Evaluating nitrate sources in Suffolk County groundwater, Long Island, New York

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Abstract of the Thesis

Evaluating nitrate sources in Suffolk County groundwater, Long Island, New York

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The purpose of this study is to asses the sources of nitrate in Suffolk County groundwater and to constrain the dynamics of nitrate leaching below turfgrass sites. Major and minor elements that accompany nitrate in the groundwater may distinguish between nitrate sources in residential areas. I characterized the geochemistry of soil water samples collected monthly from below eight turfgrass sites where natural organic fertilizer, traditional chemical fertilizer or no fertilizer were used and wastewater from residential septic tanks/cesspools and sewage treatment plants samples that were acquired from Suffolk County Public Works. Binary and ternary plots of the elements Na, Mg, Ca, SO_4, N-NO_3 and Cl proved useful as nitrate tracers. Groundwater sourced in (1) vacant or open land use show a signature very close to rain water (2) low residential density land use are mostly influenced by rain water with some contributions of soil water and wastewater and (3) medium residential density land use plot as a mixture of rain, soil water and wastewater. The plots used in this study do not distinguish agricultural land use from nitrate associated with urban land use.

Soil water samples collected below the root zone of turfgrass sites were analyzed for nitrogen as nitrate to understand nitrate leaching on Long Island. The N-NO_3 concentration in soil water is dependent on the age of the turfgrass system (soil organic matter content), infiltration rate, thatch thickness, timing of fertilizer and precipitation but did not depend on whether natural organic or traditional chemical fertilizer was used.

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I. Introduction

Awareness of nitrate contamination of Long Island groundwater initiated with publications by the Unites States Geologic Survey (Perlmutter and Koch, 1972; Perlmutter et al., 1964; Ragone et al., 1976), State of New York Dept. of Health (Flynn et al., 1969; Smith and Baier, 1969) and the Long Island Regional Planning Board (Koppelman, 1978; Koppelman et al., 1984) and became a reality in Nassau County when wells were abandoned due to high nitrate concentrations. The Environmental Protection Agency (EPA) has set the maximum level of nitrogen as nitrate in drinking water as 10 ppm. Young infants who consume water with greater than 10 ppm nitrogen as nitrate may develop blue baby syndrome, or methemoglobinemia. Nitrate in the immature digestive system of a young infant may be converted to nitrite. Nitrite interacts with hemoglobin in red blood cells reducing the amount of oxygen transported to the body's cells and tissues. Health effects of nitrate consumption on adults and children are inconclusive (Weyer, 1999).

Organic nitrogen and nitrogen oxides (1) are found naturally in soil where they are produced from decayed organic matter and fixation by some bacteria, (2) enter the soil with rain, (3) leach from landfills, (4) are present in storm water runoff, (5) leak from sewer lines, (6) are in leachate from cesspools and (7) are applied as fertilizer to landscapes for turfgrass and agricultural fields. Once in the soil, microorganisms may convert the various forms of nitrogen to ammonium (NH_4) or nitrate (NO_3). Ammonium is quickly converted to nitrate or adsorbed to soil particles. Due to its negative charge NO_3 is more prone to leaching than NH_4.

Groundwater is the sole source of potable drinking water for Suffolk County. Land use changes from agricultural land to residential land use began in the mid 1900's with eastward urbanization from New York City. With changing land use an understanding of sources of nitrate contamination is desirable. The major sources of the nitrate in residential areas are most likely turfgrass fertilizer and sewage from septic tank/cesspool systems and sewage treatment plants. Some sewage treatment plants provide tertiary treatment that reduces nitrate content of the effluent to less than 10 ppm nitrogen as nitrate. Recent modeling efforts (CDM, 2003) by the Source Water Assessment Project (SWAP) have characterized capture zones, travel time and land use data for approx. 1000 wells in Suffolk County. This study provided the needed tool for understanding how land use affects nitrate concentrations in groundwater. SWAP determined that 2% of 1000 wells exceeded the 10 ppm nitrogen as nitrate limit and 8% had between 6 to 10 ppm nitrogen as nitrate. When assessing susceptibility of Suffolk County municipal supply wells for nitrate contamination 62% had a rating of high susceptibility and 4% had a rating of very high susceptibility. Susceptibility takes into account prevalence, or occurrence and concentration, and sensitivity, or mobility, based on land use and travel time.

i. Description of Study Area

Suffolk County is the eastern most county on Long Island (Figure 1), covering 912 square miles of land. Population in 2001 was 1.4 million. The near surface sediments on Long Island are dominated by glacial deposits (Fuller, 1914). Underlying the glacial deposits are

Figure 1
Map showing area of study, Suffolk County, which is located on Long Island in New York State

Cretaceous sediments. In Suffolk County bedrock slopes 1^{o} to the southeast and is several hundred feet below the surface on the north shore and a couple thousand feet below the surface along the south shore.

The aquifers on Long Island are glacial and Cretaceous unconsolidated sands, gravels, silts and clays (Figure 2, (Kimmel, 1984)). Fine grained, well drained loam formed on Wisconsinan loess overlying the glacial sediments. Sandy, coarse textured, poorly drained soils

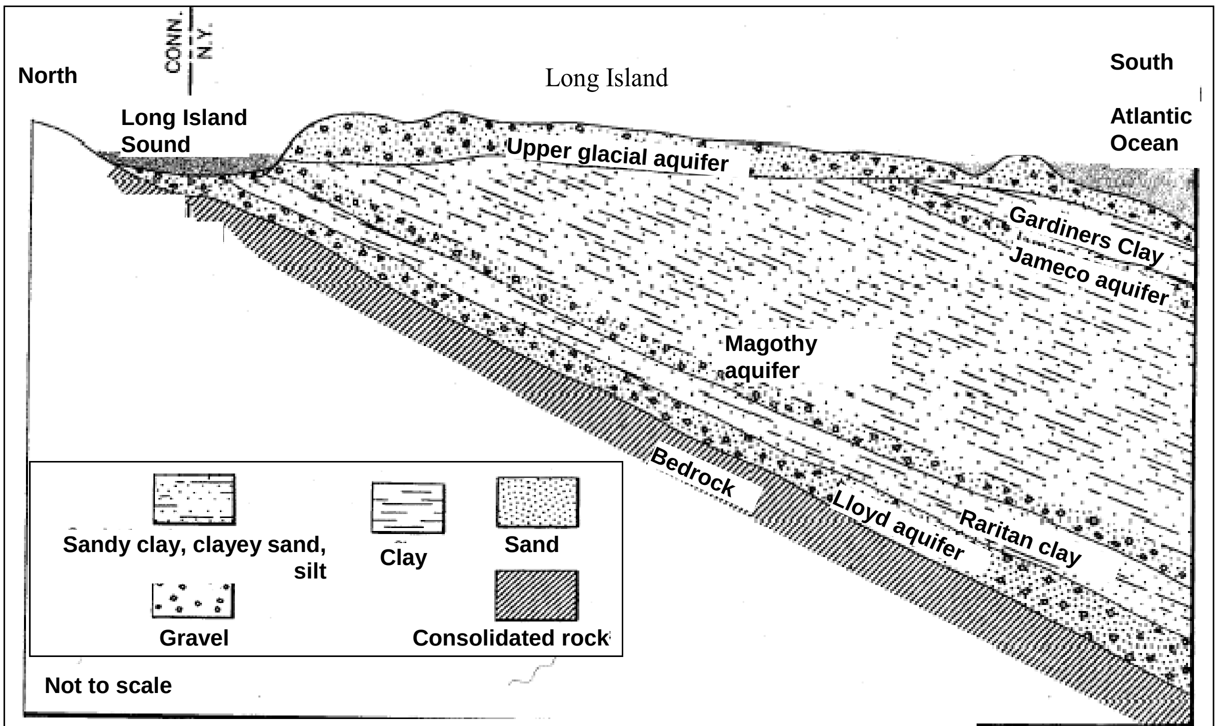

Figure 2 Hydrogeology of Suffolk County (Kimmel, 1984)

formed on glacial outwash. With development in Suffolk County much of the original soil series have been converted to cut and fill land. Cut and fill land is land that has been altered for non farm purposes to a degree so that the original soil series is unidentifiable (Warner, 1975). Long Island receives on average 44 inches of rain annually (Koppelman, 1978). Half of the precipitation recharges to groundwater, about 1,130 million gallons of water per day in Suffolk County. The majority of water served to Suffolk County Water Authority customers comes from the Magothy Aquifer. This water is greater than 1,000 years old in its deepest aquifer underlying the south shore (Buxton and Modica, 1992).

ii. Nitrate Sources

Main sources of nitrate in groundwater in developed areas of Suffolk County are turfgrass fertilizers and wastewater via septic tank/cesspool systems and discharge from sewage treatment plants (Flipse et al., 1984; Kimmel, 1984). Farming was extensive on Long Island before World War II but since then development has spread eastward from New York City, and a high proportion of the land is now used for residential purposes. In 1981 turfgrass occupied 25% of Suffolk County (Koppelman et al., 1984), either as golf courses, parks and residential or commercial lawns. Suffolk County Water Authority estimates 21 million gallons/day, or 30% of the water pumped is used for the sole purpose of lawn irrigation (Written Communication, Michael Stevenson Suffolk County Water Authority, 2003). Nitrogen is a major nutrient needed to keep turfgrass healthy and green.

About two-thirds of the population (Allee et al., 2001) in Suffolk County disposes of wastewater through septic tank/cesspool systems. A typical rural home in Colorado yields 44.5 gallons of sewage/day/person (Bennett et al., 1974). Flynn et al. (1969) monitored 4 septic systems in Suffolk County and reported effluent values from 775-3130 gallons/week. Individual water usage can vary from 26-84 gallons/person/day (Wayland and Oppelt, 2002). The 2000 census bureau reported 522,323 housing units in Suffolk County. Using the average discharge (Flynn et al., 1969) of 1690 gal/week or 241gal/day and if all the homes reported in 2000 operated on septic tank/cesspool systems the total discharge is 126 million gallons/day (MGD) from septic tank/cesspool systems in Suffolk County. Since 2/3 of the housing units operate on septic tank/cesspool systems this number is closer to 84 MGD. Values from Flynn et al. (1969)

were used in this calculation since the study was specific to Suffolk County, water usage may have decreased since then due to water saving appliances.

Public and private sewage treatment plants in Suffolk County yield 70 MGD (Heath and Cohen, 1966). Using flow rates reported on the Environmental Protection Agency web site for 172 treatment plants in Suffolk County yielded 24 MGD for sewage treatment plants discharging to groundwater and 48 MGD discharging to surface waters. This calculation equals the value reported in Health and Cohen, 1966, but shows that most of the effluent is discharged to surface waters. Essentially all plants perform at least secondary treatment of waste and some provide tertiary treatment that reduces the nitrate content of the effluent to less than 10 ppm nitrogen as nitrate. A majority of these plants are relatively small and dispose their effluent to the groundwater while less than 15% discharge to surface waters including Long Island Sound and the Atlantic Ocean. Most sewage treatment plants that discharge to groundwater serve a limited clientele such as a housing community, a shopping mall, a college, a nursing home or a small community (Oral Communication, Chris Biemiller Suffolk County Public Works, 2003). Table 1 summarizes recharge values to groundwater as described above. Water used for irrigation is a maximum value since most of the water used for turfgrass irrigation evaporates or transpires.

Table 1: Recharge to groundwater

Infiltration Source	Million gallons per day
Precipitation	1,130
Septic tank/cesspools	84
Sewage treatment plants	24
Water used for irrigation	21

Previous researches have quantified nitrogen loads to Long Island groundwater. Koppelman (1978) reports initial nitrogen loads in 1975-1976, of 8500 tons/yr from septic tanks/cesspools, 200 tons/yr from sewage treatment plants that discharge to groundwater, 9300 tons/yr from turfgrass fertilizers and 4000 tons/yr from rain. Porter (1980) reported values in Nassau County of 4.5 lbs. nitrogen per person from septic tank/cesspools, or 3000 tons/yr and 1.46 lbs. fertilizer nitrogen per 1000 sq. ft, or 4200 tons/yr. Kimmel (1984) reports that 5200 tons (52%) of the nitrogen load to Long Island groundwater is from lawn fertilizers. Nitrogen loading calculations suggest that more than 50% of the nitrate in residential groundwater in the Northport area may be derived from turfgrass cultivation. The $\delta^{15}N_{nitrate}$ values (Bleifuss et al., 2000) of residential monitoring wells supports this conclusion. However enriched $\delta^{15}N$ measurements (Kreitler et al., 1978) from multiple samples in the Upper Glacial aquifer in Suffolk County indicate the nitrate source can't be solely from fertilization. Kreitler et al. (1978) concluded that groundwater nitrate does not appear to result from direct leaching of nitrate fertilizers to the water table but must be influenced from increased septic-tank contributions.

iii. Research Objectives

The purpose of this study is to determine the proportions of nitrate derived from residential sources in Suffolk County groundwater. The assumption is that most nitrates in groundwater are derived from wastewater effluent of septic tanks/cesspools, soil water influenced by turfgrass fertilizer and rain. Previous researchers have used nitrogen isotopes to determine sources of nitrate but this approach can be problematic due to subsurface fractionation and source signature overlap (Bleifuss et al., 2000; Flipse and Bonner, 1985; Flipse et al., 1984; Kreitler et al., 1978). Some studies have shown that major and minor elements that accompany nitrate in the groundwater may distinguish between sources (Bleifuss et al., 2000; Elhatip et al., 2003; Renyolds, 1994; Thomas, 2000; Trauth and Xanthopoulos, 1997; Wayland et al., 2003) but few studies determined the major and minor element composition of the sources themselves.

This study intends to characterize the source signatures of wastewater from septic tanks/cesspools and sewage treatment plants and soil water collected below turfgrass sites that are fertilized with natural organic fertilizer, chemical fertilizer or not fertilized. The investigation will use binary plots of Na, Mg, Ca and SO_4 versus N-NO_3 normalized to Cl as well as a ternary and binary diagrams of Cl, N-NO_3 and SO_4 to place constraints on the fraction of mixing for each nitrate source for a given groundwater and verify mixing fractions using mass balance equations (Langmuir et al., 1978). It is expected that using a conservative element such as Cl will minimize dilution affect of the sources by the groundwater. Using a mix of conservative elements such as Cl, N-NO_3 and SO_4 should yield the most accurate depiction of the sources since the elements in the source signature will only be affected by dilution. Elements such as Na, Mg and Ca will tend to adsorb onto the aquifer material and be utilized by the plants. Results from Bleifuss et al. (2000) showed that positively charged ions can be used to accurately asses nitrate sources in Long Island.

Previous work has shown that lawn fertilizers contribute a significant fraction of the non-point source nitrogen load to Long Island groundwater (Bleifuss et al., 2000; Flipse and Bonner, 1985; Flipse et al., 1984; Kimmel, 1984; Koppelman, 1978; Koppelman et al., 1984; Porter, 1980). It is important to determine the fate of nitrogen applied to turfgrass systems to understand how to minimize its affect on groundwater quality. Nitrogen applied as fertilizer to turfgrass is converted to nitrate in the subsoil and that not used by the plants will leach to the groundwater. The goal of this study is to determine if nitrogen as nitrate concentrations will be higher in soil water collected below sites that are treated with natural organic fertilizer or traditional chemical fertilizer. Lysimeters, soil water samplers, are installed below the root zone at eight turfgrass sites so that soil water can be collected monthly and analyzed for nitrogen as nitrate concentrations. Two of these sites are treated with traditional chemical fertilizer, five sites are maintained by a natural organic landscaper and one site receives no treatment.

Studies have shown that increases in $N\text{-}NO_3$ leaching is a function of (1) soil texture (2) application rate of fertilizer (3) infiltration (4) turfgrass age and (5) the seasons (Bergstrom and Johansson, 1991; Easton and Petrovic, 2004; Engelsjord and Singh, 1997; Geron et al., 1993; Hummel and Waddington, 1984; Petrovic, 1990; Roy et al., 2000; Schuchman, 2001; Shaddox and Sartain, 2001; Starr and Deroo, 1981; Wong et al., 1998). Most studies of turfgrass systems have similar plots and change only one variable to determine a specific effect on nitrate leaching. This study's goal is to understand the current turfgrass environment on Long Island which included sites of variable characteristics. Site and soil properties that have influenced nitrate leaching in other studies will be quantified for all eights sites. This includes infiltration rate, age of turfgrass, thatch thickness, soil organic matter (SOM), grain size distribution, porosity, rate and timing of fertilization and monthly precipitation totals.

Nitrate leaching from January to December 2003 will be compared between (1) the two traditional chemical fertilized sites (2) two plots as the same location; one treated with traditional chemical fertilizer and one treated with natural organic fertilizer and (3) between sites treated with natural organic fertilizer that were similar in turfgrass age; which include three sites that were between 6-10 years old and two sites that were 22 and 23 years old.

iv. References

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