CAULWELL ENGINEERING GEOSCIENCE

State of nitrogen reduction certification and regulation in North America and a brief update on two case studies involving the use of permeable reactive barriers for passive nitrate (and pathogen) removal from onsite wastewater effluent.

Bryer Manwell, M.Sc., P.Eng. (bryer@caulwell.ca), Hydrogeological Engineer

CaulWell Engineering and Geoscience Ltd.

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The opinions and views being expressed are those of the authors and not those of NOWRA.

Presentation Overview

- Presenter Introduction
- Presentation Objectives:
  - Better understand nitrate renovation from onsite wastewater effluent
  - Review potential Onsite WW Nitrate Contamination
  - Nitrogen Cyle in Onsite Wastewater Treatment
  - Global Initiatives to Reduce Nitrate Contamination
  - Provide a summary of Regulations or Guidance Documents that Address Nitrate Contamination and Renovation from Onsite WW Systems

Presentation Overview (con’t)

- Review Nitrogen Reduction Certification in North America
- Provide information on Solution Focused – Low Carbon Resilience In Situ Effluent Polishing (Permeable Reactive Barriers) and validation of Design (Plan), Ongoing Maintenance and Monitoring (monitored natural attenuation)

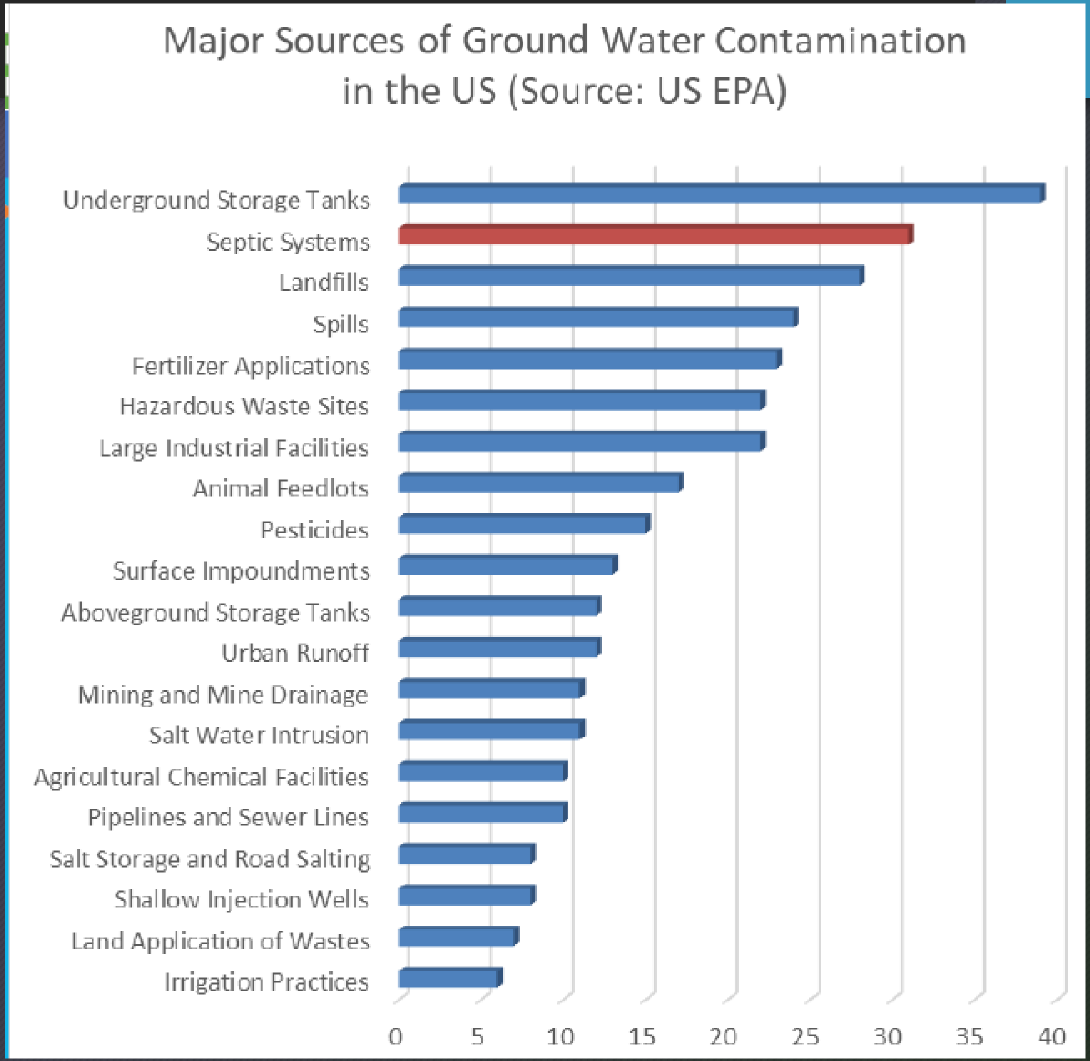
- Question Time

Who are we?

Bryer Manwell M.Sc., P.Eng. – Hydrogeological Engineer (hydrogeologist)

- 24+ years experience in solution focused environmental engineering and geoscience throughout Canada
- M.Sc. – Environmental Engineering – specializing in hydrogeology (U of C)
- Owner of Caulwell Engineering and Geoscience Ltd.
- Registered Professional in British Columbia, Canada
- Consultant:
  - Groundwater Supply Development
  - Contaminant Hydrogeology
  - Published on NO3 and Cl in Environment
  - Supports the onsite wastewater industry
- Volunteered on the Board of Directors for WCOWMA British Columbia (2014 to 2019)

Nitrate Contamination of the Receiving Environment



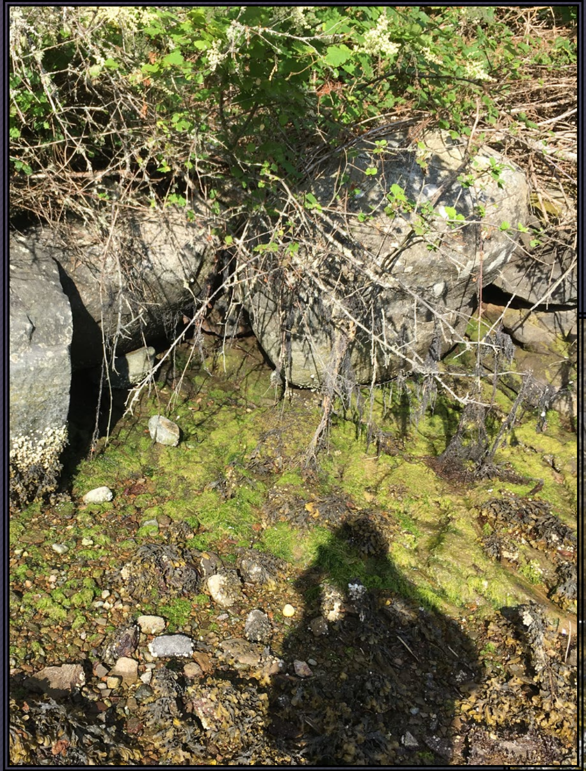
Nitrate Contamination of the Receiving Environment

Onsite Wastewater Effluent is a Potential Not Point Source Pollution, meaning it is diffuse and not from "end-of-pipe" (point source)

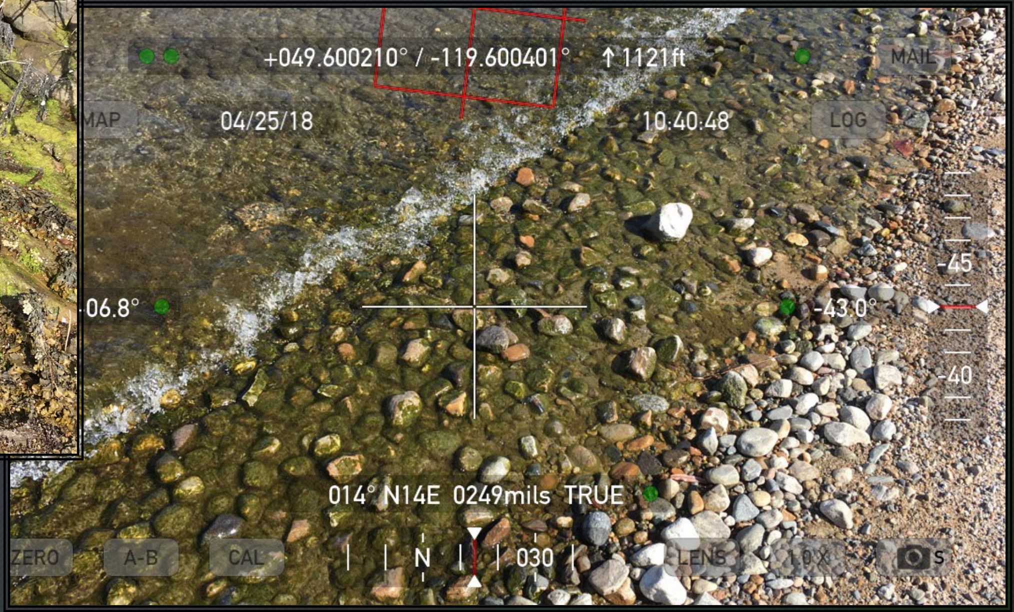
- Anthropogenic (human) Sources
  - Agriculture
  - Fisheries
  - Blasting (mining)
  - Industrial
  - Wastewater
    - Municipal (Biosolids)
    - Onsite

Nitrate Contamination of the Receiving Environment from Onsite Wastewater

Galiano Island 2018 – Eutrophication from Onsite- Pacific Ocean



Naramata 2018 – Eutrophication from Onsite- Okanagan Lake Shoreline

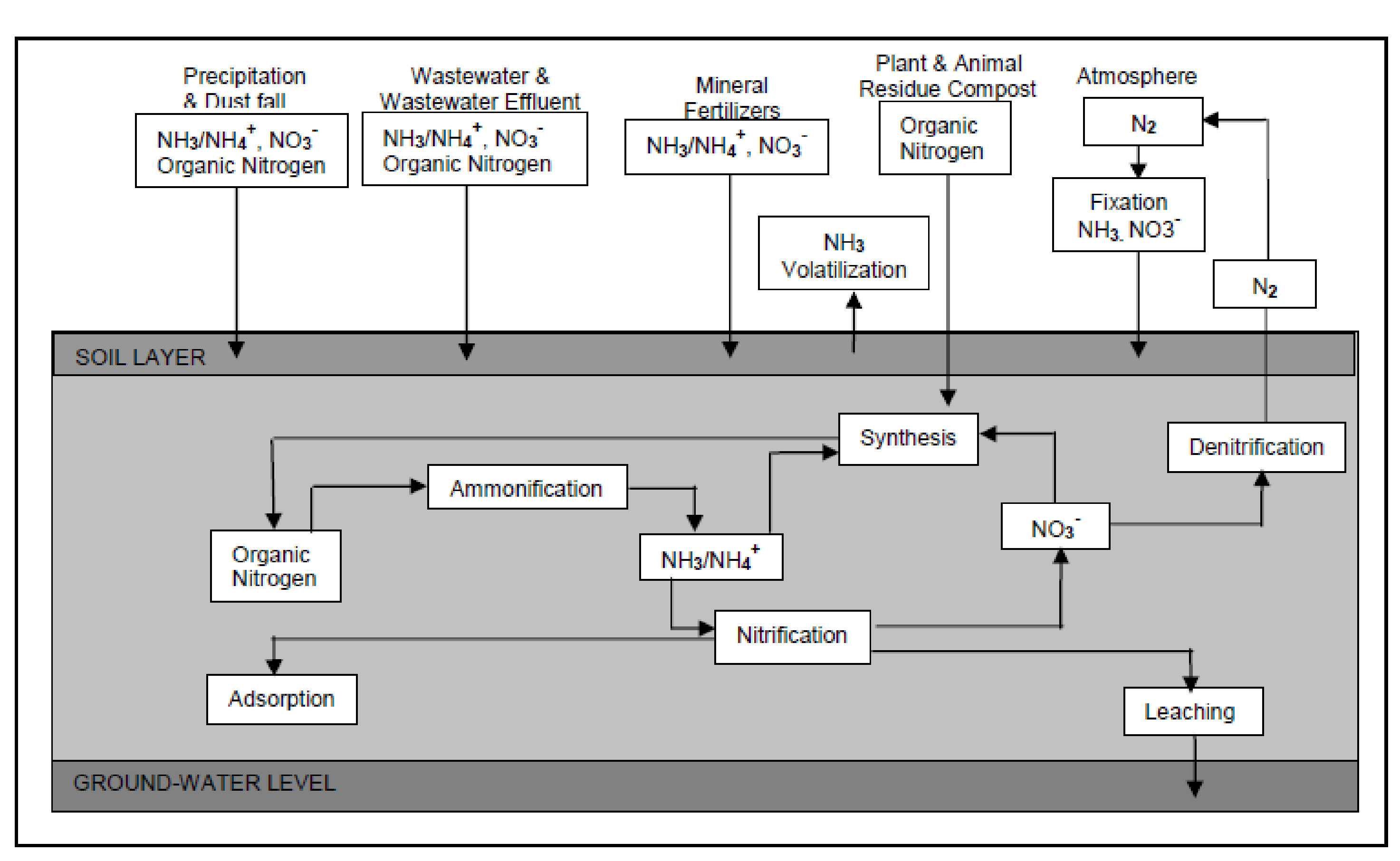


October 2024 - Bryer Manwell, M.Sc., P. Eng. (bryer@caulwell.ca)

Primary Factors Affecting Onsite Wastewater Nitrate Loading to Surface Waters

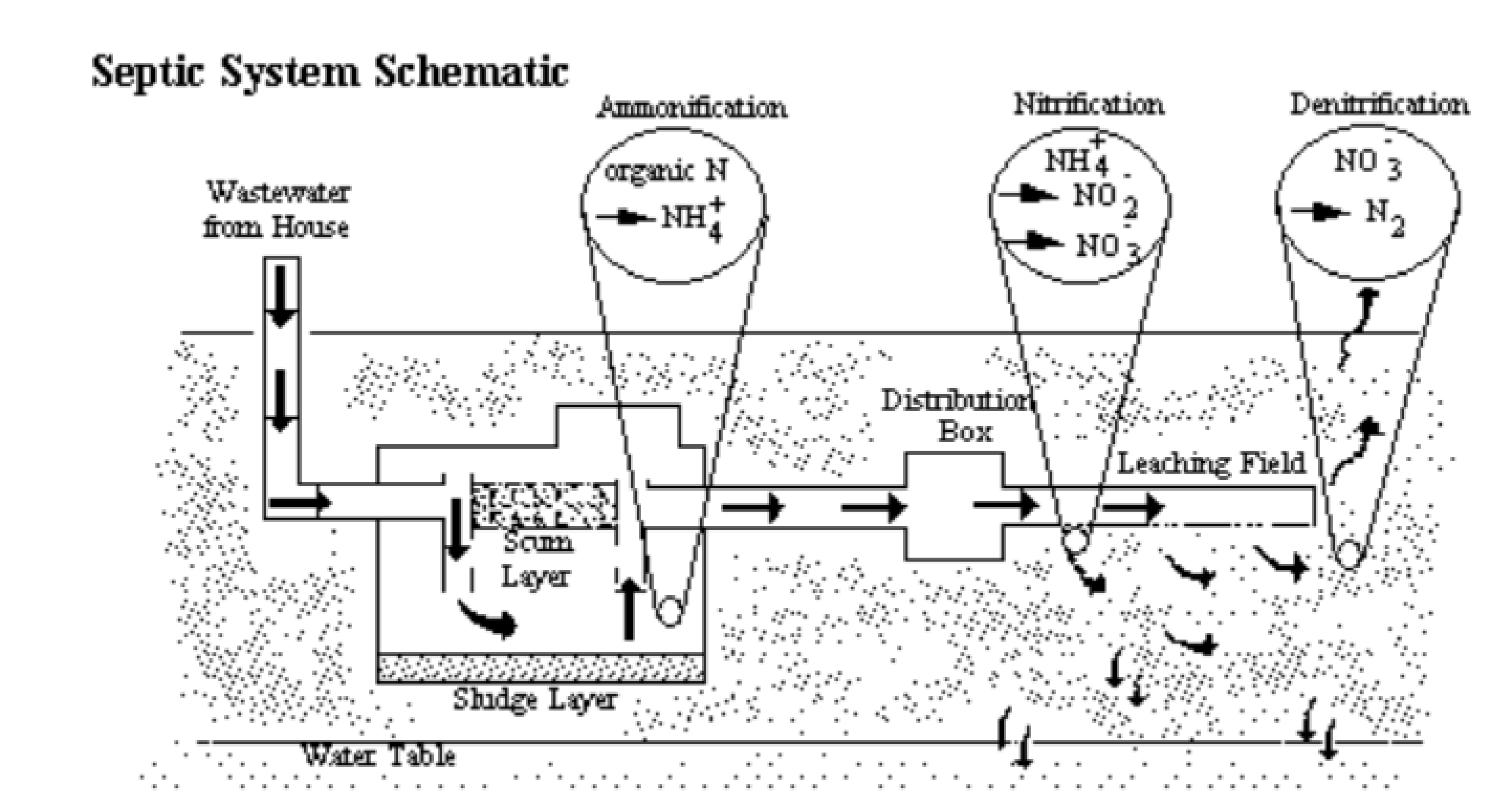
- Density (population and land-use)
- Hydrogeological Setting
  - Vertical and horizontal separations
    - Depth to groundwater /rate limiting layers
    - Annual fluctuations of water table
- Planning, Installation and Maintenance
  - Performance Based Monitoring (Monitored Natural Attenuation)

Nitrogen Cycle



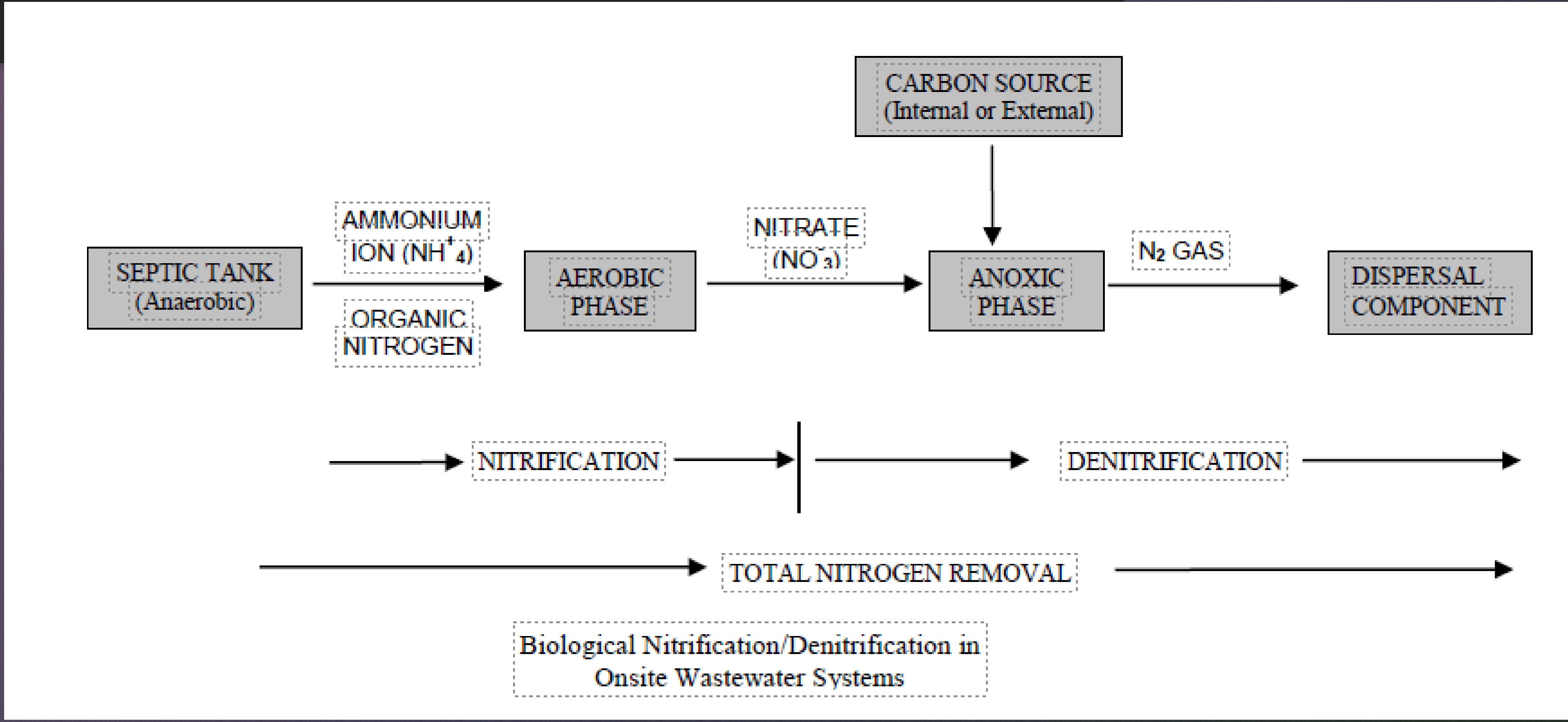
Washington State Department of Health 2005
https://doh.wa.gov/sites/default/files/legacy/Documents/Pubs/337-093.pdf

Nitrogen Cycle in Onsite Wastewater



http://ecosystems.mbl.edu/Research/Clue/onsite.html

Nitrogen Cycle in Onsite Wastewater



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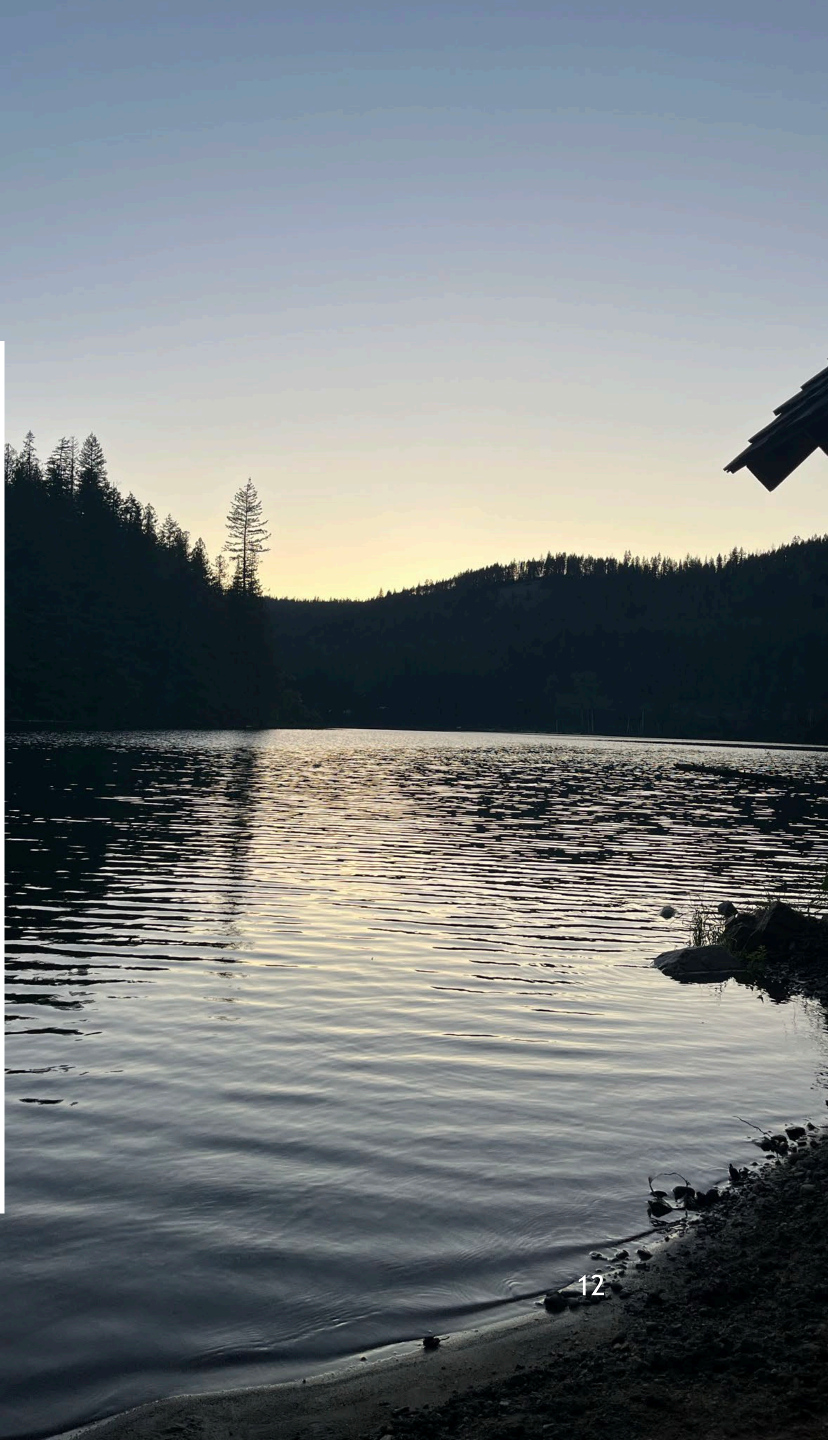
Onsite Wastewater Technologies to Reduce Nitrogen

Table 1. Standard technologies for removing NH_3/NH_{4^+} from wastewater.

Method	Working Environment	Advantage	Shortcoming	Outlet Concentration (mg/L NH_4–N)	Removal Efficiency
Chemical precipitation [41,42]	Requires a specific pH and temperature	Produces valuable fertilizers at a moderate cost	Requires additional magnesium source; incurs phosphate cost; introduces new contaminants	29–100	20–98%
Adsorption method [43,44]	Broad temperature and pH range	Simple and effective removal of NH_{4^+}; able to work at low NH_{4^+} concentrations	Adsorbents have different removal efficiencies	1	43–97%
Biological method [29,45]	Heterotrophic, photosynthetic algal, or bacterial growth is temperature sensitive	No need for chemical reagents and complicated configurations; high denitrification efficiency	High cost; requires external carbon source; only operates at low input/output concentrations; long start-up time	<5	70–99.9%

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9967642/



Onsite Wastewater Technologies to Reduce Nitrogen

Technology Examples		Total-N Removal Efficiency, %	Effluent Total-N (mg/L)
Suspended Growth:			
	Aerobic units w/pulse aeration	25-61[1]	37-60[1]
	Sequencing batch reactor	60[2]	15.5[2]
Attached Growth			
	Single-Pass Sand Filters (SPSF)	8-50[3]	30-65[3]
	Recirculating Sand/Gravel Filters (RSF)	15-84[4]	10-47[4]
	Multi-Pass Textile Filters	14-38[5, 9]	9-83[5, 9]
	RSF w/Anoxic Filter	40-90[6]	7-23[6]
	RSF w/Anoxic Filter w/external carbon source	74-80[7]	10-13[7]
	RUCK system	29-54[8]	18-53[8]
	Nitrex	96[10]	2.2[10]

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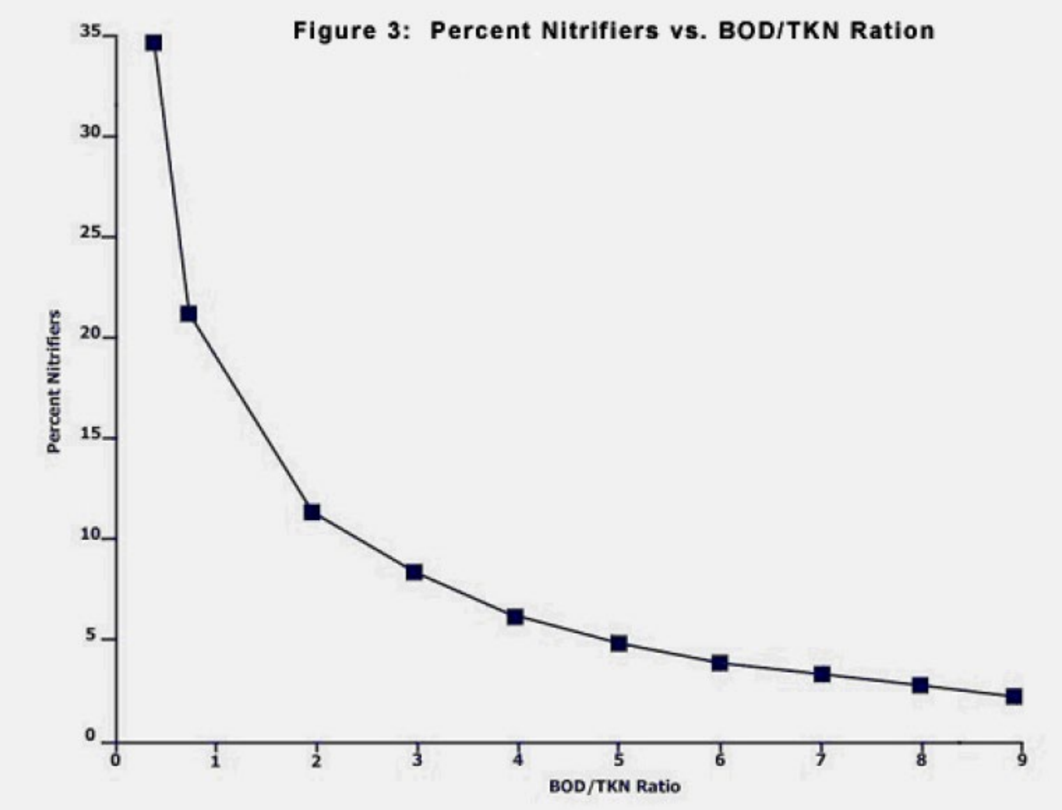
Onsite Wastewater Technologies to Reduce Nitrogen



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Onsite Wastewater Technologies to Reduce Nitrogen

Treatment performance efficiencies is due to the inter-relationship of numerous factors including:

- Fluctuating flow rates
- Variability in waste strengths
- Complexities in the biological and chemical treatment processes
- Temperatures
- pH and Alkalinity
- Inhibitory chemical compounds
- Increased complexity of the additional mechanical devices such as pumps, filters, timers, controllers, etc. that are added to the process.

Inorganic Compounds		Organic Compounds
Zinc	Thiocyanate	Acetone
Free Cyanide	Sodium cyanide	Carbon Disulfide
Perchlorate	Sodium azide	Chloroform
Copper	Hydrazine	Ethanol
Mercury	Sodium cyanate	Phenol
Chromium	Potassium chromate	Ethylenediamine
Nickel	Cadmium	Hexamethylene diamine
Silver	Arsenic	Aniline
Cobalt	Fluoride	Monoethanolamine
Lead	FreeAmmonia	
Free Nitrous Acid		

Inhibitory chemical compounds

Global Initiatives to Reduce Nitrate Contamination

- UN Sustainable Development Goals (SDG's) - Goal 6 Clean Water and Sanitation - Human activities, on the global scale, have doubled the natural cycle of nitrogen in the environment

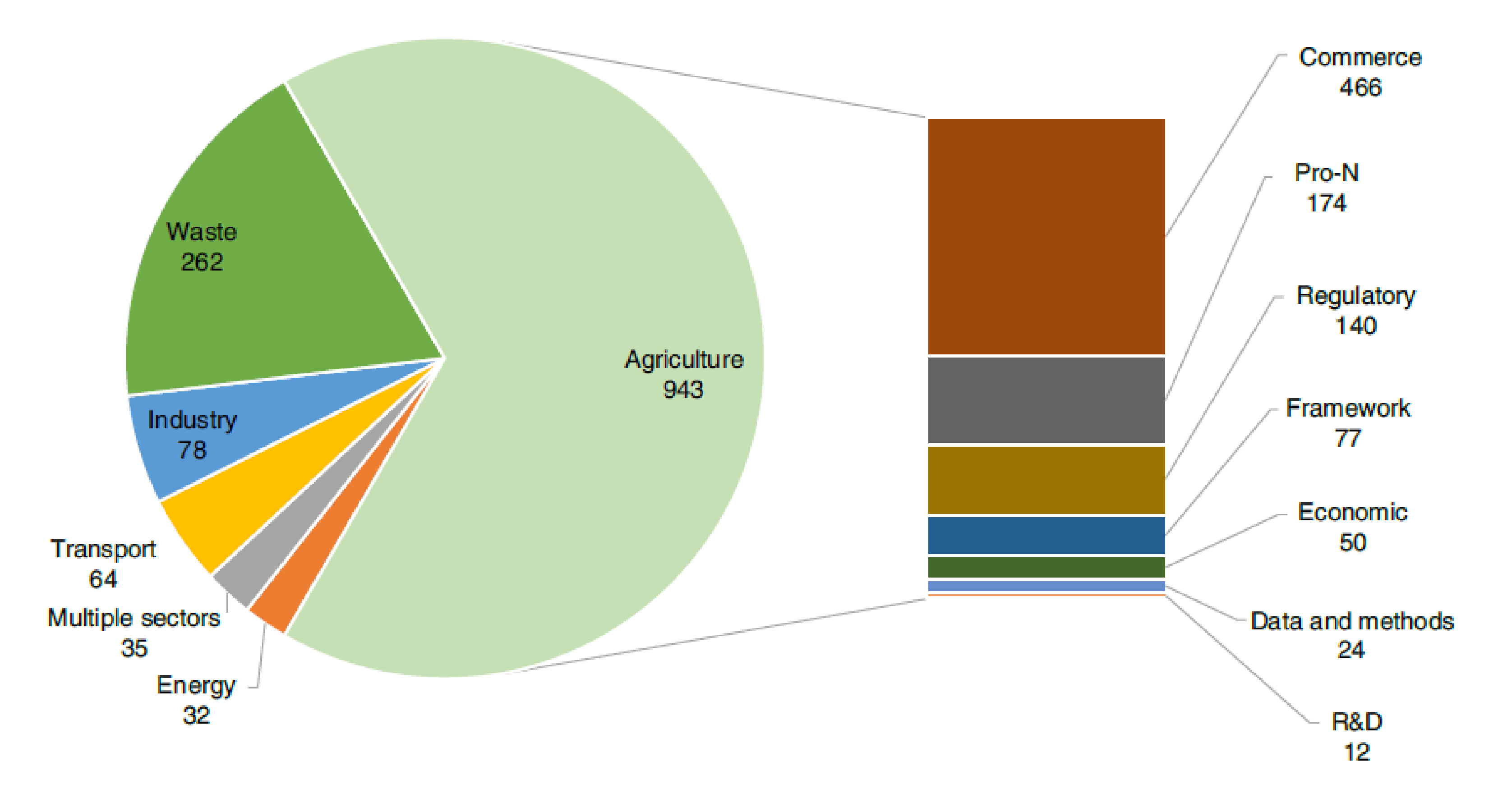
- One in three people do not have access to safe drinking water – groundwater has been considerably damaged by human activities. https://www.sciencedirect.com/science/article/pii/S0048969721073095

- Align the integrated management of nitrogen with the UN Sustainable Development Goals https://iopscience.iop.org/journal/17489326/page/Focus_on_Reactive_Nitrogen

Global Initiatives to Reduce Nitrate Contamination

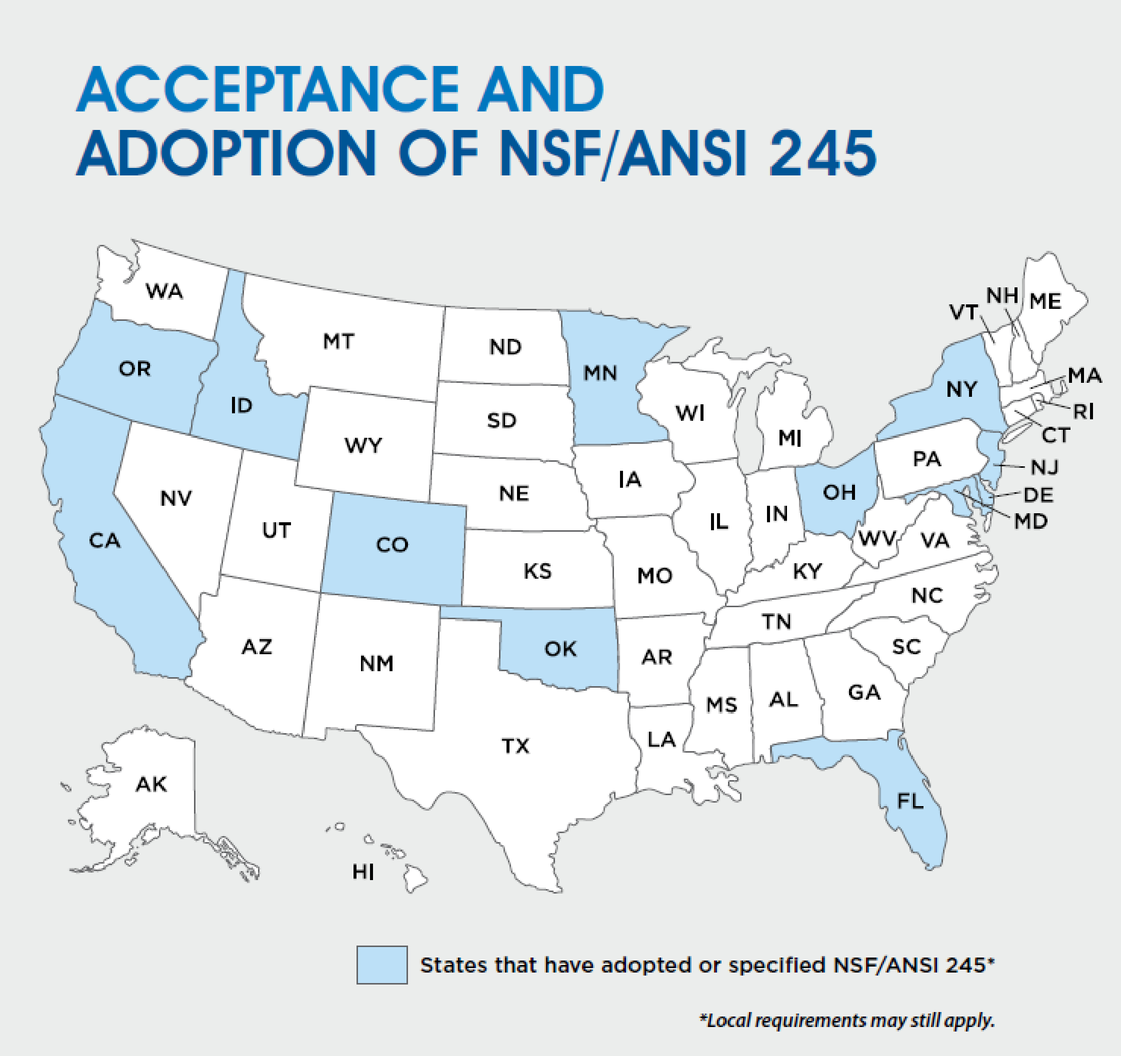
- UN Sustainable Development Goals (SDG's) Goal 6: Clean Water and Sanitation
  - 6.3 By 2030, improve water quality by reducing pollution
  - 6.5 By 2030, implement integrated water resources management at all levels
  - 6.6 By 2020, protect and restore water-related ecosystems
  - 6.7 A By 2030, expand international cooperation and capacity -building support for wastewater treatment, recycling and reuse technologies

Distribution of N policies by sector and breakdown of agricultural policy types



Gaps and opportunities in nitrogen pollution policies around the world (Kanter et al 2020)

Testing of Onsite Wastewater Technologies that Reduce Nitrogen



www.nsf.org

Testing of Onsite Wastewater Technologies that Reduce Nitrogen

- NSF/ANSI 245 for nitrogen reduction provides access to the on-site residential wastewater market in which total nitrogen reduction is a requirement.
- NSF/ANSI 245 requires 50% reduction for total nitrogen to meet the growing demand for nutrient reduction in coastal areas and sensitive environments.
- Certification to NSF/ANSI 245 also meets all the requirements of NSF/ANSI 40

https://d2evkimvhatqav.cloudfront.net/documents/ww_nsf_40_and_245.pdf

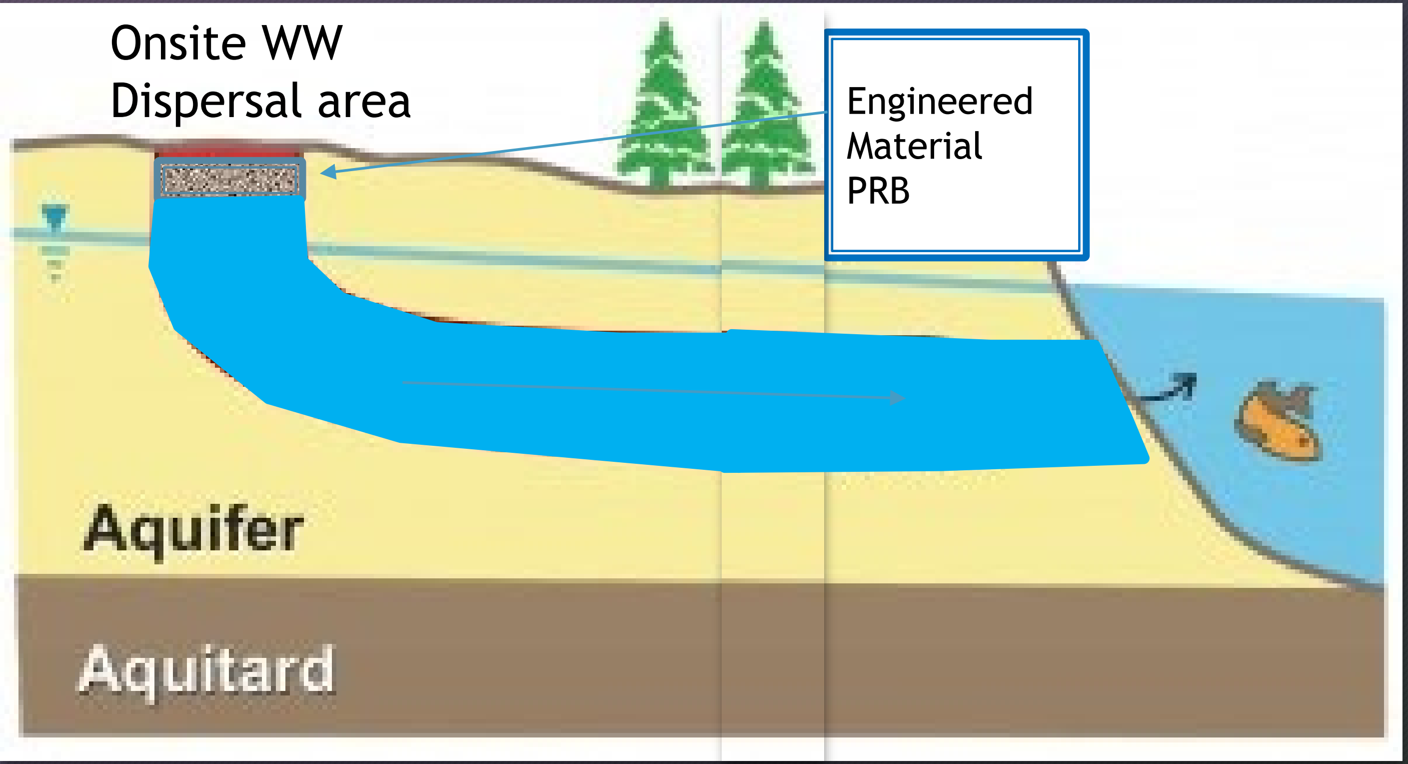
Nitrogen Reduction Regulation in North America

- Local, regional or provincial (state) by-laws
- Federal sponsorship (i.e. Quick Reference Guide for Best Management Practices Nonpoint Source BMPs to Reduce Nitrogen, Phosphorus and Sediment Loads to the Chesapeake Bay and its Local Waters – US EPA)
- Not succinct
- In Canada we relay on Guidance Documents as opposed to regulation:
  - British Columbia - Professional Practice Guidelines Onsite Wastewater (EGBC 2018)
  - Ontario – **D-5-4 Individual On-Site Sewage Systems: Water Quality Impact Risk Assessment (MOEE 2024)**

Planning
Solution Focused - In Situ Effluent Polishing (Permeable Reactive Barrier)

- Application - Small lots near surface waters
- Engineered Material - Adding a carbonaceous material (i.e. zeolite, hog fuel) to the sand component of the dispersal area (i.e. trench, seepage bed, sand mound)
- Material must allow for adequate hydraulic loading rate over-time (no clogging), while providing passive treatment for nitrate (and pathogenic bacteria) reduction.

Adding In Situ Effluent Polishing (PRB) to Onsite Wastewater Designs



Installation – Consider Long-term Monitoring

- Locations of Sampling
  - Effluent from ATU
  - Point of Application (pan lysimeters)
  - Environmental Monitoring
    - Near-surface groundwater sampling
    - Water Wells

Maintenance Plan - Long-term Monitoring

- Parameters Sampling
  - Effluent from ATU
    - BOD, TSS, NO3, Cl, Alk, EC, pH
  - Environmental Monitoring to assess fate of effluent
    - NO3, Cl, Alk, EC, pH, Temp

Maintenance Plan - Long-term Monitoring

- Two site examples from British Columbia
  - 35 homes - Polishing Cells
  - Trailer park – passive PRB beneath dispersal area

Effluent Quality Monitoring – example - remote nitrate sensor

Performance Objectives at Compliance Boundary
(Hyporheic Zone Downgradient of New Dispersal Area)

Boundary	Water Quality Objectives	Water Sample Taken From	Notes
Flow Restrictive Horizon (water table)	Nitrate: 10 mg/l	Compliance boundary (for this site, the hyporheic zone, to be installed during system installation).	Nitrate monitoring sonde installed in monitoring well (piezometer) for continuous monitoring.


IN-SITU AQUA TROLL® 600
Multiparameter Sonde

Aqua TROLL® 600 Multiparameter Sonde

Reduce operational expenses with this customizable, powerful, and easy-to-use multiparameter sonde. The Aqua TROLL 600 combines unique industry-leading water quality technology, built-in LCD display, and revolutionary smartphone mobility. Low power consumption and advanced antifouling for up to 9+ month deployment supports long-term installation in any application.

The Aqua TROLL 600 water quality platform is rugged in groundwater and corrosion-resistant in surface water, delivering accurate, reliable data in an easy-to-use, flexible instrument that performs for years. Base sensor configuration includes EPA-approved optical dissolved oxygen, pH/ORP, turbidity, conductivity, temperature, and pressure. Integrate with In-Situ telemetry systems and HydroVu™ Data Services for real-time feedback on your remote monitoring sites.

Be Mobile

- **Use the Aqua TROLL 600 anywhere:** Titanium components and vented or non-vented options make it perfect for challenging environments and long-term deployments in fresh and salt water. Every detail has been engineered to be easy, reliable, and cost-effective.
- **Save time in the field:** Intuitive software simplifies instrument configuration, data analysis, and reporting. No training required, and no waiting for sensor warm-up or set-up.
- **Streamline data management**: Set up logs and manage data from the field using the VuSitu™ Mobile App. Consolidate all site information on your mobile device and tag sites with photos and GPS coordinates. Log data to your smartphone and download results in a standard file format for profiling, low-flow sampling, and more.

Be Smart

- **Status in an instant**: LCD display gives you an instant visual indication of sensor status, data log, battery life, and overall functionality to give confidence during deployment. The onboard SD card allows for quick and easy data backup and transfer.
- **No fuss antifouling**: Antifouling to protect all sensors. The only multiparameter sonde to have a sub-2 inch active antifouling system with cleanable conductivity.
- **Get accurate results**: Self-compensating tubidity/RDO/level, smart diagnostics, and stable sensor technology provide minimal drift and increased accuracy with NIST-traceable factory calibration report. Smart sensors store information internally, maintaining data and calibration within the sensor for traceable results.

Be In-Situ

- Receive 24/7 technical support and online resources.
- Order products and accessories from the In-Situ website.
- Get guaranteed 7-day service for maintenance (U.S.A. only).

Applications

- **Lake, stream and wetland monitoring**
- **Stormwater management**
- **Coastal deployments**
- **Dam monitoring**

Maintenance

- During Field Review – Planner, Installer and future Maintenance Provider should be present
- Training- environmental sampling and maintaining records
- Validation (audit)
- Better Buy-in from property owners (retainer for 3-years post installation)

In Summary

- Human derived nitrogen is considered a global issue and onsite water is regarded as the second most significant source of groundwater contamination in the US by the EPA

- Regulation around nitrogen reduction is not succinct and is based on regional and local nitrogen loading issues (i.e. density and proximity to surface water bodies)

- The primary parameter of concern from onsite wastewater impacting foreshore environments in British Columbia, Canada is nitrate

In Summary (con't)

- NSR / ANSI 245 testing standard is the current North America certification for nitrogen reduction technology

- Adding passive polishing (PRB) of nutrient and pathogen to an onsite wastewater plan (design) is a Low-Carbon Resilience method of reducing nitrogen in the effluent as it enters the receiving environment (groundwater)

- Performance-based monitoring (monitored natural attenuation) to prove system design effectiveness

Questions

Bryer Manwell, M.Sc., P.Eng. (bryer@caulwell.ca)

Krista Podwin, M.Sc., P.Eng. (kspseptic@shaw.ca)