Preliminary Assessment of Nitrogen Concentrations in Groundwater at a Swine CAFO in Eastern North Carolina

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ABSTRACT

North Carolina is one of the leading producers of pork products in the nation. Most swine are grown at concentrated animal feeding operations (CAFOs) in the eastern part of the state. Swine waste swine is stored in lagoons and irrigated onto agricultural fields, typically planted with hay. Swine waste is enriched with nitrogen which stimulates crop and plant growth. However, if excessive amounts of nitrogen leave the farm via runoff, groundwater transport, or volatilization, there can be detrimental environmental and human health outcomes. The effectiveness of the lagoon-spray field wastewater management strategy in reducing nitrogen exports from CAFOs has not been extensively studied. This research is being conducted to determine the concentrations of nitrogen in wastewater and groundwater beneath and near the spray fields at a CAFO in Lillington, NC. The farm is located within the Cape Fear River Basin, with an estimated 1,200 permitted CAFOs. Piezometers were installed at ten locations for groundwater sample collection and analyses including the up-gradient of a spray field, within a spray field, and in a riparian buffer down-gradient from a spray field. Samples were collected monthly between July and October 2023, and analyzed for Total Dissolved Nitrogen (TDN). The results show that the median TDN concentration in wastewater from the lagoon was 2182.05 mg/L, while the background groundwater had a median TDN concentration of 1.07 mg/L, and groundwater beneath the spray field was 12.49 mg/L. Therefore, preliminary results suggest that wastewater irrigated onto the spray fields was influencing the TDN concentration in groundwater.

INTRODUCTION

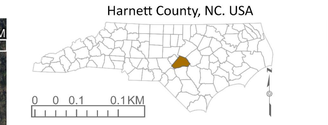
- North Carolina has the 3rd highest number of registered CAFOs across the US (USDA, 2022), with most of these hogs being produced in Eastern NC.
- Swine waste contains elevated concentrations of organic matter, nitrogen, phosphorus, solids, pathogens, odorous volatile compounds, trace elements, and chemicals of concern (Bernet and Béline, 2009, Choi, 2007).
- Swine waste is typically managed via open waste lagoons and spray fields (soil and cropping systems) but the efficiency of the lagoon/soil/crop system in reducing nitrogen concentrations has not been extensively researched.
- Excess nitrogen in the environment may stimulate eutrophication and lead to emergence of harmful algal blooms, fish kills, and public health concerns.
- Examples of adverse impacts on human health related to excess nitrogen include methemoglobinemia and various cancers.
- Some waste lagoons are covered by synthetic liners to reduce odor complaints from neighboring properties and to reduce atmospheric emissions of volatile compounds. There has been less research regarding the TDN treatment efficiency of the covered lagoon/soil/cropping system in comparison to uncovered lagoon waste/soil/cropping strategy.
- The goal of this study is to monitor concentrations of TDN in wastewater from a covered lagoon, groundwater beneath spray fields, groundwater in a riparian buffer between spray fields and a creek, and groundwater up-gradient from the farm. This will allow an estimate of TDN treatment efficiency of the waste management system.

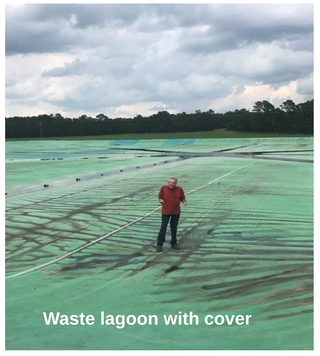
MATERIALS & METHODS

- Piezometers (n =10) were installed in locations including within spray fields, a riparian buffer down-gradient of a spray field, and in a location up-gradient from the farm (background).
- Waste samples from the lagoon and groundwater samples from the piezometers were collected once per month (July 2024 to October 2024).
- Depth to groundwater at each piezometer was measured using a *Solinst* TLC meter prior to collecting groundwater samples.
- Piezometers were purged using bailers and allowed to recharge.
- *A Hanna Instrument 9829* multiprobe meter was used in the field to measure physicochemical parameters including pH, specific conductance (SC), temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), of water and wastewater samples.
- Groundwater samples were transferred from the bailer to polypropylene bottles, labeled with the sampling location and date.
- The sample bottles were submerged in an iced cooler and transported to laboratories at East Carolina University for preparation and anlalyses.
- The samples were filtered using a vacuum filter and 1.5- and 0.7-micron Whatman glass microfiber filter paper. The filtrate was analyzed by a KPM Analytics SmartChem 170 or 200 discrete auto-analyzer for nitrate and ammonium and a Total Organic Carbon and Total Nitrogen.

MATERIALS & METHODS

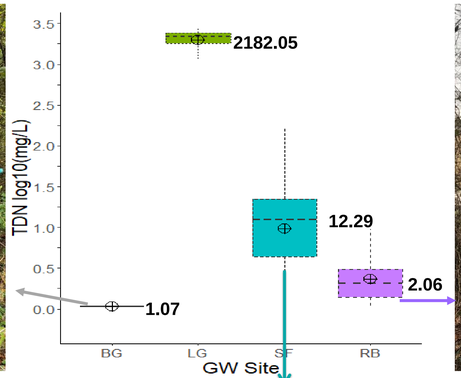
A map showing the reference points where samples were collected on the farm. These are generalized as Groundwater (GW), Surface water(SW) and Lagoon (LG).





Wastewater from the covered lagoon was sampled, and monitoring wells were installed to allow for collection of groundwater samples in various locations across the farm.

RESULTS & DISCUSSION



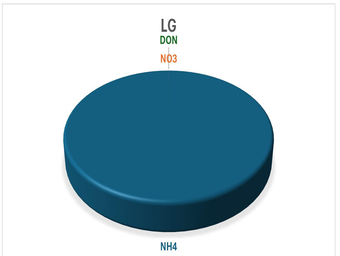
- The median concentration of TDN in groundwater beneath the spray field (12.29 mg/L) was 99% lower relative to wastewater in the lagoon (2182.05 mg/L)
- The median concentration of TDN in groundwater beneath the riparian buffer (2.06 mg/L) was 83% lower relative to groundwater beneath the spray field (12.29 mg/L), but still elevated in comparison to background groundwater (1.07 mg/L).
- The covered lagoon/soil/cropping system was efficient at lowering concentrations of TDN but was still causing relatively high concentrations of TDN in groundwater.

- Lagoon wastewater had the highest mean pH (7.74), temperature (26.06 °C), and specific conductance (13,042 µS/cm) and lowest mean oxidation reduction potential (-259.0 mV) and dissolved oxygen concentration (0.31 mg/L).
- Conversely, groundwater within the riparian buffer had the lowest mean pH (5.77), temperature (21.51 °C), and specific conductance (192.3 µS/cm) and highest mean oxidation reduction potential (75.9 mV) and dissolved oxygen (3.11 mg/L).
- Groundwater beneath the spray field had intermediate values of all the physicochemical parameters.

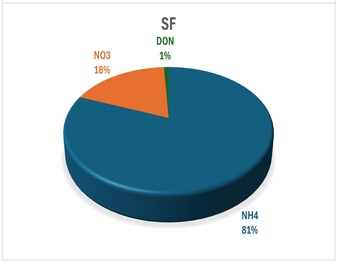
Table1: Shows mean and standard deviation for the physiochemical parameters such as DTW – Dept to water, Temperature – Temp, Specific Conductance – SC, Oxidative Redox Potential – ORP, Dissolved Oxygen – DO, and pH

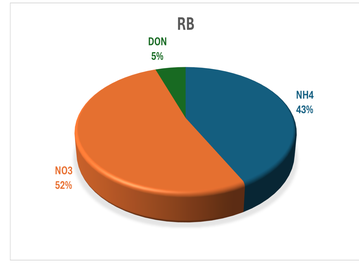
Location	DTW (ft)	Temp (°C)	SC (µS/cm)	pH	ORP (mV)	DO (mg/L)
SF	2.77(1.98)	23.88 (2.46)	435.5 (220.78)	5.99 (0.76)	10.9 (114.9)	1.80 (1.38)
RB	2.93(1.33)	21.51(1.67)	192.3 (47.1)	5.77(1.13)	75.9 (90.1)	3.11 (2.12)
LG	N/A	26.06 (4.92)	13042.5 (2015.7)	7.74(1.02)	-259.0 (56.7)	0.31 (0.24)

RESULTS & DISCUSSION



The dominant species of dissolved nitrogen in wastewater from the lagoon and groundwater in the spray field was NH4, while NO3 was dominant in groundwater within the riparian buffer. Conversion of NH4 to NO3 (nitrification) is an important step to removing NO3 mass via denitrification (conversion of NO3 to N2). Both NH4 and NO3 can be immobilized via plant and microbial uptake.





Speciation of total dissolved nitrogen (TDN) in groundwater and swine waste from the lagoon (LG). The GW locations sampled include background (BG), spray field (SF) and riparian buffer (BF).

CONCLUSIONS

- The median concentration of TDN was greatest for wastewater sampled from the lagoon (2182 mg/L), followed by groundwater sampled from the spray field (12.29 mg/L), groundwater within the riparian buffer (2.06 mg/L), and background groundwater (1.7 mg/L).
- The median concentration of TDN was significantly higher in wastewater sampled from the lagoon in comparison to groundwater sampled in the riparian buffer ($p = 0.02851$), the spray field ($p = 0.00033$), and background groundwater ($p < 0.0001$).
- Groundwater sampled in the riparian buffer had significantly ($p = 0.02851$) lower concentrations of TDN relative to groundwater sampled within the spray field, suggesting nitrogen concentration reductions mechanisms (e.g., denitrification, immobilization, dilution) were active in the buffer.
- While the covered lagoon/soil/cropping system was efficient, the median TDN concentration in the spray field of 12.29 mg/L is relatively high and a cause for environmental and public health concern.
- The concentration of NH4 in wastewater sampled from the covered lagoon is higher relative to wastewater sampled from uncovered lagoons, possibly because of less volatilization of ammonia.
- More research is suggested to evaluate the overall TDN removal efficiency of CAFOs using soil/cropping systems with covered in comparison to uncovered lagoons.

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