Nitrogen Sources and Environmental and Public Health Issues in Coastal Watersheds

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RI NEMO Nonpoint Education for Municipal Officials

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Nonpoint Education for Municipal Officials

RI NEMO provides training and technical support to local decision makers in evaluating and managing impacts of land use on local water resources.

RI NEMO is part of URI’s Cooperative Extension Water Quality Program

Funded by RI HEALTH, RI DOT, RI DEM and EPA
Topics

1. Why worry about nitrogen
2. Estimating nitrogen inputs
3. Management
Topics

1. Why worry about nitrogen
   • sources, effects to health and environment
2. Estimating nitrogen inputs
3. Management
## Why worry about nitrogen?

| N is a pollutant | • Nitrogen is a drinking water contaminant.  
|                 | • Critical nutrient overfertilizing coastal waters. |
| Indicator of Pollution | • High groundwater NO3-N (nitrate-nitrogen) indicates human impact  
|                     | • NO3-N is soluble and mobile in deep groundwater – used to model potential development impacts. |
| Inputs linked to land use | • N in wastewater, fertilizers and stormwater.  
|                          | • N removal potential in hydric (wetland) soils. |
Nitrogen – too much of a good thing?
N Inputs
- Fertilizers
- Animal waste
- Human waste
- Precip - NOx

Atmosphere
- 78% nitrogen
- \( N_2 \)
- NOx

N2 Fixation (Nitrification)

Natural N2 fixation by soil bacteria living on roots of legumes, also algae & lightening.

Artificial N2 fixation invented 1909 by Fritz Haber and used to make WW1 bombs. More than half of world’s supply of useable N is now man made.

N Outputs
- Stream flow
- Crop uptake
- Microbial Denitrification

NH\(_3\), NO\(_3\)
Used by plants

N\(_2\), N\(_2\)O
Completing the cycle

Stream

Denitrification

\( NO_3 \)
Major Sources of Nitrogen to Groundwater

Agricultural Activities

– Commercial fertilizers
– Varies by type of crop
– Animal manure

Onsite Wastewater Treatment Systems

- Failed systems (Org.-N and NH4+-N)
- Systems working properly (NO3-N)
Health Impacts

Public drinking water supply standards
EPA and RI Dept of Health

10 mg/l nitrate-N Maximum Contaminant Level (MCL)

MCL prevents methemoglobinemia “blue baby syndrome” in infants < 6 months old.

5 mg/l nitrate-N Action Level

Supplier must take action to reduce. Should not use to mix infant formula.

Concentration

milligram per liter (mg/l) = parts per million (ppm)

Most labs report nitrate as nitrate-nitrogen, the amount of N in that form (NO$_3$-N)

Other Health Issues

Suspected Risks

2.5 – 4 mg/l nitrate-N associated with cancer risk.

> 19 mg/l implicated in miscarriage.

Private wells

Annual monitoring recommended, but not required. Homeowners are on their own.

RI Major Community Water Supplies are meeting all drinking water standards – but maximum levels near 5 mg/l is a concern.
Wastewater impacts to private wells
1996 field study by A. Veeger (1996)

Study area
• Densely developed, unsewered, private wells.
• Slowly permeable, high water table soils.
• Lot size: Median < ½ acre; many < 7,500 sf.
• 119 private wells sampled.

Results
High NO3 is associated with fecal coliform and small lot size
• Fecal Coliform bacteria detected in 15% of wells.
• Wells with bacteria detects averaged 3.6 mg/l nitrate-N, compared to 2.3 mg/l nitrate-N for all wells.
• Lots < 1acre averaged 3.2 mg/l NO3 and were most likely to have fecal coliform detects.
Wastewater impacts to private wells
1996 field study by A. Veeger (1996)

As a result of this study:

Town worked with URI Cooperative Extension to estimate N sources and other pollution threats

Town adopted High water table ordinance for lots < 1 acre which:
- limits impervious cover,
- requires on-lot stormwater management, and
- advanced wastewater treatment.
Aquatic life impacts

Old direct discharge problem: Ammonia toxicity (NH₃) with high concentration of untreated discharge and drop in dissolved oxygen with conversion to nitrate (NO₃).

Current “Non Point” Pollution Problem: Nutrient enrichment (eutrophication) of coastal waters based on total amount or loading of nitrogen (lbs/yr), all forms.
Eelgrass filters pollutants, adds oxygen.

Sandy bottom sediment creates habitat for fish and shellfish.

Healthy Coastal Waters with Low Nutrients

Healthy Levels of Nutrients

Algae growth is limited

Sunlight penetrates clear water

Submerged aquatic grasses use sunlight to make food

Healthy grasses provide habitat for other organisms

Grasses produce oxygen

Healthy aquatic community
Effects of Nutrients in the Bay

Healthy Levels of Nutrients
- Algae growth is limited
- Sunlight penetrates clear water
- Submerged aquatic grasses use sunlight to make food
  - Healthy grasses provide habitat for other organisms
  - Grasses produce oxygen
  - Healthy aquatic community

Excess levels of nutrients
- Algae use nutrients to grow and reproduce rapidly
  - Algae cloud water and block sunlight
  - Algae use up nutrients and die
    - Submerged grasses die
    - Bacteria feed on dead algae
      - Loss of grass habitat
      - Dissolved oxygen levels are decreased
        - Bay organisms that breathe oxygen or live in grasses are stressed or die
Degraded Coastal Waters with High Nutrients

Attached and suspended algae reduces light and eelgrass function.

Muck sediment poor habitat for fish and shellfish.

Excess levels of nutrients

Algae use nutrients to grow and reproduce rapidly

Algae use up nutrients and die

Algae cloud water and block sunlight

Submerged grasses die

Bacteria feed on dead algae

Loss of grass habitat

Dissolved oxygen levels are decreased

Bay organisms that breathe oxygen or live in grasses are stressed or die
Nitrogen Enrichment

Nuisance seaweed replaces eelgrass,

Smothers habitat,

Algae decays and consumes oxygen.

Many poorly flushed coastal waters are impaired due to excessive nutrients and low oxygen.
Direct effect of coastal nitrogen contamination

- Low dissolved oxygen leads to summer fish kills.

- Sediments may continue to store and recycle nutrients.

Greenwich Bay fish kill, RI August 2003
Summary - How much nitrogen is too much?

**Increasing nitrogen**

**Increasing pollution risk**

**0.5 mg/l or less**
- Natural background in RI groundwater in forested areas.
- Healthy shellfishing habitat at 0.3 mg/l or less.

**1 mg/l**
- Sign of impact to groundwater from waste water or fertilizer. (USGS, 2000)
- Freshwater EPA guideline for Total N: lakes 0.32 mg/l, rivers 0.71 mg/l

**2.5 mg/l**
- Increasing risk of impact to groundwater supplies and coastal habitat.

**5 mg/l**
- Public drinking water action level. Triggers additional monitoring.
- Standard adopted by some towns.

**10 mg/l**
- Drinking water standard.
- Acute health effects to infants. With “blue baby syndrome” nitrate replaces oxygen in blood.
- Suspected risk of cancer other health effects.
Topics

1. Why worry about nitrogen.
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How much Nitrogen comes from septic system vs. other sources?

One parcel vs. watershed?
1. Based on 3-bedroom house septic system with 1-acre.
2. Loss estimates based on 17,000 feet of lawn and forest.
3. Nitrogen application rate 5lbs./1000 sq. ft/yr; watered 1.5 inches/week.
4. Nitrogen application rate 5lbs/1000 sq ft/yr; watered 0.5 inches when dry.
5. Losses based on 17,000 sq ft of forest.

**Groundwater Nitrate-N Loading Mass balance**

**Source assumptions:**

**Septic System**
7 lbs N/person/yr  
90% Leaching = 6 lbs/person

**Pet Waste**
0.41 N/person/yr

**Lawn Fertilizer**
175 lbs N/ac/yr  
6-20% leaching = 10-35 lbs/acre

**Tilled Cropland**
175 - 215 lbs N/ac/yr  
20-30% leaching = 35-65 lbs/acre

**Forest and unfertilized Area**
1.2 lbs N/ac/yr

**Atmospheric** 8 lbs N/ac/yr  
- 15% leaching from forest  
- 100% input to surface waters and pavement.
Estimated Sources of Nitrogen to a rural / suburban coastal watershed

Pawcatuck Watershed RI
- 156,700 acres
- 73% forest & wetland
- 3% surface water
- 5.5% Cropland fertilized
- 99% unsewered
- Impervious 3 - 4% avg.
- Protected shoreline buffers - 83% vegetated.

URI MANAGE, 1995 land use
Estimated Sources of Nitrogen to a rural / suburban coastal watershed

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5.2 lbs N /acre /yr loading
1.1 mg/l NO3-N average in recharge

URI MANAGE, 1995 land use
Estimated Sources of Nitrogen to a developed Coastal Pond watershed

- **Green Hill Pond RI**
  - 3,400 acres
  - 14% surface water
  - 13% Impervious
  - 55% shoreline disturbed
  - 100% unsewered
  - Up to 8 units/acre
  - Shellfishing ban

- 14.2 lbs N /ac/yr loading to groundwater
- 3.4 mg/l NO3-N average in recharge
Caveats in using simplified nutrient loading models

• Screening level analysis designed best applied over entire aquifer, wellhead or watershed.

• Results useful in identifying relative impacts and location of pollution risks.

• Doesn’t address all sources, contaminants, and effluent plumes.

• Does not take into account N removal and delivery – an active area of research...
Riparian (shoreline) areas can be N treatment zones

Potential for denitrification as shallow groundwater moves through hydric soils

NO₃ → N₂O → N₂
Hydric soils in both wetlands and wetland buffers can be N sinks

Nitrogen removal rates

> 80% within wetlands generally

50-78% in high water table transition zones to wetlands.

Source: Simmons, R.C., A.J. Gold, and P.M. Groffman, 1992
Potential Denitrification Hot Spots

- Wet soils
- Land-Water interface at riparian zones
- Headwater streams
- Ponds and Reservoirs

Current Research Premise:
High resolution spatial data can improve identification, management and assessment of watershed N sinks

Digital topography & hydrography (1:24,000) apply digital elevation models to track

Source: Art Gold, D.Q. Kellogg, Kelly Addy, Suzanne Cox, Peter Groffman
Topics

1. Why worry about nitrogen
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Natural Landscape
- Low runoff
- High recharge
- Healthy summer stream flow
- Natural pollutant treatment

Developed
- High runoff, Low recharge
- Nuisance flooding
- Lower water tables
- Low stream flow
N movement with change in hydrology

- Increased N in runoff from land use activities and precipitation.
- Bypass natural filtering and treatment by plants and hydric soil.
Effect of Storm Drains and Shoreline Alteration:
Riparian ecosystem with potential for denitrification is lost

Original coastal wetland with high denitrification soils

Tile drain or stormdrain

Original ground surface

Fill

Retaining Wall

Stream
Effects of stormwater runoff on riparian areas

Stormdrains deliver higher and faster peak flows and volume.

Stream channels enlarged by incision and downcutting.

Lowered water tables with reduced ground water recharge and stream incision.

Managing Nitrogen

Control N source

• Agricultural fertilizers and manure
• OWTS loading – denite in high risk areas
• Residential lawn management.

Maintain Natural N Sinks

• Protect hydric soils, wetland buffers, and headwater streams.
• Use site design and stormwater management to maintain infiltration
Avoid conventional large lot development

Increases road frontage and pavement.
Consumes open space.
Compacted soils reduce infiltration, increases runoff volume
Large lawns often have high fertilizer, water use.
Water use in large lot subdivisions often 3 times higher in summer.
Conservation Development - compact, flexible subdivision and street design, low impervious.
Low maintenance bioretention area infiltrating runoff from a commercial site since 1999.

W. Kingston, RI
Engineered Swales, Bioretention Basins and Porous Pavers
Parking Strategies - based on actual demand, consider permeable pavement.
“Bioreactors” - A New Denitrification Method

Source: Betty Buckley, URI Graduate School of Oceanography
Bioreactor Future Trends?

• Small scale units installed at surface.

• Retrofit treatment units for tile drains and stormdrains.

• In-line applications for streams.

• Animal waste runoff treatment systems for pastures and feedlots.

Photo courtesy of Betty Buckley, URI Graduate School of Oceanography
Summary

1. Nitrogen concentration (mg/l) is a concern in groundwater drinking water supplies.

   Major sources:
   
   • Agricultural fertilizers and animal waste
   • Densely sited septic systems
   • Septic systems and other sources within inner protected well radius (100 ft private wells, 200-400 ft public wells).
2. Nitrogen loading (lbs/yr) is a concern in coastal watersheds.

Major sources:

- Septic systems
- Agricultural fertilizers and animal wastes
- Stormwater runoff and loss of natural N sinks.
- Location influences delivery to surface waters – shorelines, hydric soils.
3. Denitrification ‘hot spots’ reduce N delivery to coastal waters

- Hydric soils, riparian areas, headwater streams and ponds serve as N sinks.
- Landscape denitrification depends on groundwater recharge and flow paths.
- “Low impact” stormwater controls can help maintain or restore pre-development hydrology.
- Current URI research applies GIS to identify N sinks to support local land use decisions.
Thank you for your attention!

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Resources at www.uri.edu/ce/wq and ristormwatersolutions.org