NYS Center for Clean Water Technology

Developing robust and cost-effective non-proprietary solutions for onsite residential wastewater disposal on Long Island: Nitrogen Removing Biofilters

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NYS CCWT
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Groundwater Nitrogen on Long Island

1950

200,000 people
1.5 million lbs N/yr

6 million ducks
1.8 million lbs N/yr

2022

1.5 million people
15 million lbs N/yr

One duck farm
Suffolk County: 380,000 septic systems leaching into the aquifer

Figure 2-25 Nitrogen Load Components to the 191 Subwatersheds
Substantial number of epidemiological studies on impact of drinking water nitrogen on human health in last two decades

Exposure-based assessment and economic valuation of adverse birth outcomes and cancer risk due to nitrate in United States drinking water.

Alexis Temkin,a,*, Sydney Evans,a Tatiana Manidis,b Chris Campbell,a Olga V. Naidenko,a

a Environmental Working Group, 1436 U Street NW Suite 100, Washington, DC, 20009, USA
b Duke University, Nicholas School of the Environment, 9 Circuits Dr, Durham, NC, 27710, USA

Colorectal cancer risk and nitrate exposure through drinking water and diet

Nadia Espejo-Hernera,1,2,3, Esther Gracia-Lavedana,1,2,3, Elena Bolida,1,2,3, Nufa Arangonesa,1,2,3, Beatriz Pérez-Gómeza,1,2,3

Nitrate from Drinking Water and Diet and Bladder Cancer Among Postmenopausal Women in Iowa

Rena R. Jones,1 Peter J. Weyer,2 Curt T. DellaValle,1 Maki Inoue-Choi,1,3 Kristin E. Anderson,4,5 Kenneth P. Cantor,1
Stuart Krasner,6 Kim Robien,7 Laura E. Beane Freeman,1 Debra T. Silverman,1 and Mary H. Ward1

Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study

Jörg Schullehner1,2,3,4, Birgitte Hansen2, Malene Thygesen3,4, Carsten B. Pedersen3,4 and Torben Sigsgaard1
Impacts of excess nitrogen on marine and lacustrine ecosystems

- Turbidity
- Loss of benthic plants
- Loss of aquatic nurseries and ecosystem biodiversity
- Algal blooms and oxygen stripping leading to fish kills
- Harmful algal blooms
Cesspools do not remove nitrogen.

Robust treatment systems that achieve low nitrogen concentrations at reasonable cost and with low maintenance requirements are needed
Basic principle of coupled nitrification denitrification in a Nitrogen Removing Biofilter (NRB)

<table>
<thead>
<tr>
<th>Lawn</th>
<th>8&quot; Top Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STE Distribution System</td>
</tr>
<tr>
<td>18&quot;</td>
<td>Nitrifying Sand Layer</td>
</tr>
<tr>
<td></td>
<td>Ammonium,</td>
</tr>
<tr>
<td></td>
<td>Nitrate,</td>
</tr>
<tr>
<td>18&quot;</td>
<td>Denitrifying Sand/Lignocellulose Layer</td>
</tr>
<tr>
<td></td>
<td>Nitrogen Gas</td>
</tr>
</tbody>
</table>

Nitrification: \[
\text{NH}_3 + 2 \text{O}_2 \rightarrow \text{NO}_3^- + \text{H}^+ + \text{H}_2\text{O}
\]

Denitrification: \[
5\text{C}_6\text{H}_{12}\text{O}_6 + 24\text{NO}_3^- \rightarrow 12\text{N}_2 + 24\text{HCO}_3^- + 6\text{CO}_2 + 18\text{H}_2\text{O}
\]
Three NRB designs

- Final effluent disposal to groundwater
- Woodchip biofilter subject to flow: no flow cycles where denitrification may be less efficient

Unlined NRB

- Effluent collected so requires final disposal
- Sand bed coupled to woodchip box
- High surface area of woodchips in box enhances denitrification

Nitrogen Target < 15 mg-N/L

Groundwater

Nitrogen Target < 15 mg-N/L
Total Nitrogen in Final Effluent
Article 19 means and %N removal

< 19 mg-N L⁻¹

<table>
<thead>
<tr>
<th></th>
<th>TN FE (mg-N/L)</th>
<th>% N removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>unlined NRB</td>
<td>15.4</td>
<td>77%</td>
</tr>
<tr>
<td>Lined NRB</td>
<td>7.5</td>
<td>80%</td>
</tr>
<tr>
<td>WCB</td>
<td>14.0</td>
<td>87%</td>
</tr>
</tbody>
</table>
Comparison of I/A performance in Suffolk County

- CCWT at Stony Brook systems (being piloted)
- Provisionally approved systems
- Piloted systems

Suffolk County standard

Total N in effluent (mg/L)
Wastewater contains more than nitrogen...
1,4-dioxane is a probable carcinogen, according to US EPA. NRBs removed 1,4- dioxane to \(< \) the NYS drinking water standard \((1 \mu g \ L^{-1})\)
50 – 100% removal of two dozen drugs, pharmaceuticals, personal care products by NRBs in Suffolk County (better removal than sewage treatment plants)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Use</th>
<th>Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaminophen</td>
<td>NSAID</td>
<td>94 – 100</td>
</tr>
<tr>
<td>Caffeine</td>
<td>stimulant</td>
<td>99 – 100</td>
</tr>
<tr>
<td>Paraxanthine</td>
<td>human metabolite of caffeine</td>
<td>98 – 99</td>
</tr>
<tr>
<td>DEET</td>
<td>mosquito repellent</td>
<td>82 – 96</td>
</tr>
<tr>
<td>Nicotine</td>
<td>stimulant</td>
<td>92 – 97</td>
</tr>
<tr>
<td>Cotinine</td>
<td>human metabolite of nicotine</td>
<td>86 – 98</td>
</tr>
<tr>
<td>Sulfamethoxazole</td>
<td>antibiotic</td>
<td>85 – 97</td>
</tr>
<tr>
<td>Diphenhydramine</td>
<td>antihistamine</td>
<td>97 – 95</td>
</tr>
<tr>
<td>Trimethoprim</td>
<td>antibiotic</td>
<td>87 – 90</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td>antibiotic</td>
<td>64 – 78</td>
</tr>
<tr>
<td>Atenolol</td>
<td>beta blocker</td>
<td>88 – 97</td>
</tr>
<tr>
<td>Metoprolol</td>
<td>beta blocker</td>
<td>85 – 90</td>
</tr>
<tr>
<td>Diltiazem</td>
<td>calcium channel blocker</td>
<td>76 – 90</td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>anticonvulsant</td>
<td>51 – 60</td>
</tr>
<tr>
<td>Ketoprofen</td>
<td>NSAID</td>
<td>68 – 74</td>
</tr>
<tr>
<td>TCEP</td>
<td>flame retardant</td>
<td>60 – 70</td>
</tr>
<tr>
<td>Salbutamol</td>
<td>bronchodilator</td>
<td>50 – 78</td>
</tr>
<tr>
<td>Ranitidine</td>
<td>anti-acid</td>
<td>82 – 100</td>
</tr>
<tr>
<td>Diclofenac</td>
<td>NSAID</td>
<td>76</td>
</tr>
<tr>
<td>Propranolol</td>
<td>beta blocker</td>
<td>98 – 100</td>
</tr>
<tr>
<td>Venlafaxine</td>
<td>antibiotic</td>
<td>98</td>
</tr>
<tr>
<td>Fluoxetine</td>
<td>antidepressant (SSRI)</td>
<td>64 – 66</td>
</tr>
<tr>
<td>Lamotrigine</td>
<td>anticonvulsant</td>
<td>82</td>
</tr>
<tr>
<td>Primidone</td>
<td>anticonvulsant</td>
<td>58</td>
</tr>
</tbody>
</table>

Data courtesy of Dr. Tricia Clyde
### Phosphorus removal from NRBs

(Data collected since June 2021)

<table>
<thead>
<tr>
<th>Site number</th>
<th>Configuration</th>
<th>Operation duration (months)</th>
<th>P Removal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lined</td>
<td>5</td>
<td>58.9</td>
</tr>
<tr>
<td>2</td>
<td>Lined</td>
<td>6</td>
<td>94.0</td>
</tr>
<tr>
<td>3</td>
<td>Lined</td>
<td>27</td>
<td>62.3</td>
</tr>
<tr>
<td>4</td>
<td>Lined</td>
<td>30</td>
<td>95.6</td>
</tr>
<tr>
<td>5</td>
<td>Lined</td>
<td>43</td>
<td>71.6</td>
</tr>
<tr>
<td>6</td>
<td>Box</td>
<td>17</td>
<td>80.2</td>
</tr>
<tr>
<td>7</td>
<td>Box</td>
<td>32</td>
<td>95.9</td>
</tr>
<tr>
<td>8</td>
<td>Unlined</td>
<td>5</td>
<td>82.4</td>
</tr>
<tr>
<td>9</td>
<td>Unlined</td>
<td>6</td>
<td>70.2</td>
</tr>
<tr>
<td>10</td>
<td>Unlined</td>
<td>34</td>
<td>85.7</td>
</tr>
<tr>
<td>11</td>
<td>Unlined</td>
<td>43</td>
<td>75.2</td>
</tr>
</tbody>
</table>
Advancing NRBs to from pilot testing to provisional acceptance permitting

**Experimental** → **Pilot Required units: 8** → **Provisional Required units: 20** → **General Use**

- **unlined NRB**
- **Lined NRB**
- **Woodchip box NRB**

- Anticipated decision on Provisional Acceptance: Q1-2023
- Anticipated decision on Provisional Acceptance: Q1-2023
- Additional installs Fall 2022; testing and anticipated decision on Provisional Acceptance by year-end 2023

**Center initiated grant financing of installations** → **Commercial transact potential w/ SIP grants**
NRB installations on a commercial basis under provisional permitting

• Carbon longevity
• Footprint & landscaping
• Cost
• Installation time
Carbon Longevity

TN influent 25 - 29 mg/L

Unsaturated Columns
Nitified effluent HLR 0.6 g/sq ft/day

Saturated Columns
Nitified effluent HLR 0.6 g/sq ft/day

6 year in-ground
Unlined NRB prototype

Low pressure time dosed
shallow drainfield
Unlined NRB
~ 600 ft²
Required depth to groundwater ~ 8'

Footprint of unlined NRB, landscaping
Design alternatives for a Four-bedroom home on ½ acre plot

**Unlined NRB**
~ 600 f²
Required depth to groundwater ~ 8'

**I/A OWTS**
8' X 12' leaching pool
~ 50 f²
Depth to groundwater > 17'

Unlined NRB
~ 600 f²
Required depth to groundwater ~ 8'

I/A OWTS
8' X 12' leaching pool
~ 50 f²
Depth to groundwater > 17'
Design Alternatives:
4 bedroom house on ½ acre

Unlined NRB
~ 600 f²
Required depth to groundwater ~ 8'

~ 600 f²
Required depth to groundwater ~ 8'

I/A OWTS
3 4' precast galleys
~ 140 f²
Depth to groundwater < 9'

I/A OWTS
Gravelless absorption bed
~ 520 f²
Depth to groundwater ~ 7- 8'
## Equipment & materials costs: unlined NRB at four-bedroom site

<table>
<thead>
<tr>
<th></th>
<th>Unlined NRB</th>
<th>Proposed model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septic Tank</td>
<td>1,500 precast</td>
<td>$2,200</td>
</tr>
<tr>
<td>Pump Tank</td>
<td>1,000 precast</td>
<td>2,200</td>
</tr>
<tr>
<td>electrical panel</td>
<td>Orenco</td>
<td>900</td>
</tr>
<tr>
<td>pump/float/inducer</td>
<td>simplex</td>
<td>1,400</td>
</tr>
<tr>
<td>pipes &amp; fittings, liner</td>
<td></td>
<td>750</td>
</tr>
<tr>
<td>Geomat</td>
<td>100’ roll</td>
<td>1,400</td>
</tr>
<tr>
<td>sand</td>
<td>50 cy $45</td>
<td>2,250</td>
</tr>
<tr>
<td>woodchips</td>
<td>25 cy $60</td>
<td>1,500</td>
</tr>
<tr>
<td>fill removal</td>
<td></td>
<td>2,300</td>
</tr>
<tr>
<td>Total Cost</td>
<td></td>
<td><strong>$14,900</strong></td>
</tr>
</tbody>
</table>

- Relative to total costs of installation, I/A equipment & available SIP grants, equipment and materials costs are not likely the dominant cost.

- Further cost savings potentially achievable by eliminating pump tank and rationalizing costs for woodchips and fill removal.
Installation time for different NRB design

Unlined NRB: 2 - 2.5 days

Lined & woodchip box NRBs: 2+ day
Installation time for different NRB designs

Unlined NRB: Two days

Lined & woodchip box NRBs: Two days+
Next steps for non-proprietary NRBs

• Continue research on woodchip sources and silt to improve performance of unlined NRBs to accommodate higher influent TKN

• Publish guidance document and design/installation training course
  • Reduce costs of woodchips & fill
  • Reduce time required for NRB installations

• Work with installers to make NRBs a common I/A septic solution in Suffolk County and beyond
Woodchip biofilters coupled to commercial IA OWTS
Conventional drainfields do not remove N

I/A effluent percolate in LI soil
Dec 2017- Feb 2022

Slight increase
No removal
Coupled commercial IA – CCWT woodchip box systems removal nearly all nitrate