile Description	**0-18"** 2.5Y 3/2 ***Sandy Loam***	**18-25"** 2.5Y 6/4 ***Sandy Loam***	**25-42"** 2.5Y 6/4 with common 2.5Y 7/2 and 2.5Y 6/8 mottles ***Sandy Loam***	**42-72"** 2.5Y 6/6 with common 2/5Y 7/1 and 2.5Y 6/8 mottles ***Sandy Clay Loam***	**72"+** 2.5Y 7/2 with 2.5Y 6/8 and 2.5Y 6/6 mottles ***Sandy Clay***
Well 4 Profile Description	**0-12"** 2.5Y 4/2 ***Sandy Loam***	**12-18"** 2.5Y 6/4 ***Sandy Loam***	**18-30"** 2.5Y 5/6 ***Sandy Clay Loam***	**30-38"** 2.5Y 5/6 with 10YR 6/8 mottles ***Sandy Clay Loam-Sandy Clay***	**38-48"** 2.5Y 5/6 with common 10YR 6/8 and 10YR 7/2 mottles ***Sandy Clay***

Soil Types Present

The landscape at the Oakwood School is very flat with very little slope defining the property. The soils on the property are listed as an Exum fine sandy loam with 0 to 1 percent slope. The soil survey indicates that the first eight inches should be a very fine sandy loam, followed by a silt loam, the profile then transitions into a clay loam and loam at 70 to 100 inches.

The Pitt County Soil Survey describes Exum soil as a moderately well drained soil with a depth to water located between 60 to 91 centimeters. Soils of this nature were usually classified as prime farmland due to its well draining nature. This drainage also makes it a good candidate for a drain field for the septic system.

The North Carolina Cooperative Extension suggests that soil suitable for septic systems should display brown, yellow, or reddish colors and should not be too sandy or clayey. Signs of greyish colors, which can be an indicator of excessive wetness, were not predominant (N.C. Cooperative Extension, 2004).

Meters and Sample Collection Equipment

During data collection the following meters were used onsite to collect water sample information:

- Solinst 107 TLC: used to measure depth to water within the well.
- YSI 556 Multi-Probe: used to measure dissolved oxygen, pH, conductivity, and temperature of water samples.
- YSI Professional Plus: used to measure the nitrate and ammonium levels of water samples.

Water samples were tested onsite with the meters above, while additional water samples were collected to be tested at the East Carolina University Geochemistry Lab. Water samples that were taken back to the lab were tested for total dissolved nitrogen using the Shimadzu TOC/TDN analyzer.

A disposable bailer was used to purge each well twice prior to collecting the sample to ensure that stagnant water was not collected. Meters that were used were calibrated before each sampling event to ensure accurate readings. Water samples were collected using disposable bailers and samples brought to the lab was stored in Nalgene plastic sample bottles and stored on ice during transport.

RESULTS AND DISCUSSION

Water samples were collected spanning from the spring into the summer months of 2013 in an effort to get a wide range of readings. Samples were collected on the following dates: May 16, May 31, June 19, July 18, and August 13. Each monitoring well and the septic tank was tested for pH, NO_3, NH_4, dissolved oxygen (DO) as well as electrical conductivity (EC) levels. The total dissolved nitrogen (TDN) was calculated as $NO_3 + NH_4$.

Effluent samples from the tank were compared to groundwater samples between the drain field trenches, giving insight into the treatment being provided by the OSWWS. The sample readings from the tank and drain field piezometers were also compared to background groundwater samples to determine if the OSWWS influenced groundwater physical and chemical properties.

As seen in Figures 6, 7, and 8, samples from the septic tank exhibited higher levels of TDN and EC, as well as a higher pH than that of the background well and drain field wells. As expected, the dissolved oxygen levels in the tank (Figure 9) were lower than that of the background well and drain field wells, as expected. DO levels are usually lower within the septic tank due to microorganisms demand for the available oxygen (University of Minnesota, 2010).

As represented in Figure 6 the average TDN levels in the tank were 77.4 mg/L compared to an average of 38.0 mg/L in the drain field and 0.68 mg/L in the groundwater collected from the background well. The septic tank also exhibited higher pH levels, averaging 6.7, as seen in Figure 7; while the pH averaged 4.3 in the drain field and 5.5 in the background well.

The increased salinity of direct wastewater results in a higher electrical conductivity, as seen in Figure 8. The tank water was much higher in EC averaging 1394.5 uS/cm, compared to the treated drain field levels at 636.5 uS/cm and background readings at 162.4 uS/cm.

As previously mentioned, it is common for dissolved oxygen levels to be lower within a septic tank due to the microorganisms using the available oxygen. As represented in Figure 9, the septic tank averaged 2.2 mg/L of DO, while the drain field and background well both averaged at approximately 2 mg/L.

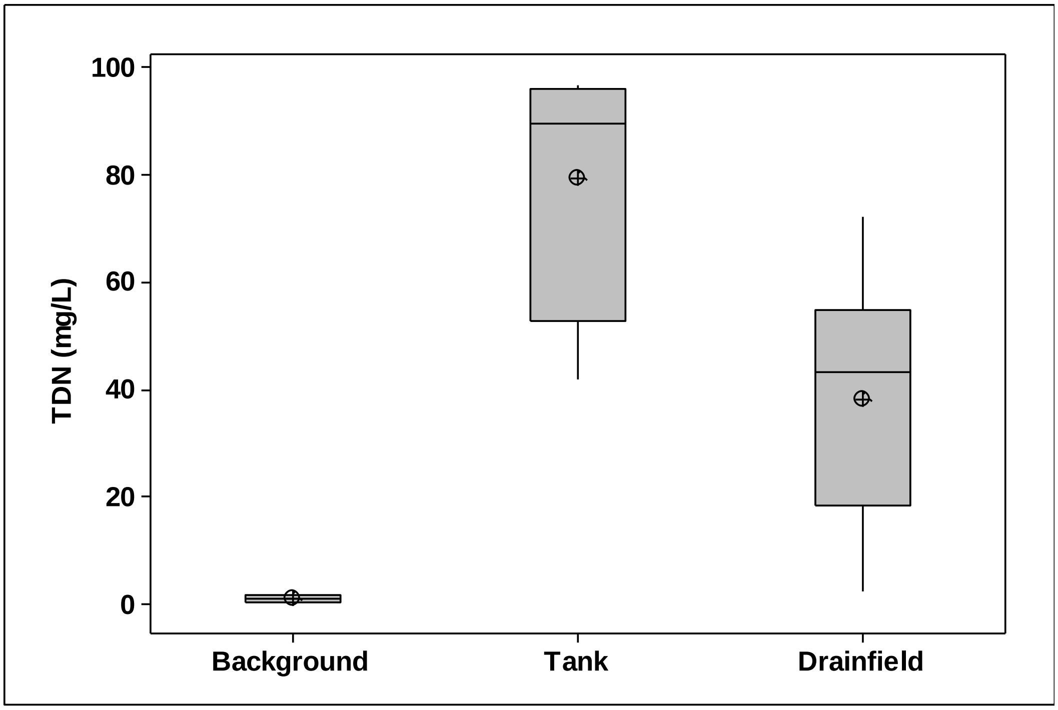

Figure 6. Box plots of total dissolved nitrogen concentrations in the background well, septic tank, and drain field wells.

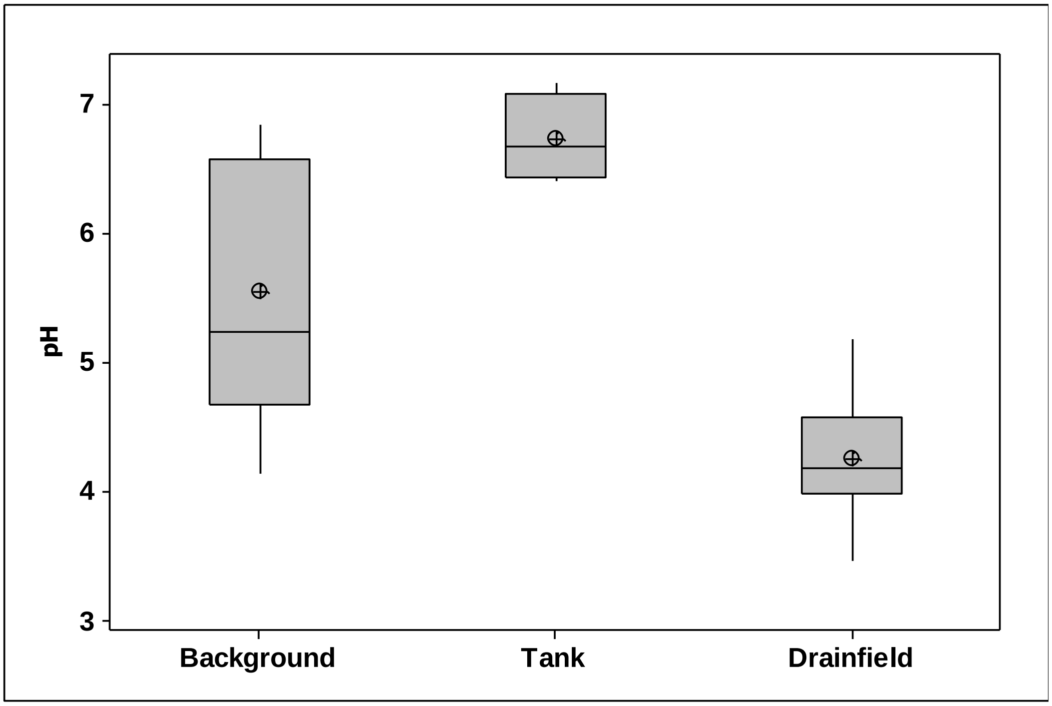

Figure 7. Box plots of the pH levels in the background well, septic tank, and drain field wells.

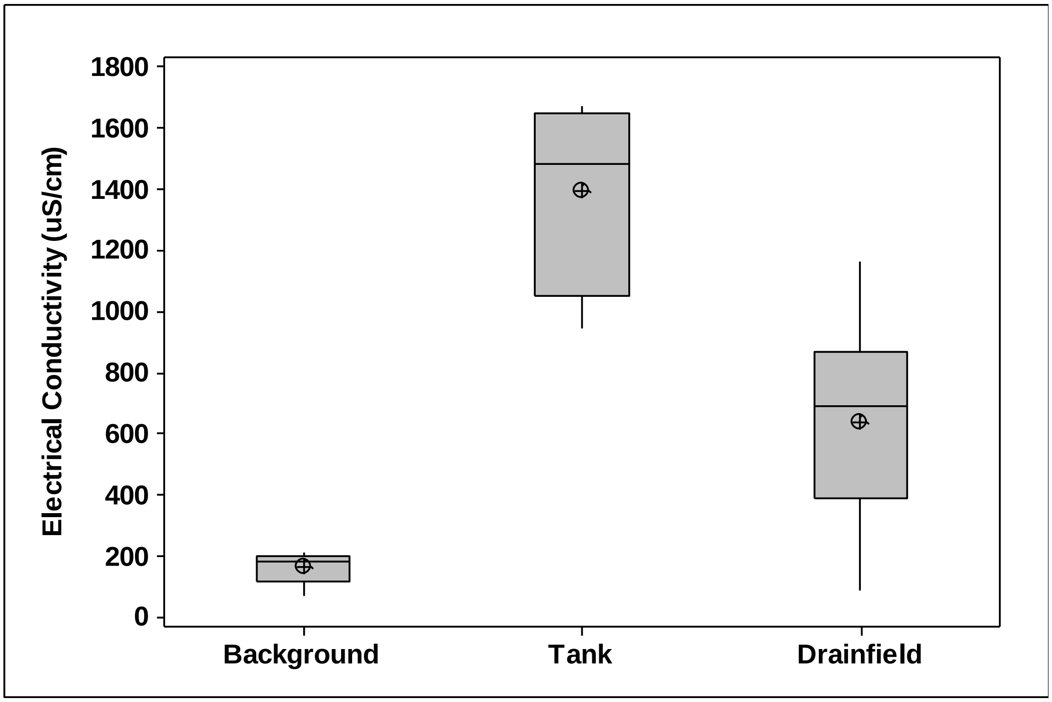

Figure 8. Box plots of the electric conductivity levels in the background well, septic tank, and drain field wells.

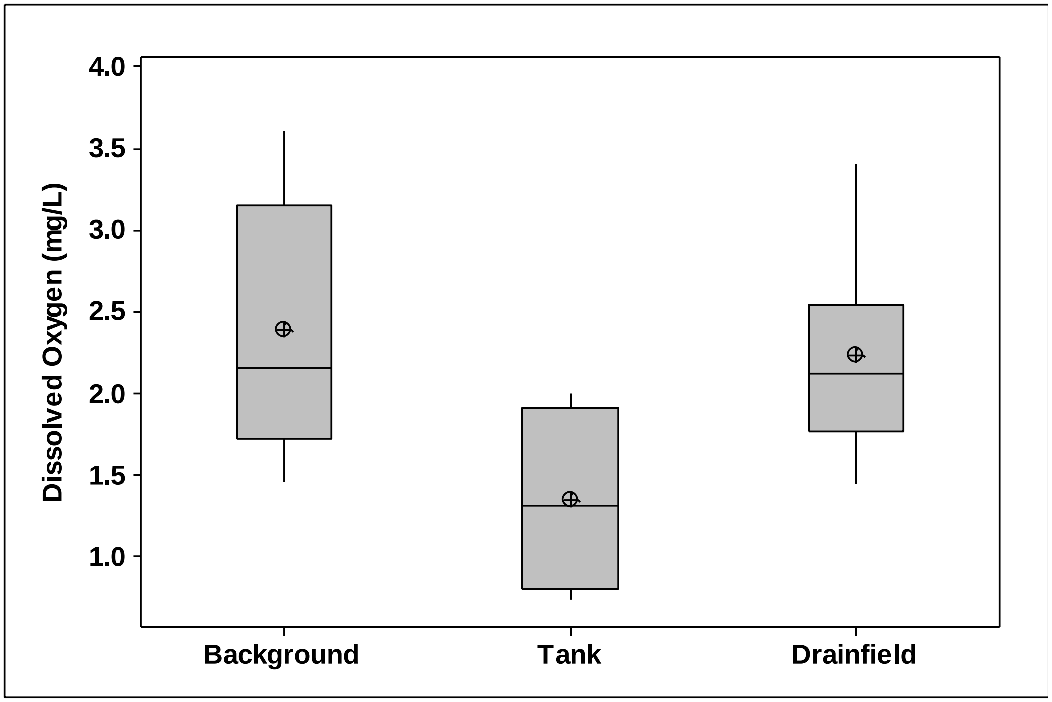

Figure 9. The standard deviation of the dissolved oxygen levels in the background well, septic tank, and drain field wells.

SUMMARY AND CONCLUSION

This study allowed for the treatment efficiency of an OSWWS to be observed through a groundwater-monitoring network. Over the course of four months, samples were collected to observe the pH, DO, EC and TDN of the tank and treatment drain field. Samples were also collected from a well up gradient of the drain field for direct comparison of groundwater.

From the tank to the drain field there was a decrease in TDN from 77.4 mg/L to 38.0 mg/L, a 49% nutrient reduction resulting from the OSWWS treatment. There was also a 46% decrease in the electrical conductivity and the pH of the wastewater decreased from 6.7 to 4.3 from the tank to drain field. The school's OSWWS is located in an area of sandy loam soils, and was determined to be a suitable drain field site. Coarse loam soils are deemed suitable for wastewater treatment by Environmental Health Specialists and a recent study done in eastern North Carolina expressed that the mean groundwater TDN concentrations for systems located in coarse loam soils were approximately 36.0 mg/L, similar to the groundwater TDN at the Oakwood site (Humphrey, Driscoll, & Armstrong, 2012). While the Oakwood site was slightly elevated compared to this study, the similar outcome shows consistency in the wastewater treatment of sandy loam soil profiles in the eastern North Carolina area.

A study done in late 1990's by Ramon Aravena and William Robertson used a large network of piezometers to characterize the NO_3 in the groundwater column resulting from septic systems at a campground at Lake Erie in southern Ontario, Canada. The piezometer nests allowed them to observe nitrogen readings at different levels within the water column showing the changes in nitrogen as it moved through the soil profile. The study expressed the significant NO_3 loading occurring in the sand aquifer being impacted by the septic systems. At three different collection sites, the piezometers averaged a nitrogen level of 52.3 – 58.8 mg/L in the coastal sandy soils (Aravena & Robertson, 1998). This system and the Oakwood system are both located in semi-sandy coastal soils and both experience a seasonal flux in the flow output. However the campground system has a higher nitrate level than what was observed at the school site.

Recently, Hinkle et al. (2008) completed a study that looked at the nitrogen transport through septic systems throughout two neighboring towns in Oregon. The samples collected showed that the septic tank effluent was almost entirely made up of reduced nitrogen. It was noted that dilution occurred as the effluent moved away from the drain field network reducing N readings. However nitrogen concentration within the drain field had a mean of 58.0 mg/L (Hinkle, Bohlke, & Fisher, 2008).

Potential Outcome Altering Contributions

When looking at the nitrogen in the drain field at Oakwood, compared to the background well, the TDN was elevated compared to the groundwater sample that had not been influenced by the OSWWS. There was a substantial reduction noted from the tank to the drain field. The system, installed in 2001, was designed to accommodate a maximum of 300 occupants at a given time. When the data was collected the enrollment was well above 300, at approximately 382 occupants.

While the sandy loam soils beneath the trench lines were deemed as a suitable soil group to use for treatment, the increase in occupancy results in an increased flow above what the system was designed. A system that exceeds the designed flow can potentially lead to the backup of wastewater into homes/buildings or into the drain field due to over saturation. Fortunately the school had not experienced either of those side effects.

One of the major potential contributions to a variable outcome is that the study area is a school whose tank effluent is a highly waste concentrated tank with minimal additional water. Oakwood is an independent school that operates at full capacity from the end of August through the last week of May and is a non-cafeteria school, resulting in no additional water being added to the tank. The summer months of June, July, and most of August have water flow being contributed to the septic system due to 12-month employees as well as summer camps, but the occupancy and flow rate drastically decrease in those months compared to the school year. In May, two sets of sample readings were taken resulting in a TDN average of 48.3 mg/L (May 16) and 37.8 mg/L (May 31), this is representative of treatment while student enrollment was still at its highest on campus. However, the following sample set taken on June 19 showed a slight spike in TDN averaging 38.7 mg/L.

Dilution of groundwater nitrogen could be a possibility due to rainfall. As rainfall percolates through the ground, the additional water will dilute the wastewater and can potentially dilute the concentration. On May 16th, the first readings were taken at the study site, and from May 16th to May 31st a decrease in

TDN was noticed from 48.3 mg/L to 37.8 mg/L. Within those fifteen days Greenville had approximately 4.5 inches of rain. The decrease in the TDN during that time period could be directly related to the increased rainfall during that short span of time. However, from May 31st to the June sampling series Greenville experienced approximately 4 inches of rainfall, but an increase in TDN was observed.

Nitrate Versus Ammonium Reduction

While the TDN reduction was substantial at 49%, it is interesting to look at the variation in ammonium and nitrate from the tank to the drain field. The nitrate in the tank averaged 7.82 mg/L with a concentration of 29.4 mg/L in the drain field after undergoing nitrification during treatment. While ammonium on the other hand, was the opposite with tank levels averaging 69.6 mg/L and a major reduction of 8.6mg/L in the drain field. The pH of the wastewater was reduced from 6.7 in the tank to 4.2 in the drain field, which is even lower than the pH of the water in the background wells. A study done by Robertson et al. (1991) has shown that as nitrification occurs, it can result in the lowering of pH from the tank to drain field (Robertson, Cherry, & Sudicky, 1991). The results from this study show that the pH levels in the drain field are lower than the tank and the background well. The electric conductivity of the wastewater from the tank to the groundwater plume at the Oakwood site is also consistent in its reduction from 1394.5 uS/cm (tank) to 636.5 uS/cm (drain field) as seen in the Roberton et al (1991) study as well.

Groundwater Effects

The study site results have shown a 49% reduction in the total dissolved nitrogen from the tank to the drain field. However, the samples used in the study were collected from monitoring wells directly adjacent to drain field lines. The 49% reduction is treatment that has occurred in this area but does not account for additional treatment the effluent will receive as it continues to move through the aquifer and away from the OSWWS towards the water sources. The nitrate readings were higher than the ammonium concentration in the drain field, and as discussed nitrates move readily with water. As nitrates move through the groundwater there is the potential that drinking sources can become contaminated with nitrates as well as pathogens. Nitrates moving through the soil profile can also enter into surface water outlets.

When evaluating the treatment efficiency of the Oakwood site and the potential groundwater effects the system could have, the location of the system must also be considered. There are no groundwater drinking sources in close proximity of the site and the drain field is approximately 321 meters from the closest stream, and over 3,000 meters (aerial measurement) from the Tar River. In addition to the distance from the OSWWS, the stream adjacent to the Oakwood site has a riparian buffer that adds additional water quality treatment; it has been shown that forested buffers along streams aid in reducing nitrate levels in groundwater by 61% (Schoonover & Williard, 2007).

Regulatory Needs

The Oakwood site does not seem to pose a great environmental risk. It is noted that this is an individualized scenario. When taking into account the amount of septic systems that are installed annually, it is easy to see that the potential for groundwater contamination is a growing threat. Within the Tar-Pamlico watershed alone there are 72,052 septic systems that contribute an estimated nitrogen loading of 1,758,866 lbs/yr (Pradhan, Hoover, Austin, & Devine, 2007). When looking at the state of North Carolina's regulatory focus for non-point source reduction, there is slight consideration taken into account for OSWWS. While there is a permit process for installation and repairs of systems, there are no additional regulatory guidelines in place to ensure that systems are functioning properly or to look at the nutrient load they are adding to the groundwater. Billions of gallons of wastewater effluent is released into the ground every year, calling for an immediate need for additional regulatory compliance and review standards to monitor this nutrient release. Non-point source pollution reduction standards have been put into place for stormwater treatment, agricultural nutrient practices, as well as, municipal/industrial wastewater treatment. In order to continue water quality improvement, standards are needed to meet the reduction of nutrient loading related to onsite wastewater systems.

Oakwood Site Update

In September 2013, The Oakwood School applied for an improvement permit to for an additional OSWWS to be installed to bring the current OSWWS back into compliance with the original designed flow rate. The school was granted the permit and moved forward with the installation of a 3,300-gallon tank, and a 2,500-gallon pump tank, allowing an estimated flow of 2,880 gallons per day. This additional OSWWS will relieve the pressure of the old system that was running above capacity.

The OSWWS was installed in late September, allowing the school the capability to accommodate an enrollment up to 450 occupants. The OSWWS repair was installed as a separate system and will service a portion of the school, reducing the loading rate of the old system. With a current enrollment of 387, the OSWWS is now at a properly functioning design rate, with room for future growth. The addition of an OSWWS may result in the performance improvement of the old system due to the wastewater flow reduction. The large campus allowed for the new OSWWS site to be installed in a location that has no drinking water sources nearby, and is significantly distanced from nearby creeks and streams.

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