The Fate of Onsite Septic System Nitrogen Discharges in Groundwater of the Hood Canal Basin

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Eutrophication and low dissolved oxygen
Hood Canal
Onsite Septic Systems (OSS) as a potential source of nitrogen loading
Denitrification – the key variable in determining the nitrogen load
Measuring denitrification in the Hood Canal basin
Substantial spatial and temporal variability in denitrification
U.S. Coastal ‘Dead Zones’ Associated with Human Activity

The color-coded flags indicate the decade or year in which the hypoxic event was first discovered (see map key). A location with more than one flag indicates it was identified as a hypoxic area from data in more than one decade or year. The prevalence of multiple events shows hypoxic conditions have not improved in any of our coastal and estuarine systems.

Eutrophication in Hood Canal

Hood Canal is an estuary where OSS N loading may exacerbate eutrophication.
What could affect oxygen?

- Change nutrient availability: septics, forest, runoff, pet waste, lawns
- Change ocean input: $O_2$, density
- Change organic biomass/production: better growing conditions, carcasses
- Change river input: flushing, stratification

Change light availability: more sun
Loading from OSS to Hood Canal

- Census data
- Trash output
- Traffic studies
- Seasonal population
- Per capita water use
- Household nitrogen
- Septic inputs
- Septic nitrogen effluent
- Nitrogen load to Hood Canal
- Denitrification rates
- Travel distance
- Groundwater velocity
- Nitrogen removal

Denitrification rates
Travel Distance
Groundwater velocity
Nitrogen removal
Nitrogen Fate and Transport

Septic Tank
Organic N → NH₄⁺

Drainfield

Drainfield and Vadose Zone
NH₄⁺ → NO₃⁻

Denitrification
NO₃⁻ → N₂

Groundwater Flow

N₂
Denitrification is the primary N removal process.

1. **Organic N** → **NH₄⁺** → **NO₂⁻/NO₃⁻** → **N₂**

**Requirements:**
1. Denitrifying microbial population
2. Anoxic conditions (DO < 0.2 mg/L)
3. Electron donor supply (carbon)
Denitrification Rates

N = 25
median = 0.06 mg/L/day

mg N removed/L/day

Frequency
Partial correlation $r$

Population $0.092$
Flow $0.315$
Concentration $0.946$
log(loss rate) $-0.762$
$1/\text{velocity}$ $-0.089$
Loading from OSS to Hood Canal

- Census data
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- Nitrogen load to Hood Canal
- Nitrogen removal
- Field Studies
- Denitrification rates
- Groundwater velocity
Field Site Locations

Hood Canal Basin

Clallam
Jefferson
Kitsap
Mason

HCDOP
Site Spatial Variability

- Upland
- Near-shore and Riparian
- Shoreline
Well Installation and Sampling
Field Site Set Up

- Septic Tank
- Drainfield
- Groundwater Monitoring Wells
Nitrogen Speciation: $\text{NH}_4^+ \rightarrow \text{NO}_3^-$

- Riparian Site
- Upland Site
- Septic Sampling Wells

$\text{NH}_4^+$ (mg/L N) vs. $\text{NO}_3^-$ (mg/L N)
Modeling of OSS N Removal

Chloride (mg/L) vs. TN (mg/L) plot showing the relationship between chloride concentration and TN concentration. The graph includes data points and bars indicating different concentrations: 0, 50, and 100 mg/L. The title and axis labels are clearly visible.
Upland: Nitrogen Removal

Upland site – Year 1
Partial removal ~ 40%

Upland site – Year 2
Partial removal ~ 66%
Extensive N removal ~ 92%
Near-shore: Nitrogen Removal

- Complicating factors – extent of removal difficult to determine.
- Nitrogen removal likely ~30 %
Shoreline: Nitrogen Removal

DIN Removal Probability for Wells Adjacent to Bulkhead

Little removal ~ 30%
Challenges

- Groundwater accessibility
- Dilution
- Multiple OSS sources
- Complex geology and groundwater flow paths
- Heterogeneity
Spatial N Removal Variability

Upland

Partial Removal

Near-shore and Riparian

Extensive Removal

Little Removal

Shoreline

Little Removal
Conclusions

- OSS ammonium is typically converted to nitrate.
- Denitrification is occurring in some locations around Hood Canal.
- The extent of denitrification varies spatially and temporally.
- Further research can be conducted to explore denitrification limiting conditions.
- Problems with scaling up and with rates.
- Common challenges with denitrification research.
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Thank you!