Evaluating nitrate leaching below maintained turfgrass sites, Suffolk County, Long Island, New York

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Abstract

Prevalence of nitrate in Suffolk County groundwater has increased within the last decade. One possible source of nitrate contamination in residential areas is turfgrass fertilizers. In this study lysimeters (soil water samplers) were installed at a meter below eight maintained turfgrass sites to capture soil water leached below the turfgrass root zone. Two sites were treated with chemical fertilizers, five sites were maintained by an organic landscaper and one site received no treatment to act as a control. The monthly data collected from January 2003 to December 2004 shows that nitrate concentrations of the leachate increased with increasing infiltration rate, increased age of the turfgrass system and decreased thatch thickness. The highest concentrations are during autumn when infiltration of rain water and mineralization rates is highest. In 2003 the sites treated with organic fertilizer showed, on average, higher nitrate concentrations than the sites treated with chemical fertilizer, while the opposite was true in 2004. Important implication of this data was that differences in leaching concentrations were less dependent on type of fertilizer used but were correlated with site properties and that concentrations vary between years demonstrating the importance of multiple year studies.

Introduction

The Environmental Protection Agency (EPA) has determined drinking water levels that exceed 10 ppm nitrogen as nitrate to be unsafe to humans. This is especially true for infants where blue baby syndrome, or methemoglobinemia, may occur. Methemoglobinemia is a blood disorder caused when nitrate is converted to nitrite which interacts with the hemoglobin in red blood cells reducing its ability to carry oxygen. Health concerns regarding nitrate in adults are inconclusive {Weyer, 1999 #168}. Nitrate is being detected more often and at higher concentrations in Suffolk County groundwater within the past decade. A major land use in Suffolk County, 25% as mapped in the late 1970’s, is turfgrass. Nitrogen is an important nutrient needed for healthy, green turfgrass. The soils on Long Island have low pH and lack of nutrients needed to support turfgrass and so the need of fertilizers. Lime is also added to maintain a proper pH and provide Ca and Mg. Irrigation is required during the summer since the amount of rain infiltrated on Long Island is not enough to maintain most turfgrass species.

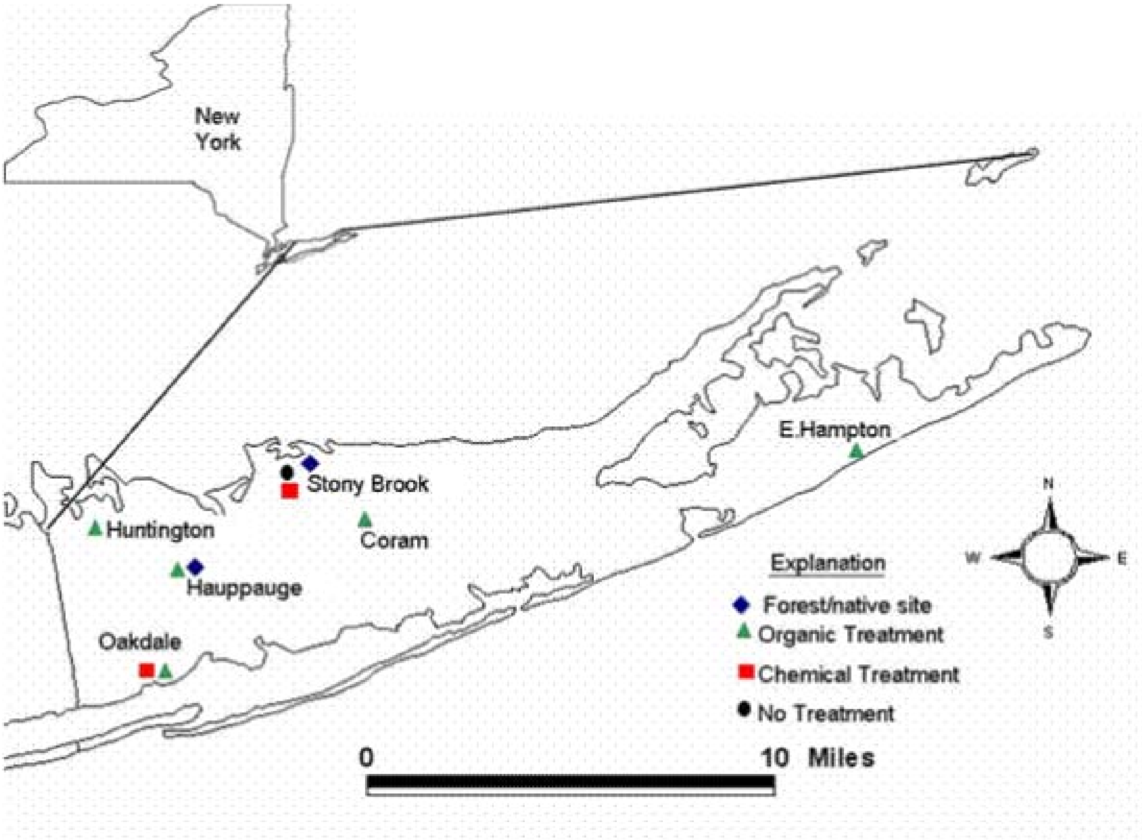

Figure 1. Location Map (forest/native sites are not discussed in this paper)

The objective of this study is to understand the concentrations of nitrate leaching below fertilized turfgrass sites. Soil water samples were collected monthly from January 2003 to December 2004 from lysimeters a meter below maintained turfgrass sites (Figure 1). The samples were analyzed for $N\text{-}NO_3$ and evaluated in regards to site properties in order to determine controls on nitrate leaching. A comparison is made between data of 2003 and 2004.

Methods *(For detailed methods please refer to Munster, 2003.)*

To evaluate the long term effects of various lawn maintenance procedures lysimeters (soil water samplers) have been installed in maintained lawns at eight locations to depths up to 150cm, on Suffolk County Water Authority property and on the Stony Brook University campus. Two of these locations are undergoing traditional chemical turfgrass treatment, five are undergoing natural organic treatment and one site receives no treatment. Lysimeters were installed at the Stony Brook University and the Oakdale chemical site by Schuchman (2001). All other sites were established in the fall or winter of 2002. Details of lysimeter installation are described by Schuchman (2001). Soil water samples from lysimeters were acquired monthly, filtered in the field, stored in acid-rinsed polypropylene bottles and frozen until analyzed. Nitrogen-nitrate concentrations were measured at the Marine Sciences Research Center, SUNY Stony Brook on a Lachat's QuickChem8500 Flow Injection Analysis System using Method 10-107-04-1-J which measures concentrations between 0.1 and 10 ppm nitrogen as nitrate. Samples with concentrations above 10 ppm where diluted and re run. Our analysis had an accuracy of 5%.

Bulk density samples were extracted vertically using a core 5.0 cm in diameter. After air-drying, samples were oven-dried for 48 hours at 60°C. Bulk density is calculated as the oven dry soil weight divided by the sample volume. The bulk density samples were used for particle size analysis. At least 20g of <2mm grain-size was needed for analysis. Grain size distribution was determined on a sonic sifter separator for the >50µm (sand) fraction and a Sedigraph on the <50µm (clay and silt) fraction. Classification of size fractions are according to the United States Department of Agriculture. Preparation of samples included removing the gravel portion (>2mm) by dry sieving and removing organic material by adding H_2O_2 and heating for no more than 1 hour on a hot plate to evaporate the H_2O_2. Samples were deflocculated by adding a 5% Calgon solution and placed in an ultrasonic bath for five minutes. Separation of the coarse and fine fractions was accomplished by wet sieving.

Infiltration rates were determined from a single infiltrometer method (Bouwer, 1986). Repeated measurements were taken at the Stony Brook and Huntington sites to see how infiltration varied over time. Measurements at Stony Brook ranged between 30% and at Huntington the reproducibility was 70%. Although site variability was great the data show relative differences between the sites i.e. high vs. low infiltration rates. Since this study was only interested in the relative difference in infiltration modeling was not performed. Thatch thickness was measured at three sides of an undisturbed soil core for three samples at each site. Soil organic matter (SOM) was determined based on a combustion method (Faithfull, 2002), for the top 15 cm of each profile, reported as SOM/g of soil in Table 9. Turfgrass age was determined from the date Suffolk County Water Authority purchased their buildings but could in fact be older, except for Stony Brook and Oakdale natural organic where exact ages were known. All sites except Stony Brook are watered with an automatic sprinkler system. Stony Brook only receives water in conjunction with fertilizer treatment as the recommendations for applying fertilizer is to “water it in.” The other sites are watered twice per week providing infiltration of 1.5-2” per week in accordance with the recommendations on the Suffolk County Water Authority web site (www.scwa.com, Oral communication, Micheal DeBlasi, SCWA, August, 2004).

Results

Site properties including depth to groundwater, soil type based on the Soil Survey of Suffolk County {Warner, 1975 #178}, treatment type, if sprinklers are present, infiltration rate, age of turfgrass, thatch thickness and soil natural organic matter (SOM) are reported in Table 1. Since this study evaluates sites with variable site conditions different leaching indices were calculated in order to better compare the sites. In this way one could compare one single value rather than evaluate all the site conditions to understand nitrate leaching between sites. A leaching index was calculated 1) as infiltration rate multiplied by soil organic matter and 2) as infiltration rate over thatch thickness. A larger value indicates a greater chance for nitrate leaching. These leaching indices are not meant to suggest nitrate absorbance, as with pesticide leaching indices, but only to be uses for better site comparison. Table 2 compares leaching indices, and the variables used in calculating the indices, with average N-NO_3 concentrations for 2003 and 2004. Nitrate as nitrogen data for all sites is compared in Figure 2.

Table 1. Site Properties [1]Scott's Brand [2]Lesco Brand

Site	Ground water Depth	Soil Survey Classification	Treatment Type (sprinklers)	Infiltration Rate	Turfgrass Age	Thatch thickness	Soil Organic Matter in Upper 15cm
	(m)			(cm/min)	(yrs)	(cm)	(SOM/g soil)
Oakdale	2	Cut and fill land	Organic (yes)	1.05	6	0.17	0.0245
Huntington	9	Riverhead and Haven soils	Organic (yes)	1.55	10	0.83	0.0696
Stony Brook	14	Riverhead and Haven soils	Chemical[2] (no)	0.20	4	0.17	0.0341
Oakdale	2	Cut and fill land	Chemical[1] (yes)	0.40	47	0.42	0.0594
Hauppauge	11	Haven loam	Organic (yes)	0.55	23	0.62	0.0561
Coram	18	Carver and Plymouth sands	Organic (yes)	0.30	8	1.42	0.0355
E. Hampton	2	Bridgehampton silt loam	Organic (yes)	0.10	22	1.33	0.0799

Discussion

As shown in Table 2, infiltration rate, turfgrass age and thatch thickness are the site properties which most affect nitrate concentrations in leachate below turfgrass sites. Leaching index[1] has a positive correlation with average N-NO_3 concentrations for 2003 and 2004. A higher index[1] is associated with a higher average concentration such that Huntington with an index of 10.8 (the highest) has the greatest average concentration of 12.38 ppm and 7.58 ppm for 2003 and 2004 respectively. Hauppauge has the second highest leaching index[1], 3.1, and concentrations of 5.09 ppm and 3.40 ppm for 2003 and 2004 respectively. The three sites with the lowest indices[1], Oakdale (2.6), Coram (1.1) and E.Hampton (0.8) have overlapping concentrations ranging from 1.0-3.2 ppm for 2003 and 2004. Leaching index[2] agrees with leaching index[1] except for Oakdale where it overestimates leaching. Both leaching indices do not predict average concentrations for the two sites treated with chemical fertilizers.

All sites treated with organic fertilizer either decrease or remain constant from 2003 to 2004. This may be a function of fertilizer applications. The organic landscaper decided, based on soil test, that the organic sites did not need further applications in 2004. While fertilization was relatively constant among the sites treated with chemical fertilizers between years the average concentrations nearly doubled from 2003 to 2004.

Table 2. Leaching indices

[1]Infiltration rate multiplied by soil organic matter [2]Infiltration rate over thatch thickness

Site	Infiltration Rate	Turfgrass Age	Thatch Thickness	Leaching Index[1]	Leaching Index[2]	2003 Average N-NO_3	2004 Average N-NO_3
	(cm/min)	*(yrs)*	*(cm)*			*(ppm)*	*(ppm)*
Organic Sites							
Huntington	**1.55**	**10**	**0.83**	**10.8**	**1.9**	**12.38**	**7.58**
Hauppauge	**0.55**	**23**	**0.62**	**3.1**	**0.9**	**5.09**	**3.4**
Oakdale	**1.05**	**6**	**0.17**	**2.6**	**6.2**	**2.15**	**3.17**
Coram	**0.3**	**8**	**1.42**	**1.1**	**0.2**	**1.34**	**1.02**
E. Hampton	**0.1**	**22**	**1.33**	**0.8**	**0.1**	**2.58**	**2.51**
Chemical Sites							
Oakdale	**0.4**	**47**	**0.42**	**2.4**	**1.0**	**3.22**	**5.75**
Stony Brook	**0.2**	**4**	**0.17**	**0.7**	**1.2**	**3.43**	**12.08**
Control Site	**0.2**	**40**	**0.17**	**0.7**	**1.2**	**2.4**	**1.7**

[1] Leaching Index calculated as infiltration rate multiplied by soil organic matter
[2] Leaching Index is calculated as infiltrate rate over thatch thickness

Using Table 2 the soil properties can be examined by comparing sites of similar age and similar treatment to see affects of infiltration rate and thatch thickness on nitrate concentrations below the root zone. Turfgrass age is a function of soil organic matter, such that soil organic matter increases with age (Petrovic, 1990). Hauppauge and E.Hampton are 23 and 22 years respectively and both treated with organic fertilizer. Hauppauge has a higher infiltration rate and thinner thatch thickness compared to E.Hampton and because of this has higher average N-NO_3 concentrations in 2003 and 2004. Oakdale and Coram are similar age, 6 and 8 years respectively. Again Oakdale with a higher infiltration rate and thinner thatch thickness than Coram and has higher average N-NO_3 concentrations in 2003 and 2004. A relationship between site properties and nitrate leaching between the sites treated with chemical fertilizers is less direct. Both Oakdale and Stony Brook have similar infiltration rates and similar average concentrations in 2003 yet in 2004 the Stony Brook site has an average concentration twice that of Oakdale. This is unexpected since for Stony Brook the leaching index[1] is lower, the site is younger and Stony Brook received less total nitrogen for both years. Schuchman, 2001, in his study also noted that Stony Brook on average leached higher concentrations that Oakdale. Easton and Petrovic, 2004, noted in their study that until turfgrass sites are established that leachate concentrations are considerable. So although the organic sites show that older turfgrass sites leach more nitrate than younger sites, Stony Brook may not yet be established.

All sites are compared in Figure 2. The control site shows considerable concentrations at times reaching at or above 5 ppm N-NO_3. In both years concentrations peak in the autumn months. This effect can be attributed to a reduction in plant uptake, high levels of mineralization of soil organic nitrogen due to warm, moist soil conditions and reduction in evapotranspiration from summer to autumn seasons (Roy et al., 2000). The control site is also an older site, being established in the mid 1960's. As described by Petrovic, 1990 older lawn sites on Long Island have reached equilibrium in regards to total nitrogen stored in the top 10 cm of soil. This is due to older sites having more soil organic matter and thus need less nitrogen. Younger sites are more likely to store nitrogen.

Both sites treated with chemical fertilizes show similar concentrations to the control site in 2003 but have increasingly high concentrations in 2004. We believe this to just be variability between the years since fertilization treatment was the same between both years and variability is also shown with the control site. It could also be that the fertilizer applied in 2004 was not needed and thus the system had more nitrogen than the ecosystem could use and the excess was leached.

The five organic sites show variability as described in Table 2 but a similar pattern is since between the two years. As in the control peak concentrations are in the autumn months. Concentrations decrease from 2003 to 2004. In 2003 concentrations of $N\text{-}NO_3$ below the organic sites were, on average, higher than the sites treated with chemical fertilizers. The opposite is true for 2004.

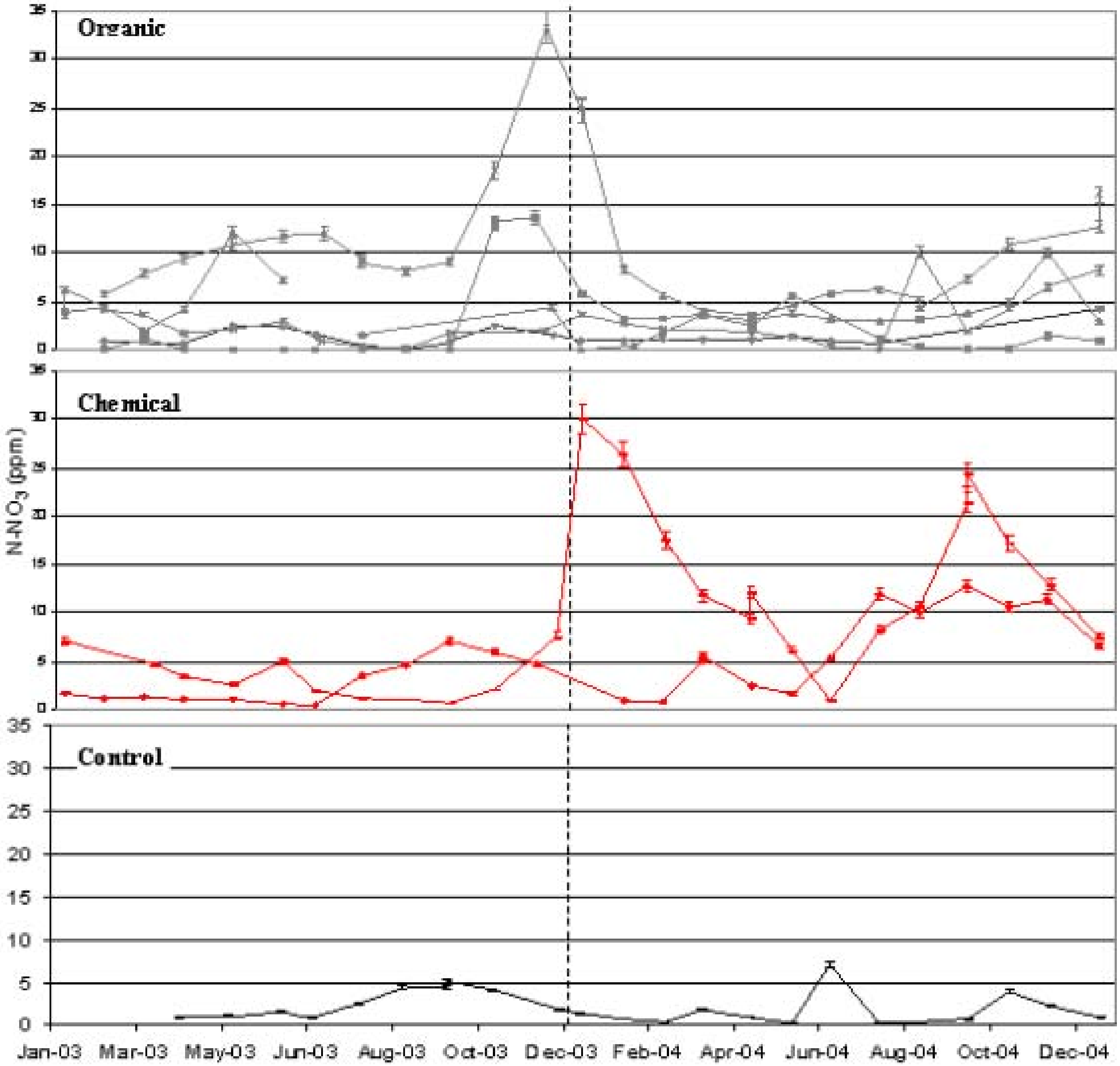

Figure 2. $N\text{-}NO_3$ **concentrations for January 2003-December 2004**

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Acknowledgments

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