Submarine Discharge of Nitrate Rich Groundwater into Port Jefferson Harbor, Long Island, NY

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Introduction

The fate of nitrogen entering Long Island Sound Embayments is dependent on both volume of submarine groundwater discharge (SGD) and geochemical transformations in the coastal aquifer. Previous work in Stony Brook Harbor revealed the importance of sediment composition in the subtidal and offshore areas of the harbor; SGD rate in the subtidal is higher than offshore areas, but experiences only 30-50% denitrification when compared to low SGD rates offshore that undergo 80-100% denitrification. In this study, SGD nitrogen loading to Port Jefferson is examined on the harbor wide scale using a combination of porewater profiles in the coastal aquifer, porewater nitrogen sampling in the subtidal zone and ^{222}Rn surves. We find nitrate rich groundwater entering Port Jefferson Harbor via shoreline SGD contributes 19 - 29.4 kg-NO_3^--N d^{-1}, in excess of inputs from Port Jefferson Sewage Treatment Plant which average 12.2kg-Nd^{-1}. This finding illustrates the importance of accounting for SGD when determining total nitrogen loading to harbor water. To accurately model SGD nitrogen loading to harbors, data refinement is required to address variation in both SGD rates and groundwater nitrate concentration.

Methods

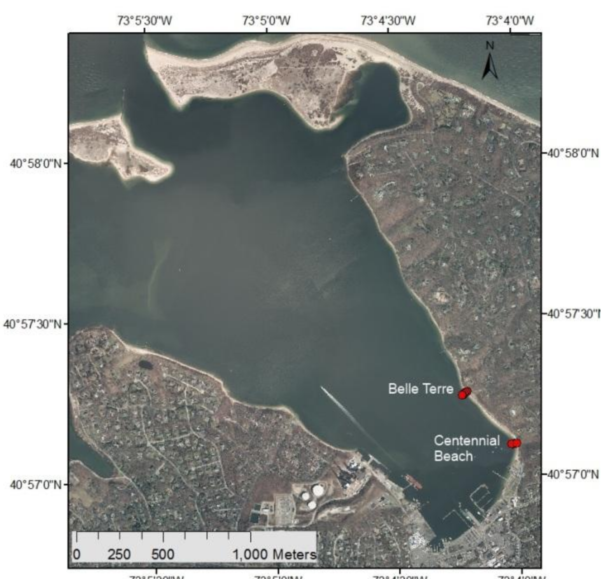


Figure 1 Map of study area. Porewater profile transect locations are shown.

We first examined biogeochemical transformations in the coastal aquifer by sampling porewater profiles at two areas previously identified to have high (Centennial Beach) and low (Belle Terre Beach) SGD rates, shown in figure 1. Porewater profiles were completed at two field areas of Port Jefferson harbor; Centennial Beach located in the southeast corner of the harbor and Belle Terre along the eastern coast. Porewater was sampled using a either Retract-A-Tip piezometer sampling system[*Charette and Allen*, 2006] or cluster wells in July, 2012. At Centennial beach piezometer samples were taken at depths ranging from 0.6m-10.1m in a shore perpendicular transect. At Belle Terre beach five cluster wells were sampled in a shore perpendicular transect from depths ranging 0.45m-12.2m. This detailed investigation provided insight into nitrogen transformations in the subtidal and offshore zones, to determine which areas contribute the bulk of nitrate to surface water.

A harbor wide trident survey was performed to measure nitrate concentrations in porewater just prior to discharge into overlying water. The Trident sampler takes porewater samples from 60cm beneath the sediment water interface[*Chadwick et al.*, 2002]. Samples were taken from within 3m of mean low tide in the subtidal zone. Sampling points and results from this survey are shown in figure 4.

To determine the amount of freshwater SGD entering Port Jefferson Harbor we employed geochemical tracer Radon (^{222}Rn). ^{222}Rn is a noble gas, is highly enriched (1000 times or more) in groundwater than seawater. It is used as a geochemical tracer for groundwater, or fresh fraction of surface water, in SGD studies[*Burnett and Dulaiova*, 2003]. ^{222}Rn has a short half life ($t_{1/2}$= 3.83days) therefore it does not accumulate in surface water and is subject to atmospheric evasion. A ^{222}Rn survey was performed in August 2012 using a RAD-7 sampler that measures ^{222}Rn concentrations every 10 minutes. This provides an integrated amount of ^{222}Rn every ~250m of shoreline in Port Jefferson Harbor.

We used Geographical Information Systems (GIS) to integrate piezometer, trident and ^{222}Rn data to determine the volume of fresh SGD entering the Harbor. We then used nearest neighbor concentrations of nitrate as determined from trident sampling to calculate a total discharge of nitrate into overlying water from the intertidal and subtidal shore areas.

Results and Discussion

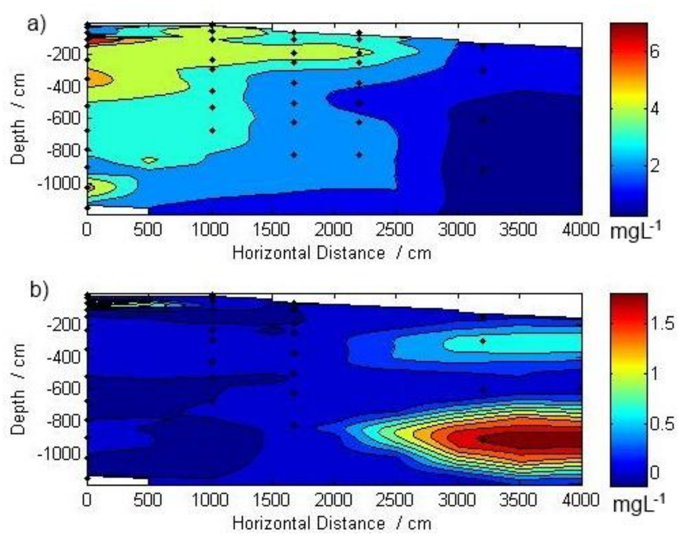


Figure 2 Nitrate (a) and ammonium (b) profiles from porewater samples taken at Centennial Beach. High tide and low tide are located at horizontal distance 0cm and 2500cm respectively.

Results from porewater profiles show significant differences in how coastal aquifers process nitrogen during SGD. At Centennial beach, located in the southeast corner of Port Jefferson Harbor, porewater is fresh throughout the intertidal and subtidal zone. Tidally driven saltwater recirculation is observed at mean high tide, in sampling depths of 0.2m-1.2m. Porewater in the remaining piezometers at depths from 0.55m-11.5m contain freshwater salinities (<2ppt). These results indicate SGD at Centennial Beach is comprised of primarily freshwater discharge that extends offshore beyond mean low tide at least 26m. Nitrate concentrations of 5.1-7.3mg NO_3^--N L^{-1} are highest within a meter of the sediment water interface, at the base of the salt water recirculation zone, figure 2. Groundwater nitrate concentrations decrease along SGD flowpaths, reaching minimum values of 1.6mg NO_3^--N L^{-1} at a depth of 1.5m beneath the sediment water interface at 26m beyond mean low tide (figure 2). These results indicate that nitrate persists in groundwater as it moves offshore, but may undergo mixing with seawater during discharge.

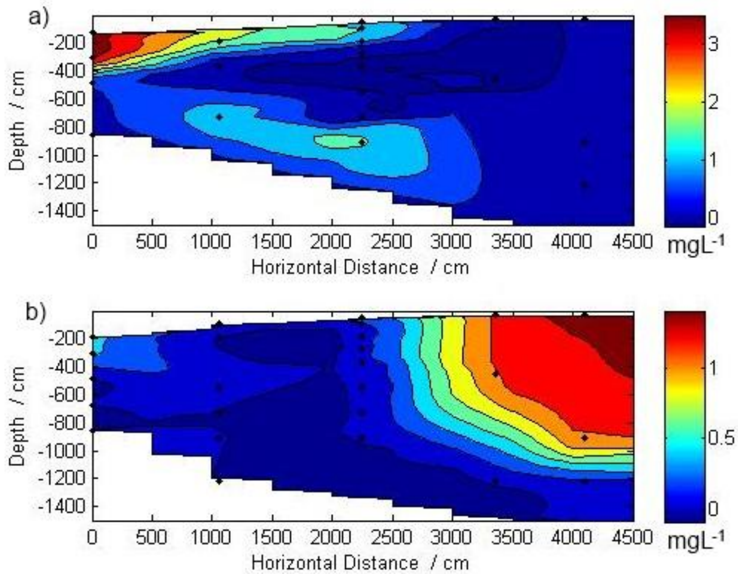
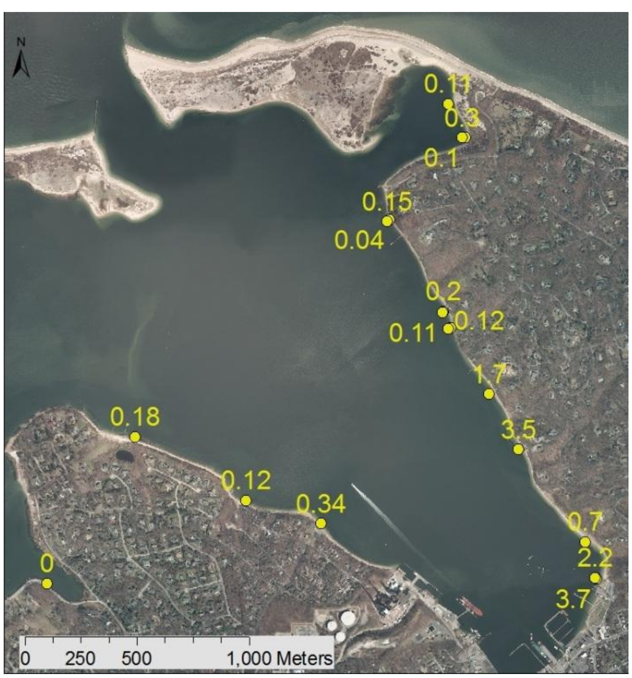


Figure 3 Nitrate (a) and ammonium (b) profiles from porewater samples taken at Belle Terre. Mean high tide and low tide are located at horizontal distance 0cm and 2450cm respectively.

A second study site, at Belle Terre on the eastern shore of Port Jefferson Harbor, contains significantly more seawater infiltration. Porewater salinity, sampled from cluster well transects at Belle Terre indicate seawater infiltrates to a depth of 4.8m at mean high tide. This infiltration creates an upper saline plume (USP) that extends the length of the intertidal zone and extends offshore to 18.2m beyond the mean low tide line. Fresh groundwater is found at depth beneath the entire USP, with the boundary between fresh and salt porewater ranging from 3.6-4.8m beneath the intertidal sediment surface. Maximum NO_3^- concentrations at Belle Terre are 3.8mg NO_3^--N L^{-1} in samples from mean high tide at depth of 1.2m beneath the sediment surface (figure 3a). Nitrate concentrations in porewater samples decrease with increasing distance offshore to <0.08mg NO_3^--NL^{-1} at shallow offshore locations. Conversely, NH_4^+ concentrations are <0.4 mg NH_4^+-NL^{-1} in the intertidal zone but increase in offshore samples reaching a maximum of 1.2mg NH_4^+-NL^{-1} at a depth of 9.2m in offshore piezometer (figure 3b). These results indicate that NO_3^- inputs to surface water are significantly less at Belle Terre, and dissolved inorganic nitrogen exits the coastal aquifer primarily as NH_4^+ at this site.



A Trident probe was used to determine spatial distribution of nitrate concentrations throughout the harbor. The Trident probe samples porewater from 0.6m beneath the sediment water interface at locations within 3m of mean low tide. Results from a spatial Trident probe survey reveal similar results to porewater profiles, with highest nitrate concentrations of 2.2-3.7mg NO_3^--NL^{-1} in the south and southeast portions of the harbor with concentrations less than 0.5mg NO_3^--NL^-

^{1} along the north west and north east shore line.

To determine the amount of freshwater SGD entering Port Jefferson Harbor we performed shoreline survey to measure Radon (^{222}Rn) concentration.

Figure 4 Nitrate concentrations (mgL^{-1}) in porewater from 60cm beneath the sediment water interface. Samples collected using Trident system in April-May 2012

Results from ^{222}Rn survey show increased amount of freshwater discharge in the south and southeast portions of Port Jefferson Harbor, maximum values of $14.3cmd^{-1}$ (figure 5). Manual seepage meter measurements from Centennial Beach and Belle Terre field sites exhibit more shoreline spatial variance than those recorded with ^{222}Rn. This is likely due to advective mixing of freshwater as it discharges into open water, as ^{222}Rn samples are taken from 15cm above the sediment water interface and are integrated over 250m in the long shore direction.

Geographic Information Systems (GIS) was used to integrate spatial surveys of nitrate and fresh fraction SGD rates as determined using ^{222}Rn measurements. Porewater profiles were used to determine shore normal distance for fresh fraction discharge. We find sand with high porosity and permeability persists offshore in the southeastern portion of the harbor, but silt/mud is found offshore along the north west and north east portions of the harbor[*Koppelman*, 1976]. Therefore we calculated fresh discharge to 26m beyond mean low tide in the southeastern portion of the harbor, but we calculate fresh discharge to a distance of only 8m beyond low tide in the north eastern and western shoreline. This was done to reflect changes how changes in offshore sediment composition effect SGD rates along the shoreline.

Figure 5 SGD fresh fraction discharge rate (cmd^{-1}) as determined using ^{222}Rn measurements.

Shoreline areas contribute a fresh discharge flux of 3.2-5.4mgal d^{-1} in Port Jefferson Harbor. The range of values is attributable to standard deviation of ^{222}Rn measurements. Applying nearest neighbor nitrogen concentrations, as measured using Trident probe, we calculate 19 to 29.4 kg-NO_3^--N d^{-1} discharging to surface water from shoreline areas. We consider this analysis to be a conservative estimate of nitrate entering surface water for three reasons. First, we only include discharges from the coastline and do not include offshore discharge. Second, our ^{222}Rn calculated flux to overlying water is consistently less than direct SGD measurments using manual and ultrasonic seepage meters. Finally, we only account for nitrate inputs, and do not include NO_2^- or NH_4^+ possibly released during SGD travel through anoxic sediments.

Despite these caveats this analysis is useful in comparing SGD nitrogen inputs with point source pollution inputs such as sewage treatment plant discharges. Currently Port Jefferson Sewage Treatment Plant (PJSTP) is regulated to discharge a maximum 17.6kg-Nd^{-1} into Port Jefferson Harbor. In 2012 the PJSTP averaged 12.2kg-Nd^{-1} discharge. Therefore, even conservative estimates of SGD nitrate loading to Port Jefferson Harbor exceed inputs from PJSTP.

This study illustrates the importance of measuring nitrogen flux to surface water on at the Harbor scale. Reliance on mass balance models that use inland groundwater nitrate concentrations do not adequately measure shoreline variance in both SGD flux and nitrogen loading. The results of this study highlight the importance of SGD nitrogen inputs to harbors, particularly when compared to point source nitrogen pollution.

Acknowledgements

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