Nitrate in well water – results from 20 years of monitoring in Nova Scotia

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ABSTRACT
The Nova Scotia Well Water Nitrate Monitoring Program involves annual testing for nitrate at 150 randomly selected water wells in an intensely developed agricultural area of Kings County, Nova Scotia, Canada. The wells have been tested on ten different years between 1989 and 2008. The results indicate that 15% to 25% of the wells exceeded the nitrate drinking water guideline on any given year since 1989. The results also show that 66% of the wells have no statistically significant trend in nitrate levels, 31% have a decreasing trend and 3% have an increasing trend.

RÉSUMÉ
Le programme de surveillance des nitrates dans l'eau souterraine de la Nouvelle-Écosse implique des analyses annuelles de 150 puits sélectionnés aléatoirement dans le comté de Kings, une région où l'agriculture est très présente. Les puits ont tous été testés 10 fois entre 1989 et 2008. Les résultats indiquent que 15 à 20% des puits dépassent la limite d'eau potable pour chacune des années depuis 1989. Les résultats montrent également que 66% des puits ne montrent pas de tendance statistiquement significative pour les concentrations en nitrates, 31% ont une tendance décroissante et que 3% ont une tendance à la hausse.

1 INTRODUCTION

1.1 Background and Objectives

The Nova Scotia Well Water Nitrate Monitoring Program is a long-term study that involves annual testing for nitrate at approximately 150 water wells in Kings County, Nova Scotia, Canada. The program was initiated in 2002 as a follow-up to water quality studies that carried out nitrate sampling in 1989 (Briggins and Moerman, 1995), 1999 and 2000 (Blair, 2001). Since 2002, the nitrate testing has been completed each year on the same group of water wells.

The objectives of the program are to monitor nitrate levels in a group of randomly selected water wells in an intensely developed agricultural area to determine the number of wells that meet the nitrate Guideline for Canadian Drinking Water Quality (hereafter referred to as the drinking water guideline) and to identify any long-terms trends in nitrate levels. This paper presents the nitrate results from 1989 up to and including 2008.

1.2 Description of the Study Area

The study area is located in Kings County, Nova Scotia, Canada and covers approximately 53,000 Ha of land. The study area and locations of the water wells that were sampled are shown in Figure 1. The area is part of the fertile Annapolis Valley, one of the most intensely developed agricultural areas in the province. The study area encompasses four sub-watersheds whose rivers ultimately empty into the Minas Basin. These include: the Cornwallis River, the Canard River, the Habitant River, and the Gaspereau River.

The bedrock in the study area is bordered by Triassic basalt of the North Mountain, and granite and Palaeozoic metasediments of the South Mountain. The valley between the North and South Mountains consists of red sandstone, siltstone, conglomerate and shale. These materials are a part of the Blomidon and Wolfville formations that comprise the majority of the land in the study area and where the main bedrock aquifers exist. Most of the surficial geology was deposited during the Pleistocene glaciation and consists of glacial till, glacio-fluvial sand and gravel deposits (Briggins and Moerman, 1995).

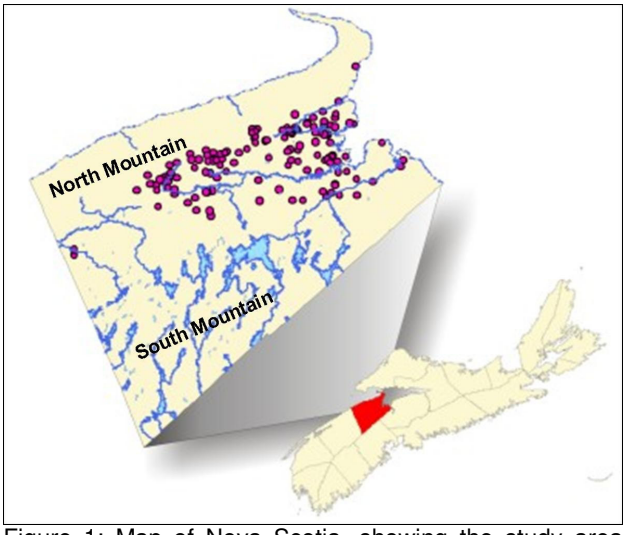

Figure 1: Map of Nova Scotia, showing the study area and well locations.

1.3 Nitrate in the Environment

Nitrate is a naturally occurring ion that is ubiquitous in the environment. Sources of nitrate in groundwater include decaying plant or animal material, agricultural fertilizers, manure, domestic sewage and geological formations containing soluble nitrogen compounds (Health Canada,

1987). Because nitrate salts are very soluble, nitrate is highly mobile in soil and migrates readily to the water table when it is present in excess of the amount utilized by plants.

Nitrogen (N) is an essential nutrient both for plants and animals and it is commonly the limiting nutrient for plant growth. To maintain high yielding crops in agricultural operations it is important to provide non-limiting access to this nutrient, and this has been achieved through the use of fertilizers. Therefore, agricultural fertilizers and manures are often the most significant anthropogenic sources of nitrate in the environment.

Nitrate-impacted groundwater will migrate in an aquifer and can be captured by a water well or discharged to a surface water body as baseflow. Nitrate is a health concern in water wells used for drinking water if the nitrate concentration exceeds the drinking water guideline of 10 mg/L (expressed as nitrate-nitrogen). In addition to the direct health concerns associated with nitrate, elevated nitrate levels in well water can indicate that other contaminants may be present, such as microbial pathogens, which can also cause health problems.

If nitrate-impacted groundwater is not captured by a water well, it will continue to migrate in the aquifer and will eventually either attenuate naturally, or discharge to a surface water body as baseflow. High nitrate levels in surface water contributes to eutrophication, which results in a reduction of available oxygen for aquatic life.

2 METHODS

2.1 Field Methods

There are a total of 153 water wells in the NS Well Water Nitrate Monitoring Program. The majority of the wells are private water wells that are used as domestic or barn water supplies, however, the program also includes 10 municipal water wells. The wells were randomly selected during the initial study in 1989 (Briggins and Moerman, 1995) and the same group of wells has been sampled each year since 2002, normally in the month of August. Although sampling is attempted at all 153 wells each year, on any given year there are usually several wells that cannot be accessed because the well owners cannot be reached when the sampling is being carried out. As a result, the total number of water wells sampled each year usually ranges between 130 and 140.

There is a lack of information about well construction details for the wells in the monitoring program, however, based on information provided from the initial 1989 study, the majority of the wells are drilled (approximately 69%), and the remainder are dug wells or sand points (16%), or unknown/other (15%). Most of the well depths are unknown (i.e., 76% unknown). However, of the 24% of wells with known well depths, approximately 14% are shallow (<31 m), 8% are moderately deep (31 m to 61 m), and 2% are deep (>61 m).

The initial water quality study in 1989 tested well water for a variety of parameters, including: nitrate, general chemistry, bacteria and pesticides. The current monitoring program has been refined to focus on nitrate because the results of the 1989 study indicated that nitrate was the parameter that most commonly exceeded the drinking water guideline.

The well water samples were collected by Nova Scotia Environment at an outdoor water tap, if possible. Prior to collecting the sample, the water was run for approximately five minutes to clear the lines of stagnant water. The samples were collected in 100 mL laboratory-supplied bottles and kept refrigerated for a maximum of three weeks until they were delivered to the Nova Scotia Agricultural College laboratory in Truro, Nova Scotia, for nitrate analysis (reported as nitrate-nitrogen).

During sample collection, field duplicates were also collected at approximately 5% of the wells. For wells where field duplicates were taken, the relative percent difference was calculated. For the 2008 monitoring event, the relative percent difference of the duplicate samples was less than 12%.

2.2 Data Assessment Methods

The data were evaluated by comparing the nitrate concentration at each water well to the drinking water guideline (10 mg/L for nitrate-nitrogen) for every year that data was available. The minimum, maximum and median nitrate concentration from the entire dataset was also calculated for each year.

The Mann-Kendall trend test (Gilbert, 1987) was used to determine whether a statistically significant trend was present in the nitrate concentrations at each well (i.e. upward trend, downward trend or no trend). Trends were considered "statistically significant" if there was at least a 95% confidence level. Note that "statistically significant" means there is statistical evidence that there is a trend present, but does not indicate whether the trend is large or small.

Two methods were used to assess annual trends of the entire dataset. The first approach was to complete a trend analysis on the annual median nitrate concentrations of the dataset. The second approach was to complete a trend analysis on the surface area of land with wells that had nitrate levels exceeding the drinking water guideline. This was done by plotting a map of nitrate concentrations for each year and contouring the area above 10 mg/L. Contouring was done with inverse distance weighted interpolation. The surface area (in Hectares) exceeding 10 mg/L was then calculated. The contouring and area calculations were done using ArcInfo 9.3. This is a two dimensional approach to assessing the extent of nitrate impacts in groundwater. Due to the lack of information about well construction it was not possible to assess the vertical extent of nitrate in groundwater.

For all statistical analyses presented in this paper, non-detect results were included in the calculations by dividing the detection limit by two.

3 RESULTS

A summary of the nitrate data is presented in Table 1 and Figure 2. Please note that all nitrate results discussed in this paper are expressed as nitrate-nitrogen (NO_3-N) in milligrams per Litre (mg/L). Although the wells were first sampled in 1989, regular annual sampling was not initiated until 2002. Therefore, the wells have not been sampled every year since 1989, however, in total 10 annual sampling events have been completed.

The maximum nitrate concentration during the period of record has varied between 25.5 mg/L and 46.9 mg/L, consistently exceeding the nitrate drinking water guideline of 10 mg/L. The percentage of wells exceeding the nitrate drinking water guideline has ranged from 15% to 25% and the median nitrate concentration has always been below the drinking water guideline. Approximately 6% of wells consistently exceeded the drinking water guideline every year they were sampled.

A trend analysis was carried out on each well to determine if nitrate concentrations were changing over time on a well-by-well basis. The trend analyses were completed for all wells that had at least four years of data available, which was a total of 143 wells. The trend analyses indicated that 3% of the wells had an upward trend, 31% had a downward trend, and 66% had no statistically significant trend present with a 95% confidence level.

A trend analysis was also carried out on the annual median nitrate concentrations shown in Figure 3. One trend analysis was carried out for the period of 1989 to 2008 and another analysis was carried out for the period of 1999 to 2008. No statistically significant trends were identified with a 95% confidence level, however, a downward trend was identified with a 80% confidence level for the period from 1999 to present.

Table 1 lists the annual surface area of land with wells exceeding nitrate levels of 10 mg/L and Figure 3 shows a graph of these data. Figure 4 and 5 show maps of the nitrate distribution in well water in the study area for 1999 and 2008. A trend analysis was carried out on the annual surface area data. One trend analysis was carried out for the period of 1989 to 2008 and another analysis was carried out for the period of 1999 to 2008. No statistically significant trends were identified with a 95% confidence level, however, a downward trend was identified with a 80% confidence level for both of the periods referenced above.

Table 1. Nitrate in well water – summary statistics.

Year	No. of wells tested	Median nitrate level[1]	Max. nitrate level[1]	Percent of wells above drinking water guideline[2]	Size of nitrate-impacted area (Hectares) above guideline[2]
1989	135	3.6	46.1	20%	12,000
1999	142	4.2	43.0	24%	13,800
2000	137	3.4	46.9	20%	11,700
2002	139	4.1	33.1	20%	8,900
2003	138	4.7	42.5	19%	12,700
2004	134	5.1	46.7	25%	15,400
2005	130	2.2	39.3	15%	8,500
2006	133	3.0	38.5	22%	11,800
2007	132	2.9	34.9	22%	10,900
2008	135	2.6	25.5	19%	6,500

[1]Nitrate levels are expressed as NO_3-N in mg/L.
[2]The drinking water guideline for nitrate is 10 mg/L.

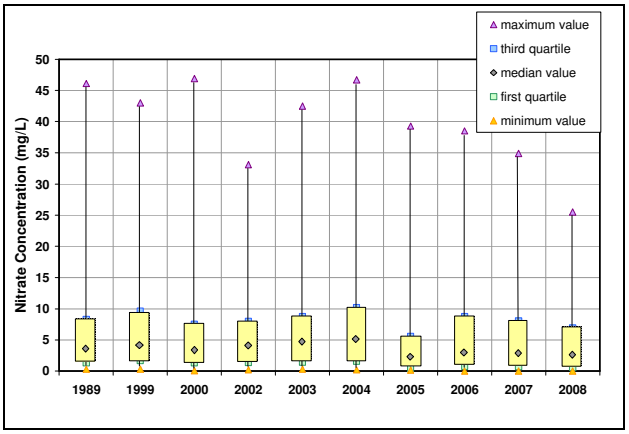

Figure 2: Nitrate in well water – box whisker plots.

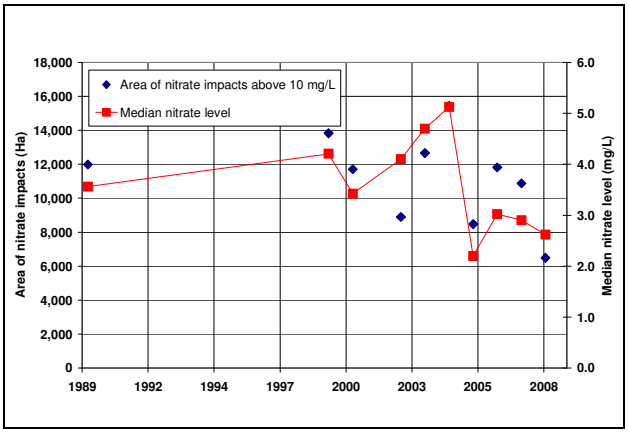

Figure 3: Annual median nitrate concentrations and size of area with nitrate-impacted wells.

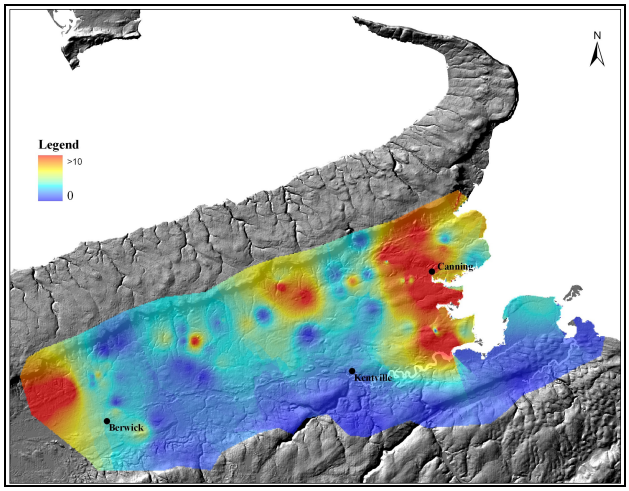

Figure 4: Nitrate distribution in well water in study area for 1999 (nitrate concentration expressed in mg/L).

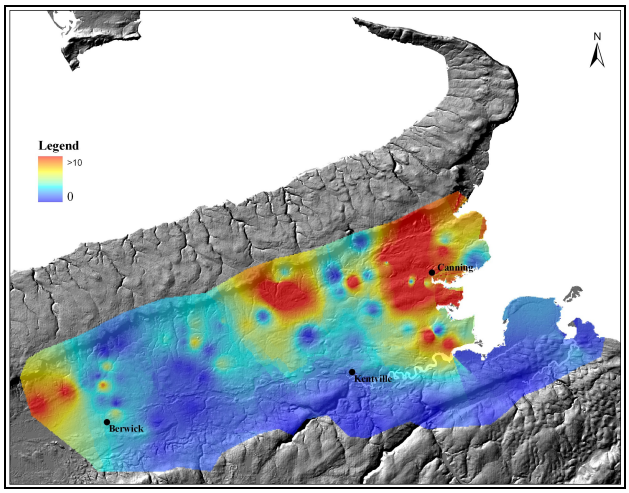

Figure 5: Nitrate distribution in well water in study area for 2008 (nitrate concentration expressed in mg/L).

Further monitoring and assessment are needed to confirm the presence and cause of the downward trend in median nitrate levels and size of the nitrate-impacted area. However, declining levels may be due to the Environmental Farm Plan Program that was introduced in Nova Scotia 10 years ago to address a broad range of environmental management issues on farms, such as nutrient management and the storage and use of manure and fertilizer. Although the Environmental Farm Plan Program is not specifically designed to address nitrate levels in groundwater, it has potential to do reduce impacts by reducing nitrate application rates and improving storage and handling practices.

4 CONCLUSIONS

The results from 10 annual sampling events completed between 1989 and 2008 show that 15% to 25% of the 150 water wells tested in the study area exceeded the drinking water guideline for nitrate. The maximum annual nitrate concentration ranged from 25.5 mg/L to 46.9 mg/L and the median annual nitrate concentration ranged from 2.2 mg/L to 5.1 mg/L.

A trend analyses on the nitrate levels in each individual well indicated that 3% of the wells had an upward trend, 31% had a downward trend, and 66% showed no statistically significant trend. A trend analysis on the entire dataset suggested a downward trend in both the annual median nitrate levels and the size of the nitrate-impacted area. Further monitoring and assessment are needed to confirm the presence and cause of the downward trends.

ACKNOWLEDGEMENTS

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