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# Transport of Indicator Microorganisms from an Onsite Wastewater System to Adjacent Stream

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## Abstract:
**The objective of this study was to determine the effectiveness of a residential onsite wastewater treatment system (OWS) in reducing E. coli and enterococci concentrations. Groundwater wells were installed upgradient and downgradient of an OWS. Samples were collected from the septic tank, wells, and adjacent stream 4 times and analyzed for E. coli and enterococci concentrations, and for pH, electrical conductivity, dissolved oxygen and temperature. The OWS reduced E. coli concentrations by more than 99% and enterococci concentrations by 37%. Groundwater downgradient from the OWS had elevated pH, electrical conductivity and microbial concentrations relative to groundwater upgradient from the OWS. The treatment efficiency of the OWS at this site could be enhanced if the drainfield trenches were elevated to provide a thicker vadose zone.**

**Keywords:** onsite wastewater, E. coli, enterococci, water quality

## 1. Introduction:
Human wastewater contains elevated concentrations of pathogenic microorganisms including various bacteria, viruses, and protozoa (US EPA, 2002; Lowe et al., 2007). Onsite wastewater treatment systems (OWS) are used by residences and businesses in rural areas where municipal sewer service is not available. Most OWS have 3 basic components including a septic tank, drainfield trenches, and soil beneath the trenches. The septic tank provides primary treatment via sedimentation and anaerobic digestion of organic matter, the drainfield trenches store liquid effluent until infiltration in soil occurs, and soil beneath the trenches provides most of the physical and chemical wastewater treatment via physical filtration, adsorption, and dilution. Because it would not be economically feasible to test groundwater and surface waters near OWS for all pathogenic organisms, indicator microorganism are often used to determine OWS treatment efficiency. The US EPA (2012) suggests the use of enterococci and/or *E. coli* as microbial indicators of pathogens in freshwaters, because of the strong correlation between human illness and certain concentrations of these indicators. The US EPA recommends that surface water concentrations of *E. coli* and enterococci should not exceed geometric means of 126 and 35 cfu/100mL, respectively, and no more than 10% of samples should exceed 130 cfu/100mL enterococci and 410 cfu/100mL *E. coli* (US EPA, 2012). Domestic wastewater contains *E. coli* and Enterococci concentrations that often exceed these standards by an order of magnitude or greater (Humphrey et al., 2011; Conn et al., 2011). If OWS are not effective at reducing microorganism concentrations before wastewater effluent enters groundwater, then groundwater and adjacent surface water may be negatively affected (Scandura and Sobsey, 1997; Cahoon et al., 2006; Humphrey et al., 2011; Conn et al., 2011; Humphrey and O'Driscoll, 2012). The objective of this study was to evaluate the effectiveness of a residential OWS in reducing *E. coli* and enterococci concentrations before reaching adjacent surface waters.

## 2. Methods:

Groundwater monitoring wells were installed upgradient and downgradient from a volunteered, residential OWS in Pitt County, NC (Figure 1). Monitoring wells were installed using soil augers, and were constructed with 2.54 cm solid PVC coupled to well screen. The OWS included a 3780 L capacity septic tank and a drainfield area with 6 trenches that were approximately 21 m in length. The OWS has been in use since 1998, and had 4 occupants during the study. Septic tank effluent samples, groundwater samples from the wells, and stream samples were collected on four different occasions between September 2012 and March 2013 using disposable bailers. During one sampling event after a heavy rain, effluent from the drainfield was surfacing and flowing overland into the creek. The overflow was also sampled for microbial indicators. The IDEXX *Colilert* and *Enterolert* methods were used for *E. coli* and enterococci enumeration of samples in the Environmental Health Sciences Waters Laboratory at East Carolina University, Greenville, NC. An YSI 556 mulitimeter was used to determine sample pH, temperature, dissolved oxygen, and electrical conductivity in the field.

Concentrations of *E. coli* and enterococci in wastewater were compared to groundwater samples collected downgradient of the OWS to determine the treatment efficiency of the OWS. Groundwater samples downgradient of the system were also compared to groundwater samples upgradient of the system to determine if there were statistically significant differences. Wastewater and groundwater samples were also compared to stream samples. A Mann Whitney test with *Minitab 16* statistical software was used to determine if the differences were significant. The same comparisons were made for pH, DO, and electrical conductivity to determine if the OWS was influencing the physical and chemical properties of groundwater. Concentrations of *E. coli* and enterococci were log transformed and compared using Pearson's Correlation test with *Minitab 16* software, to determine if there was a significant correlation between *E. coli* and enterococci concentrations.

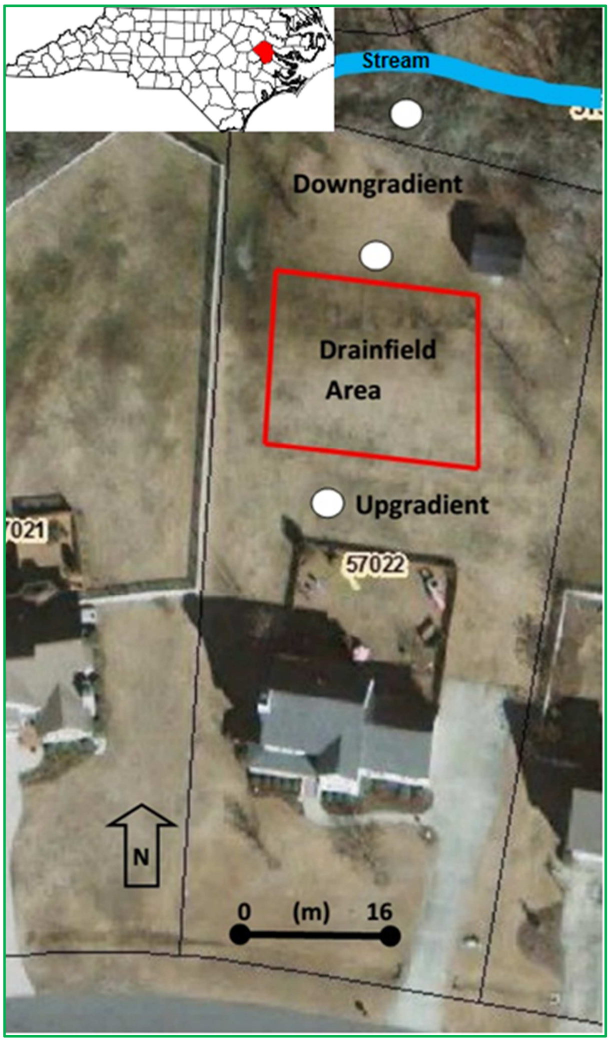


**Figure 1.** Research site in Pitt County, NC including the drainfield area (enclosed in red box), monitoring wells (white circles) installed upgradient and downgradient from the drainfield, and the stream (blue line).

## 3. Results and Discussion:

Wastewater samples from the septic tank contained the highest geometric mean *E. coli* (257,765 cfu/100 mL) and enterococci (3,369 cfu/100mL) concentrations of all sampling locations (Figure 2 and 3). Septic tank samples had significantly ($p \leq 0.05$) higher *E. coli* concentrations than all other sampling locations, and significantly higher enterococci concentrations than groundwater samples upgradient from the system ($p = 0.013$) and stream samples ($p = 0.027$). Groundwater samples collected downgradient from the OWS had elevated geometric mean *E. coli* (312 cfu/100 mL) and enterococci (2118 cfu/100 mL) concentrations relative to groundwater samples collected upgradient from the system (*E. coli*: 29 cfu/100mL; enterococci: 318 cfu/100mL). The stream had lower geometric mean enterococci concentrations than the groundwater samples, but higher geometric mean *E. coli* concentrations (431 cfu/100 mL) than the groundwater samples. All sample locations had more than 10% of samples exceed the statistical threshold values for *E. coli* and enterococci, recommended by the US EPA.

After log transforming all *E. coli* and enterococci data, and conducting a Pearson's correlation test using Mintab 16, a significant positive correlation ($\rho=0.52$; $p = 0.018$) between *E. coli* and enterococci concentrations was observed. Overall, *E. coli* was more abundant in the septic effluent and stream, while enterococci were more abundant in groundwater.

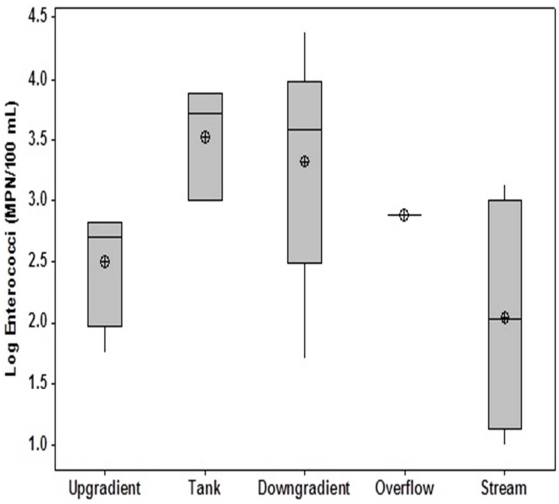


**Figure 2.** Enterococci concentrations in groundwater, wastewater and the stream.

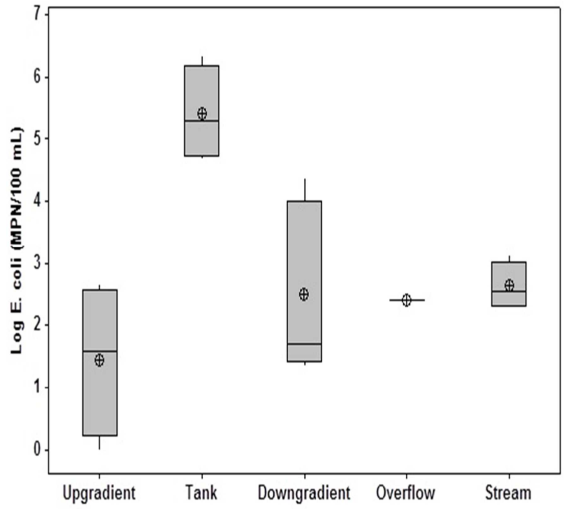


**Figure 3.** E. coli concentrations in groundwater, wastewater, and the stream.

Wastewater from the septic tank had the highest mean electrical conductivity (855 ± 183 uS/cm), followed by groundwater downgradient from the system (326 ± 132 uS/cm), groundwater upgradient from the system (181 ± 44 uS/cm) and the stream (150 ± 19 uS.cm) (Table 1). Dissolved oxygen concentrations were typically lowest in the septic tank (0.4 ± 0.1 mg/L) and groundwater downgradient from the system (1.5 ± 0.5 mg/L) relative to groundwater upgradient from the system (2.8 ± 0.9 mg/L), and in the stream (7.4 ± 0.3 mg/L) (Table 1). Mean pH was highest for wastewater (6.5 ± 0.2), and groundwater downgradient of the system had mean pH levels (6.2 ± 0.2) higher than groundwater upgradient from the system (5.0 ± 0.6). Sample temperature was less variable for wastewater (standard deviation of 4.6° C) and most variable for stream water (standard deviation of 8.0°C).

**Table 1.** Physical and chemical properties of groundwater, wastewater and surface water.

| Location | Temp (C°) | EC (uS/cm) | DO (mg/L) | pH |
|---|---|---|---|---|
| Upgradient | 18 (5.5) | 181 (44) | 2.8 (0.9) | 5.0 (0.6) |
| Tank | 18.4 (4.6) | 855 (183) | 0.4 (0.1) | 6.5 (0.2) |
| Downgradient | 17.8 (5.9) | 326 (132) | 1.5 (0.5) | 6.2 (0.2) |
| Stream | 14.6 (8.0) | 150 (19) | 7.4 (0.3) | 6.4 (0.1) |

The OWS at the study site reduced wastewater *E. coli* concentrations by more than 99% and enterococci concentrations by 37% before reaching adjacent surface waters. However, geometric mean *E. coli* and enterococci concentrations were still elevated in groundwater downgradient from the OWS in relation to recommended water quality standards. Also, during one sampling event, wastewater was flowing above the ground surface from the drainfield to the creek contributing 776 cfu/100 mL enterococci and 261 cfu/100 mL *E. coli* directly to the stream. Therefore, the OWS was influencing groundwater and adjacent surface water with regards to microbial indicators. Stream *E. coli* and enterococci concentrations were also elevated relative to EPA standards, even during sampling events when wastewater was not flowing overland. There are likely other sources of bacteria (especially *E. coli*) such as wildlife contributing to the elevated stream counts.

The OWS was also influencing the physical and chemical properties of groundwater downgradient from the system. More specifically, the OWS increased groundwater electrical conductivity and pH, and lowered the dissolved oxygen concentrations. The performance of the OWS at this site could possibly be enhanced by the addition of fill material and elevation of the trench bottom area. Prior studies have shown that vadose zone processes are important for bacteria treatment (Habteselassie et al., 2011; Humphrey et al., 2011; Humphrey and O'Driscoll, 2012), and that elevating OWS drainfield trenches to improve aeration can be beneficial for microbial reduction (Conn et al., 2011).

## 4. Conclusions:

Groundwater downgradient from the OWS in this study contained concentrations of *E. coli* and enterococci that exceeded recommended levels. Stream samples were also elevated, possibly because of the contributions from this OWS and others in the watershed, and from wildlife. The treatment efficiency of the OWS could be improved by elevating the system and providing a larger vadose zone. More work is suggested in identifying other contributing sources of bacteria to the stream.

## 5.Acknowledgements:

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